Passive-Regressive

Tales from the CUNY Building Performance Lab

TWENTY-SIXTH WESTFORD SYMPOSIUM ON BUILDING SCIENCE

AUGUST 7, 2024

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CUNY Building Performance Lab (CUNY BPL)

Founded in 2006, CUNY BPL's mission is to advance high-performance building operations and practices in existing institutional, commercial, and multifamily buildings.

Energy Data Lab (EDL)

Data Solutions Team

Technology Applications Team

Building & energy data analysis

Application development

GHG reporting & benchmarking

Technical Services Team

M&V strategy, coaching, reporting

Pre & post measurement guidance

Energy modeling

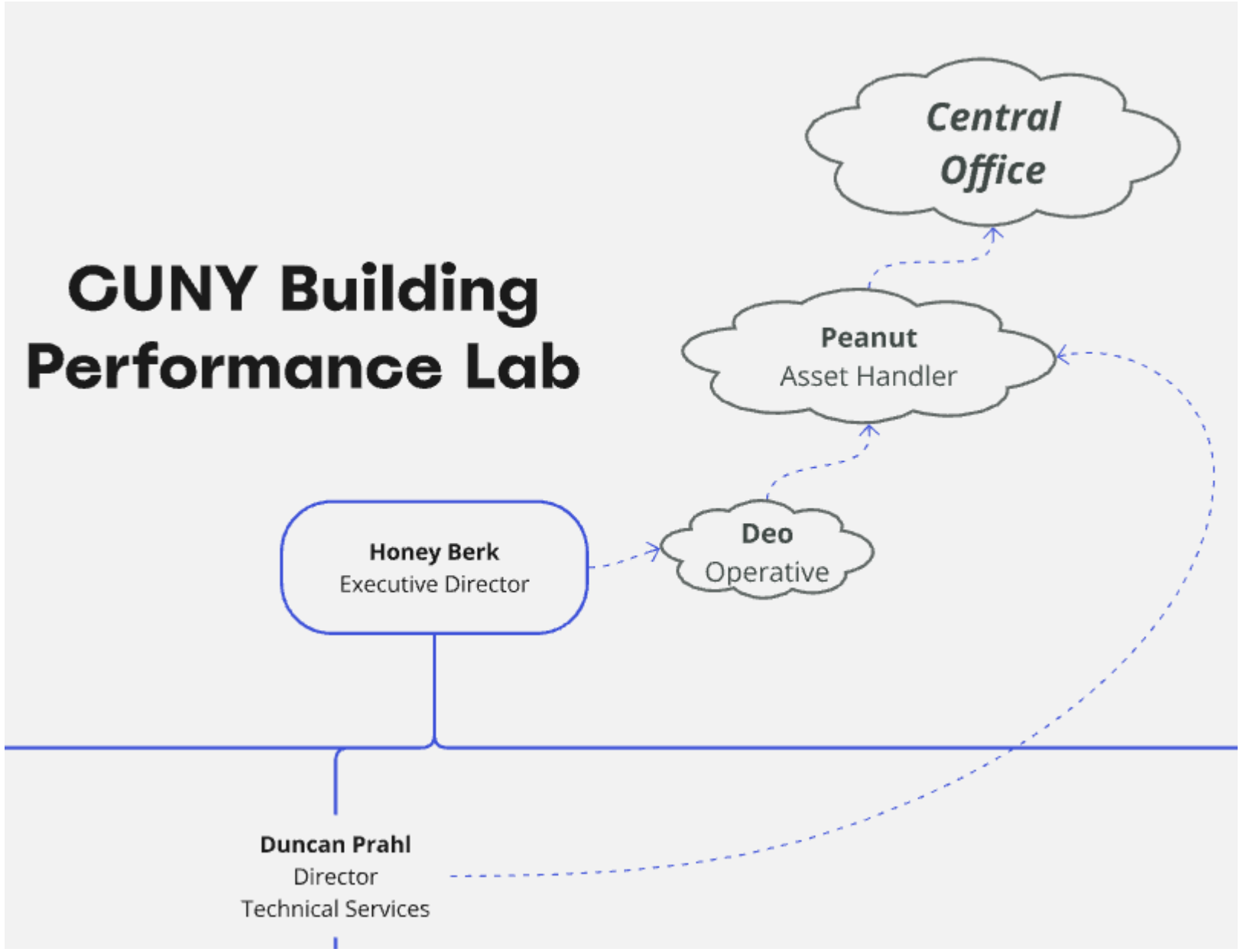
Field Equipment Lending Library

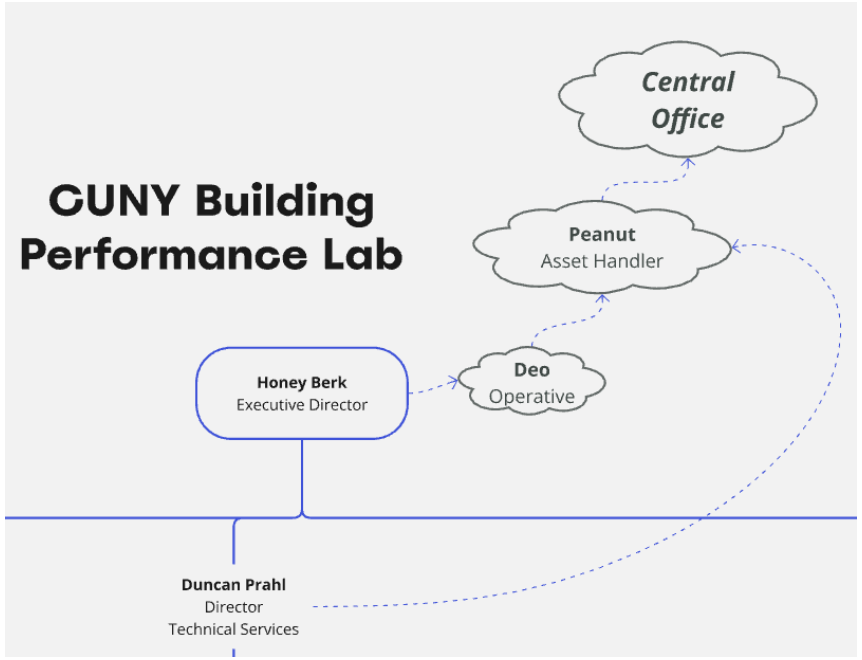
Training Department

Building Optimization Support

Sustainability Help Center

Energy and carbon management training


CUNY Building Performance Lab
Central Office
Peanut
Asset Handler
Deo
Operative
Honey Berk
Executive Director
Duncan Prahl
Director
Technical Services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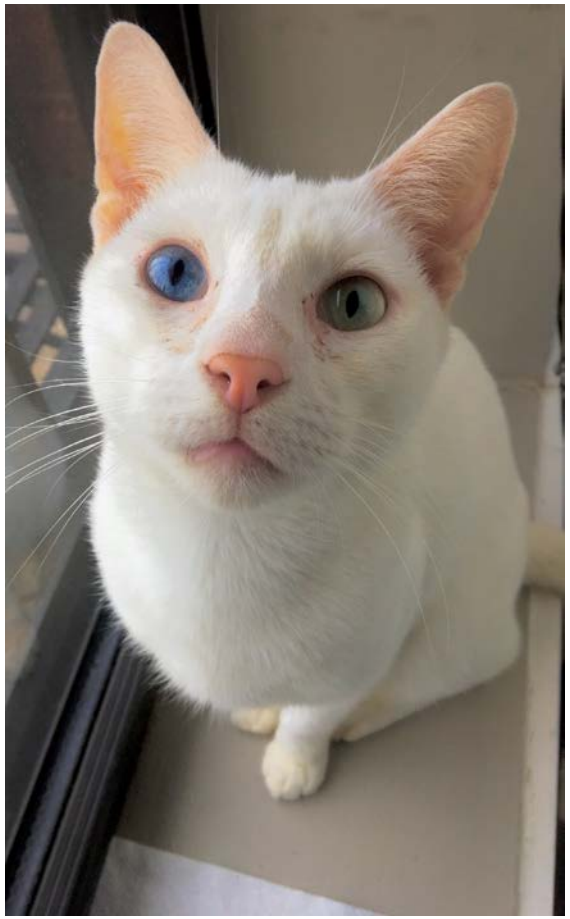
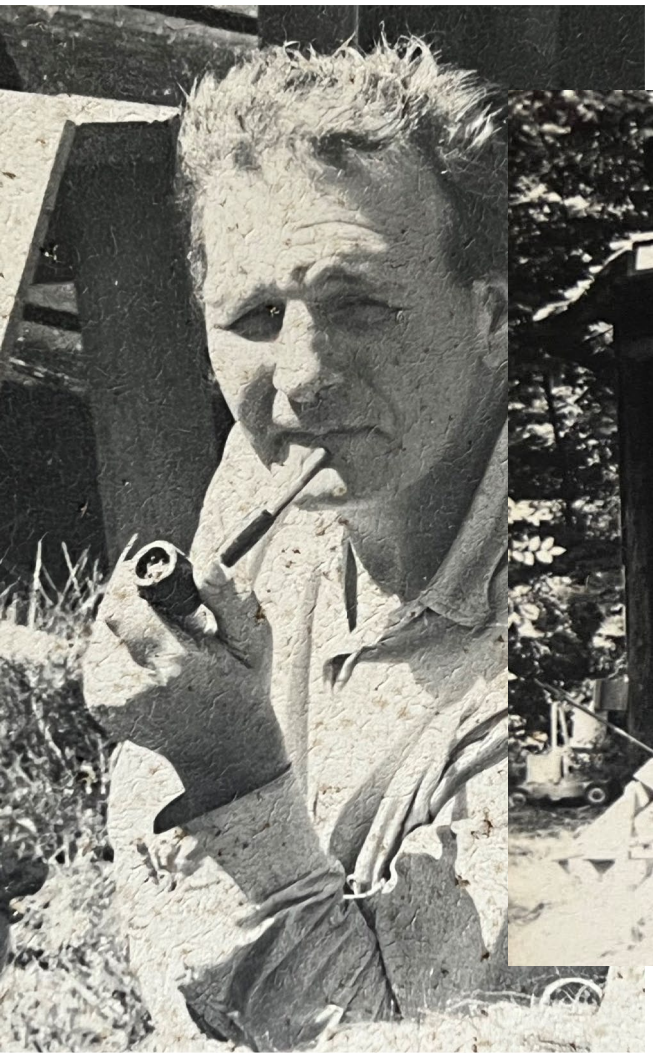


Background (or backlog?)



Topics for Today

- Measurement and Verification (M&V)
  - NYC Department of Citywide Administrative Services (DCAS) Division of Energy Management (DEM) funded applied research
- Data-Driven Commercial Building Energy Code Compliance Analysis for New York City
  - USDOE and NYC Department of Citywide Administrative Services (DCAS) Division of Energy Management (DEM) funded research

Acknowledgments and Caveats

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Advanced Building Construction program, award number(s) DE-EE0009081

Additional support was provided by the NYC Department of Citywide Administrative Services, Division of Energy Management

Project partners include the NYC Mayor's Office of Climate and Environmental Justice, the NYC Department of Buildings, and the New York State Energy Research and Development Authority

Dedicated CUNY BPL staff and interns:

- Too numerous to list, but here is one anyhow:
- Honey Berk, Krystyna Horn, Marco Ascazubi, Stephania Castro, Max Brownstein, Orlando Castillo, Sylvana Vicuna, Johnny Deblase, Po Ki Chui, Edgar Santamaria, Saadman Khan, Samuel Wolnerman, Zaini Rodriguez…

Best efforts have been used to check and use correct data. There is conflicting and duplicative data and significant cross-referencing was necessary to reach conclusions presented here today.

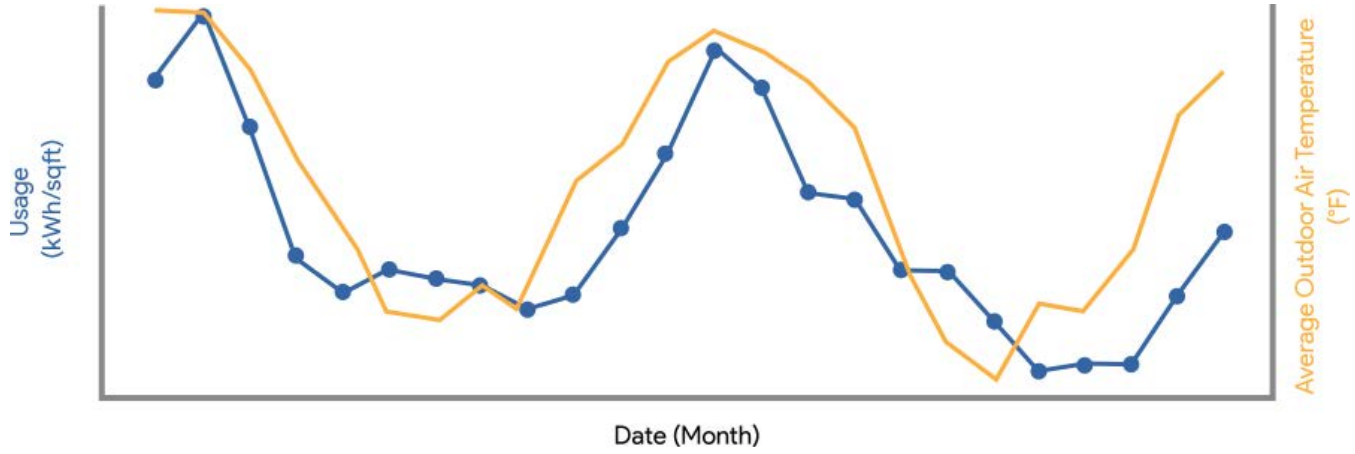
The views expressed herein do not necessarily represent the views of the U.S. Department of Energy, the United States Government, the NYC Mayor's Office of Climate and Environmental Justice, the NYC Department of Buildings, or the New York State Research and Development Authority.

Change-point Modeling

Regression model uses monthly energy consumption and monthly average outdoor air temperature

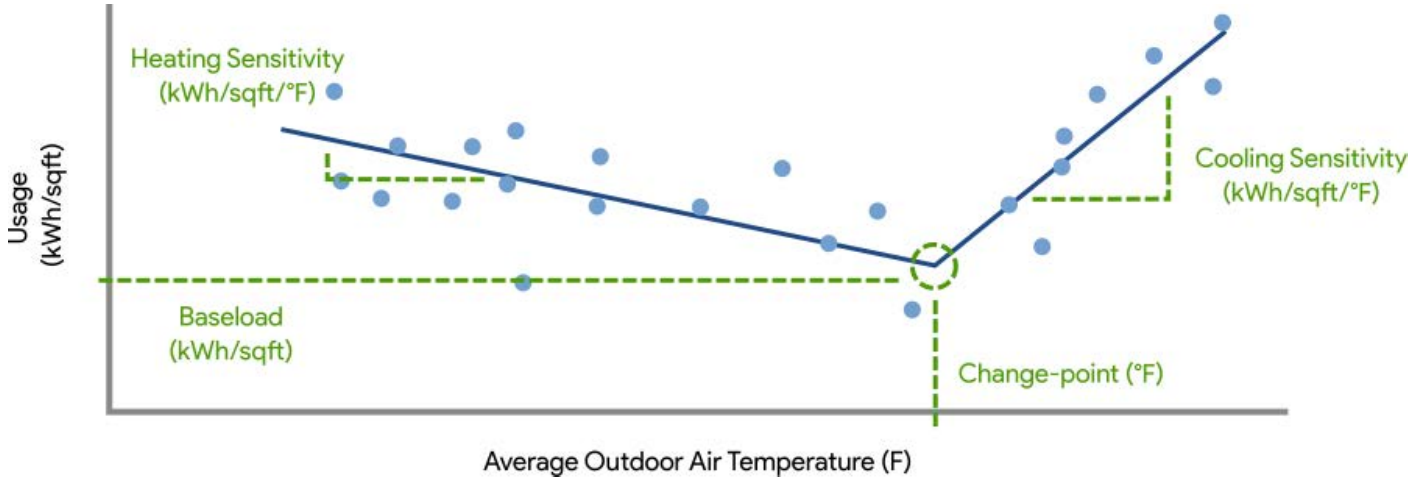
CUNY BPL uses monthly utility data to generate estimates of baseload, heating, and cooling energy consumption

Change-point modeling provides an indicator of the rate of energy consumption for heating and cooling based on outdoor air temperature



From time series…

to change-point model

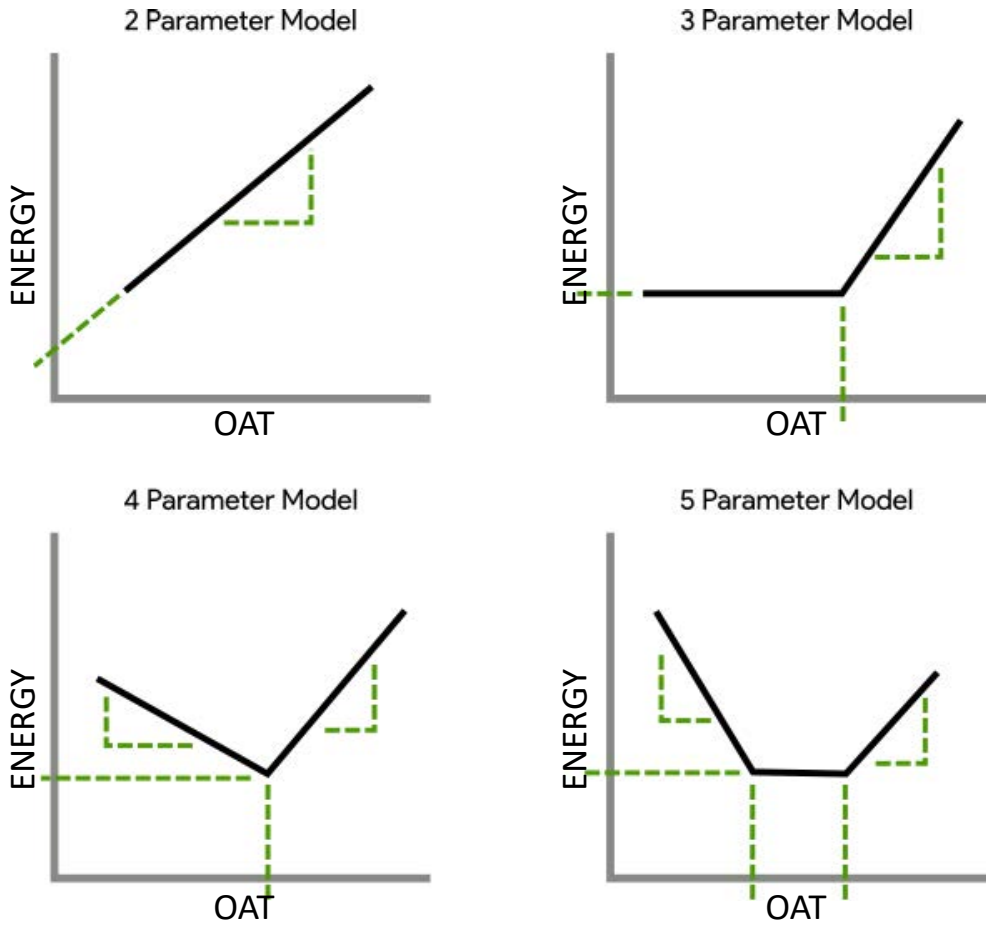


Change-point Model Types

Model types show how a building uses electricity and/or thermal energy

May have different model types for the same building per energy type

- *Example:* building with gas-fired boiler and electric cooling tower with water-source heat pumps
  - 4P electricity model
    - Uses electricity during heating and cooling seasons
  - 3P gas model
    - Uses gas during heating season



Regression Coefficients Yield Insight

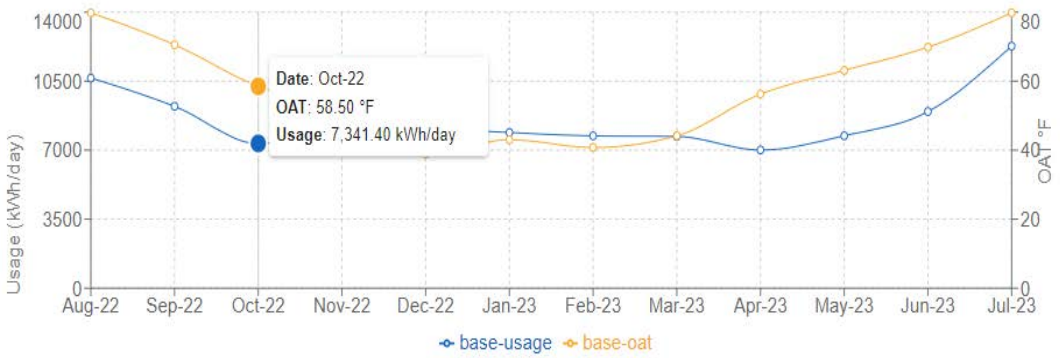
Change-points	Heating or Cooling Sensitivity	Baseload Electricity	Baseload Fuel
• Setpoint temperatures • Internal heat gain (loads from electric use, solar gain) • Building envelope efficiency	• Heat loss / gain through envelope (infiltration) • Efficiency of heating / cooling system equipment	• Lighting • Fans • Electrical equipment	• Domestic hot water • Air reheat

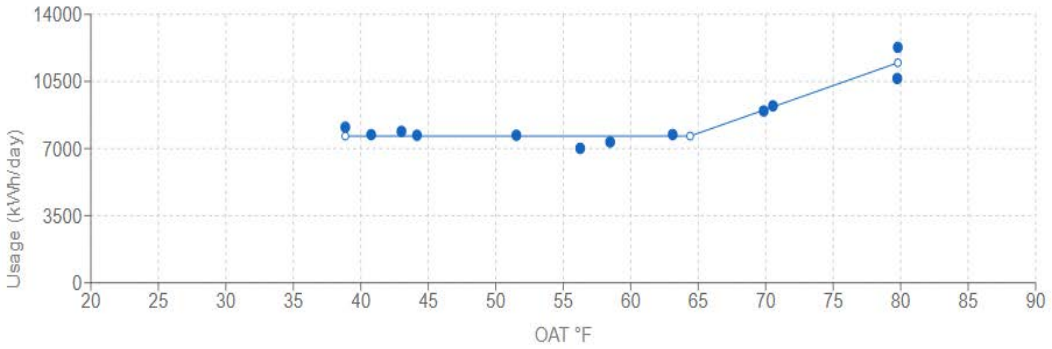
- Identify areas of poor performance
- Prioritize audits and energy efficiency projects

bema

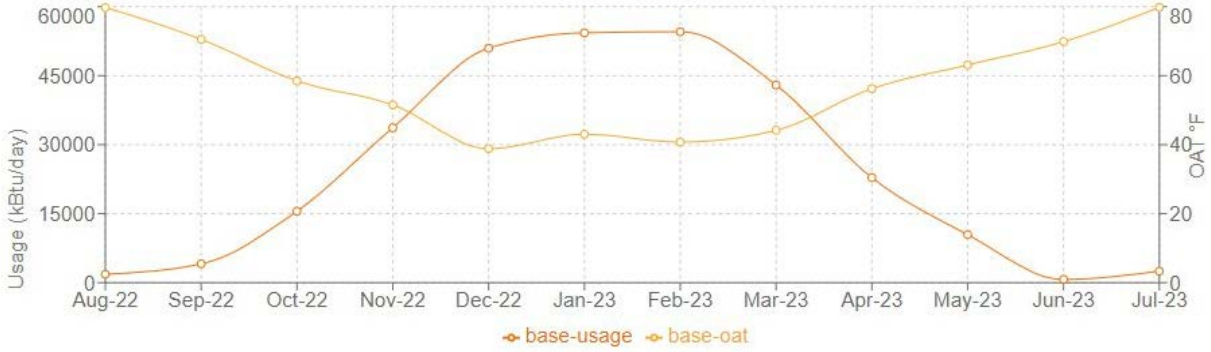
- Web-based application, under development at CUNY BPL since 2014.
- At its core, generates linear change-point regression models that depict the relationship between energy consumption and outdoor air temperature.
- Uses statistical modeling to assess baseline building energy and project performance at the building or portfolio level.
- Uses monthly utility data derived from DCAS DEM database of over 5,000 facilities.
- Used for verification of project energy savings at the whole facility level.

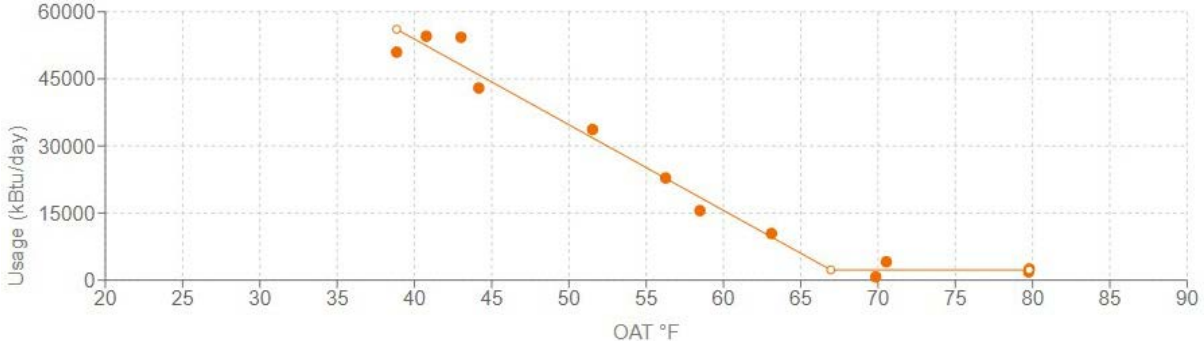
bema





Electric



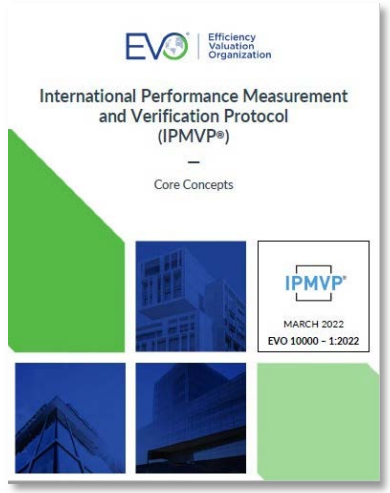


Natural Gas

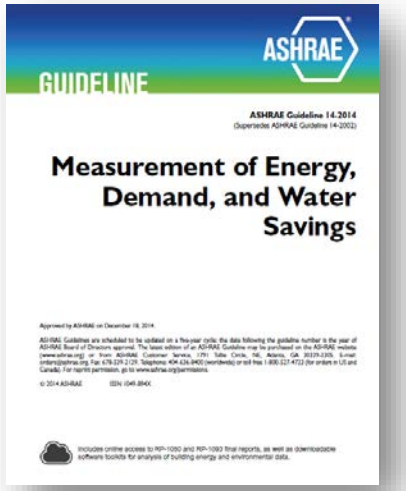
M&V Guidelines & Protocols

Primary:

- International Performance Measurement and Verification Protocol (IPMVP)
  - Maintained by the non-profit Efficiency Valuation Organization (EVO)
  - A general framework that defines terms for planning and implementing M&V activities
  - Does not include specific measures or technologies



- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Guideline 14-2023
  - Focus on reliably measuring energy and demand savings on a very technical level
  - Guideline 14 was developed to fill a need for a standardized set of energy, demand, and water savings calculation procedures



Secondary:

- M&V guidelines prepared for the U.S. Department of Energy Federal Energy Management Program (FEMP)
- Bonneville Power Administration M&V Protocol (BPA)

Lighting Upgrades in Schools

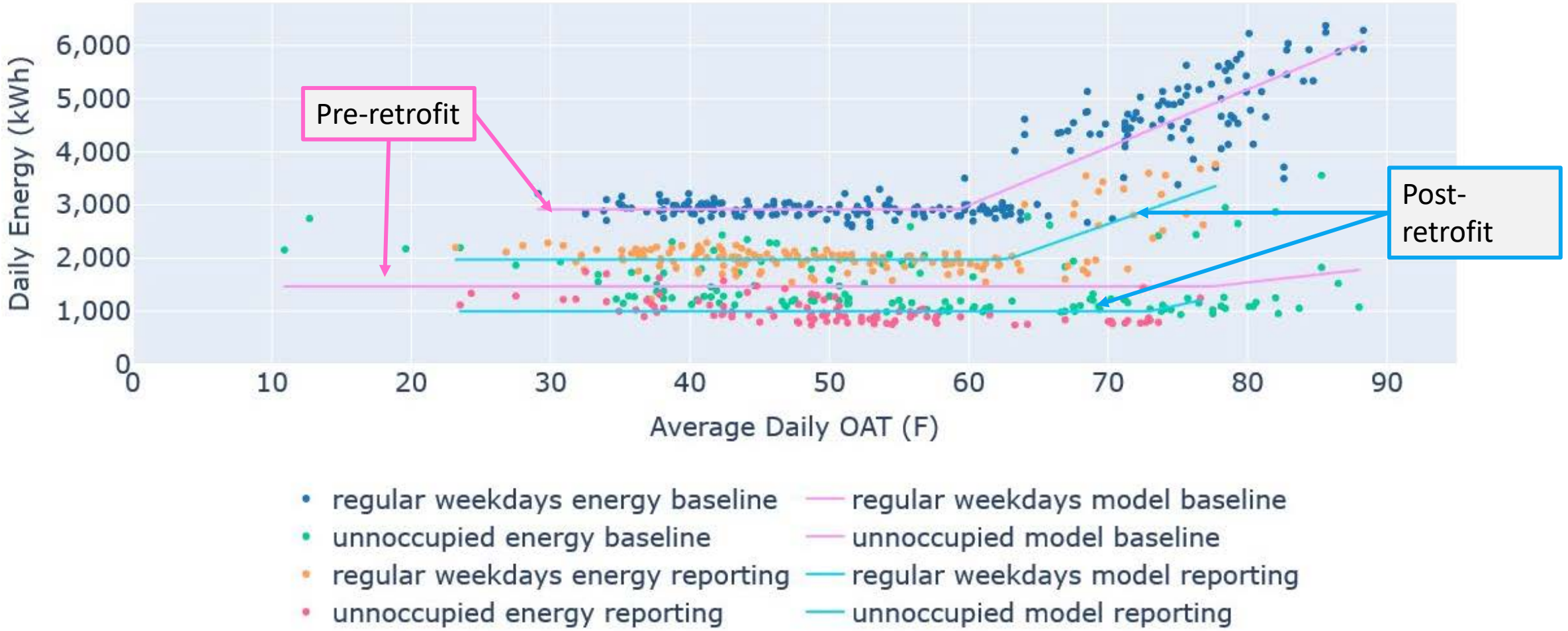
- M&V needed for lighting projects in schools
- Most projects were already initiated
- Want results sooner than 1 year after implementation
- 15-minute interval data available: larger range of conditions over a shorter period of time
- Added a day type variable to BEMA modeling code
- Achieved models with low levels of uncertainty and greater insights

15-Minute Interval Data Processing

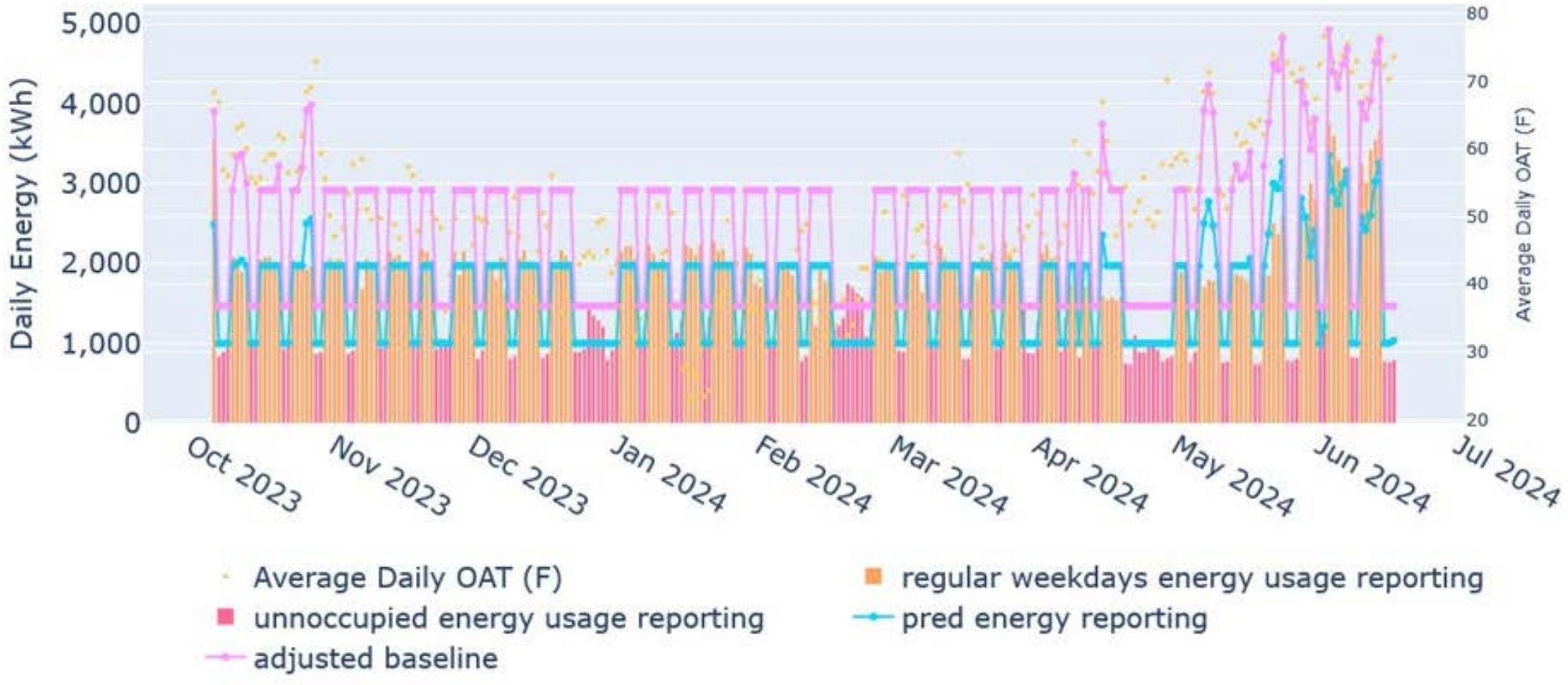
Data was aggregated to daily timescale and divided into the following day types:

- Weekdays during the regular school year (and summer school, if applicable)
- Saturdays during the regular school year (and summer school, if applicable)
- Sundays during the regular school year (and summer school, if applicable)
- School holidays
- Weekdays during the summer (excluding summer school, if applicable)
- Saturdays during the summer (excluding summer school, if applicable)
- Sundays during the summer (excluding summer school, if applicable)

Regressed Against OAT



Time Series of Savings



Summary of Savings by Day Type

Day Type	kWh Savings Since Upgrade	GHG Savings Since Upgrade (MTCO2e)	Annualized kWh Savings	Annualized GHG Savings (MTCO2e)	Relative Savings	Savings Uncertainty	Baseline R^2	Baseline CV-RMSE
Regular Weekdays	162,424	52.49	271,875	87.86	33.0%	4.7%	0.83	12.0%
Unoccupied	47,063	15.21	58,300	18.84	32.0%	18.0%	0.01	35.0%
All Day Types	209,487	67.70	330,175	106.70	33.0%	7.6%	0.88	16.0%

USDOE Research Project Overview

NYC has been at the forefront of rigorous energy codes and has passed annual CO2e limits on buildings that get progressively more stringent over time (2024-2029, 2030-2034, etc.)

NYC has a very rich open data ecosystem

- Data, data, everywhere…
- Benchmarking, permits, energy audits, boilers, cooling tower inventories…

Research Questions:

1. Can these data be used to evaluate how various policies (e.g., energy audits, benchmarking, carbon caps, energy codes) are impacting actual building energy use in the market?
2. Are there tools that can help building owners predict and better understand how energy is being used in the building?
3. What is the contribution of various plants, systems, and components to overall building energy consumption and GHG emissions?

The NYC Local Law Cheat Sheet

- LL84 – Requires Benchmarking of buildings over a certain square footage (has changed over the years) using the EPA Portfolio Manager platform
  - Key metric - energy use intensity (EUI) - energy per square foot
- LL87 – Requires energy audits every 10 years for buildings (generally) over 50,000 square feet
- LL97 – Regulates the amount of CO2e that can be emitted by a buildings (generally) over 25,000 square feet
  - First compliance year is 2024, gets progressively more stringent, down to 0 in 2050
  - Imposes fines for exceeding caps - $268 per metric ton CO2e

LL84	LL87	LL97
• Benchmarking • EUI (Energy/SF)	• Audits • Retro-commissioning	• Carbon Caps (CO2e) • Fines

Building Performance Standards

- Just energy performance, some translated to emissions
- Simple in concept, may be hard for building owners
- Emissions may change year-over-year
- No indication of plant, system or component that uses the energy

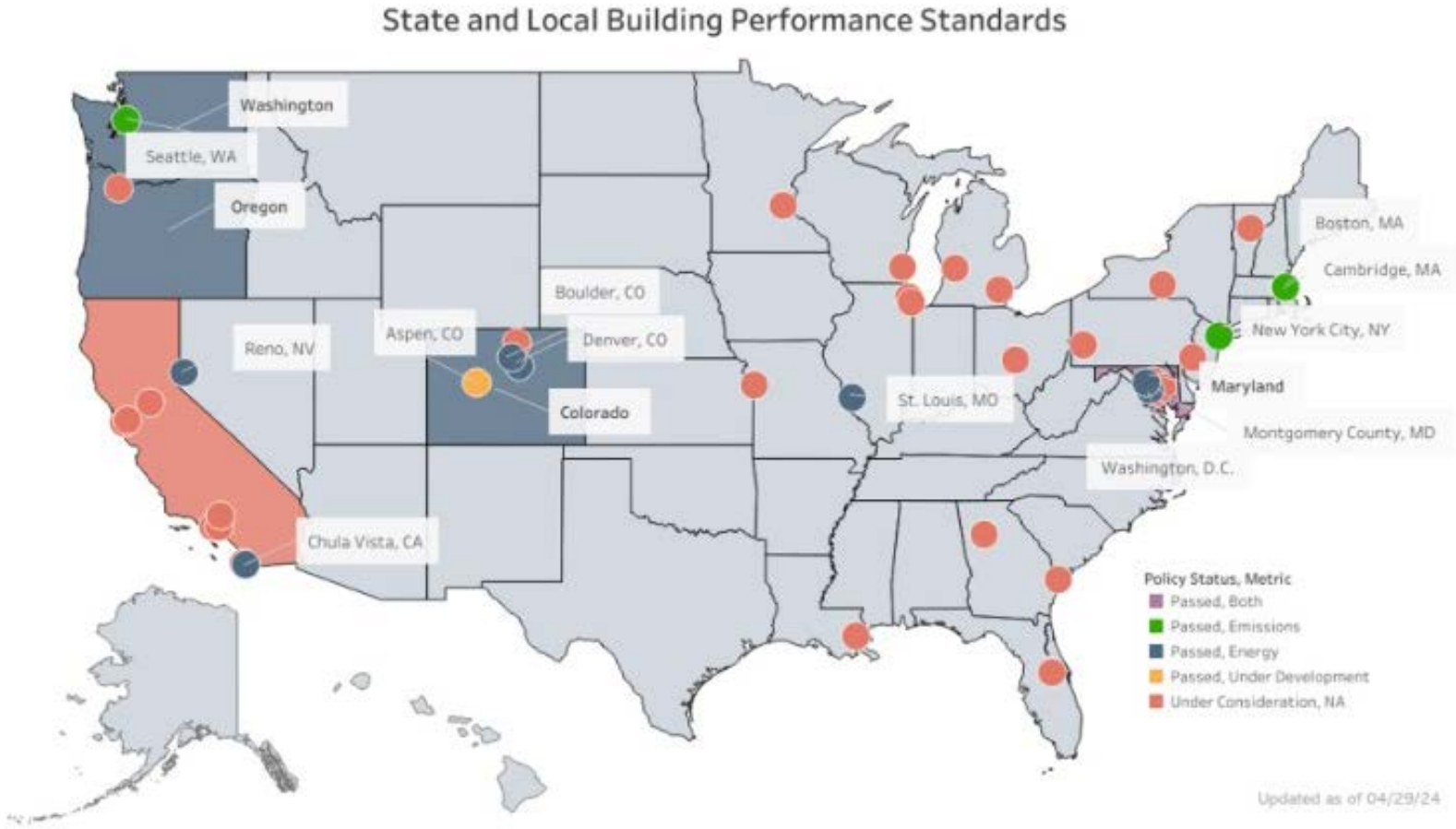


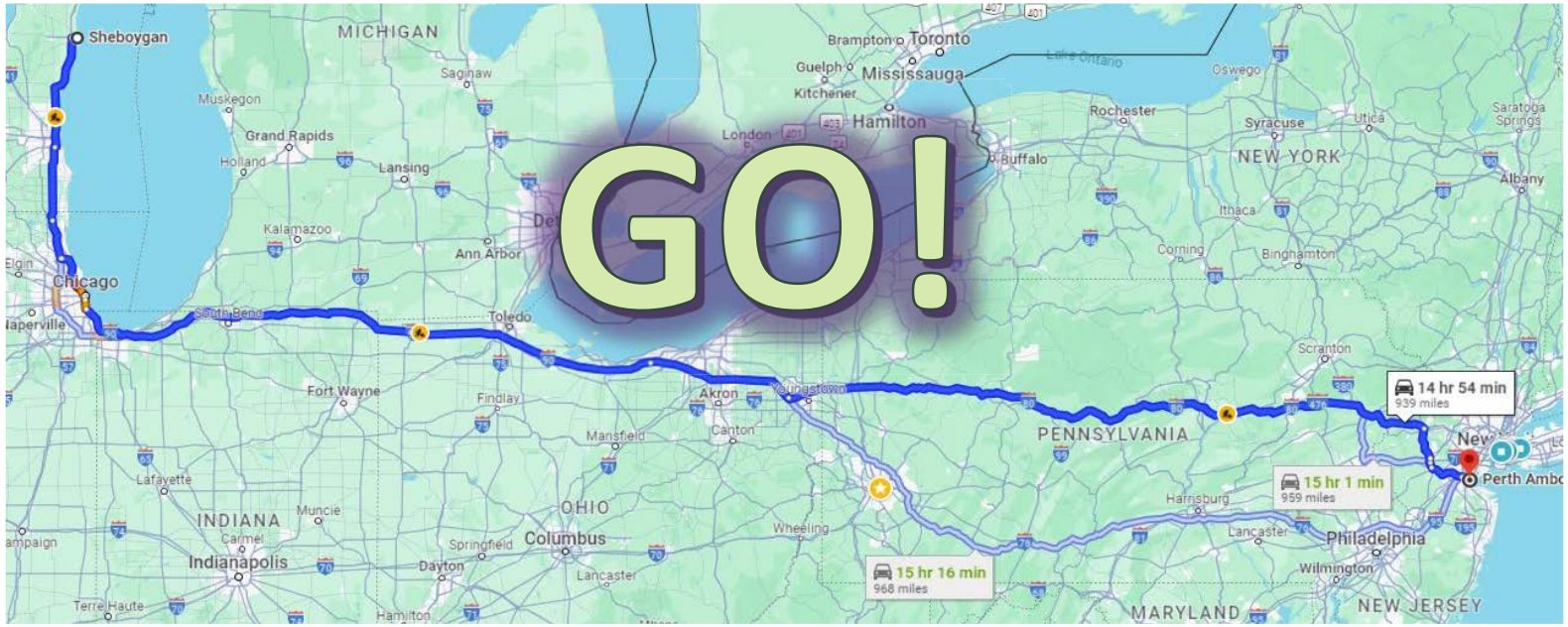
Image from https://www.energycodes.gov/BPS

A Driving Performance Standard

Drive from point A to point B using a fixed amount of fuel

- Sheboygan, MI to Perth Amboy, NJ (~950 miles)
- 2005 Hybrid (~47 MPG)
- Four 5-gallon containers of gas

- Dashboard helpers don't work – no check engine, no energy monitor, no gas gauge, just speedometer and odometer
- Will you make it?



A Building Performance Standard

Run your 237,862 sq. ft. building from Jan 1-Dec 31, keep occupants happy, and use no more than 1,803 tCO2e/year, or incur a fine

- Your BAS is old and can't trend more than a week
- Your utility sends you a monthly energy bill
- Will you make it?

Use Building Data to Predict Performance

What data exists?

- Monthly utility bills?
- 15-minute interval data from the utility?
- Submetered data?
- Simple trend data from the BAS?
- Detailed trend data from a real-time energy management system?

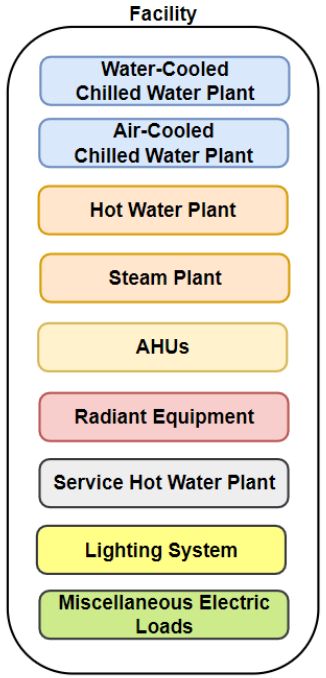
“Simple” techniques to analyze data

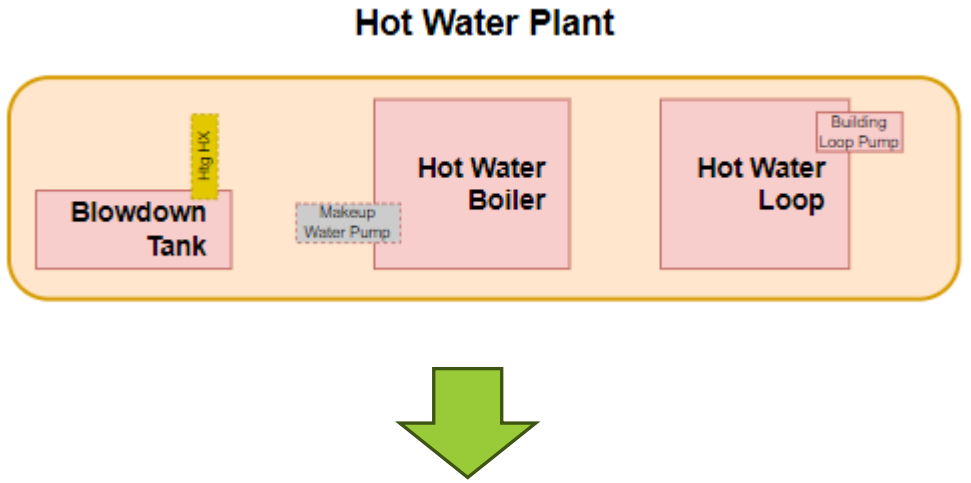
- Linear change-point regression models
- Time-of-day or day-of-week models
- Time-of-week and temperature

Energy Analysis by End-Use

What is the contribution of particular plants, systems, or components to overall building energy consumption and GHG emissions?

- CUNY BPL developed a “Stretch Standard of Care for Building Automation Systems"
- Breaks down end-uses into plants, systems, and components
- Uses tags compatible with Project Haystack





BUILDING *performance* LAB

Plant	System	Energy-consuming Component	Data point	Direct or Proxy Measurement	Project Haystack Tags			
					Plant	System	Energy-consuming Component	Data Point
Hot water heating plant	Hot water boiler	Burner: Fuel measured by utility meter or dedicated meter connected to the BAS	Daily average fuel usage (Btuh) for utility-metered fuel (e.g., natural gas) or delivered fuel (e.g., fuel oil, propane)	Daily meter reading	id, dis, equip, hot, water, hvac, plant, siteRef	id, boiler, dis, equip, hvac, equipRef, hotWaterRef, siteRef	N/A	**Natural Gas Flow:** id, cur, sensor, his, point, dateTime, tz, kind, unit, dis, naturalGas, flow, equipRef, siteRef

Energy Analysis by End-Use

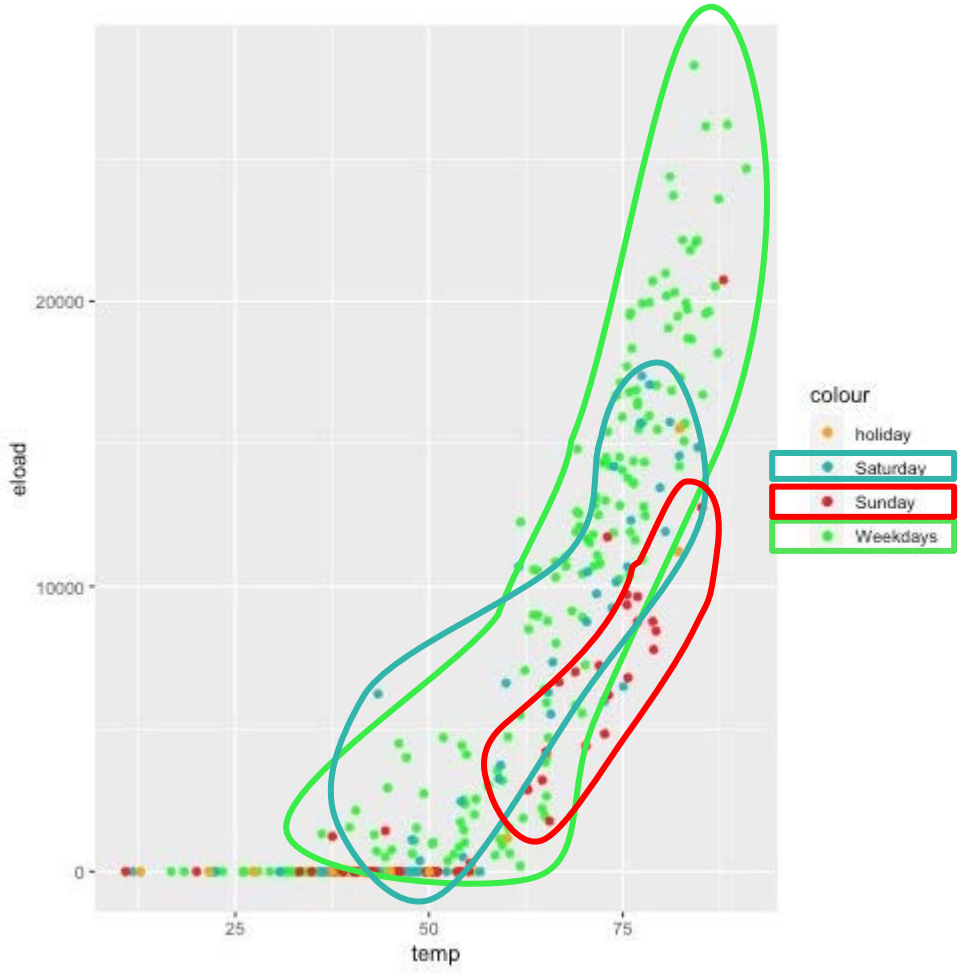
- Collected data from real-time energy management (RTEM) systems installed in NYC and NYS under the NYSERDA RTEM program

  https://www.nyserda.ny.gov/All-Programs/Real-Time-Energy-Management

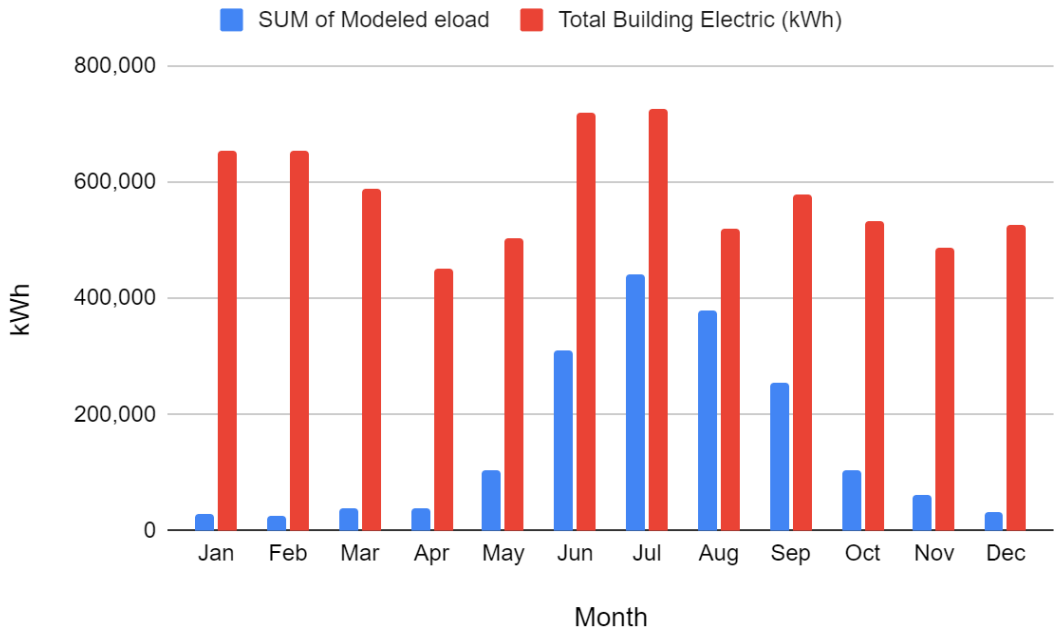
- Compared contribution of measured plant, system or component to whole building energy consumption

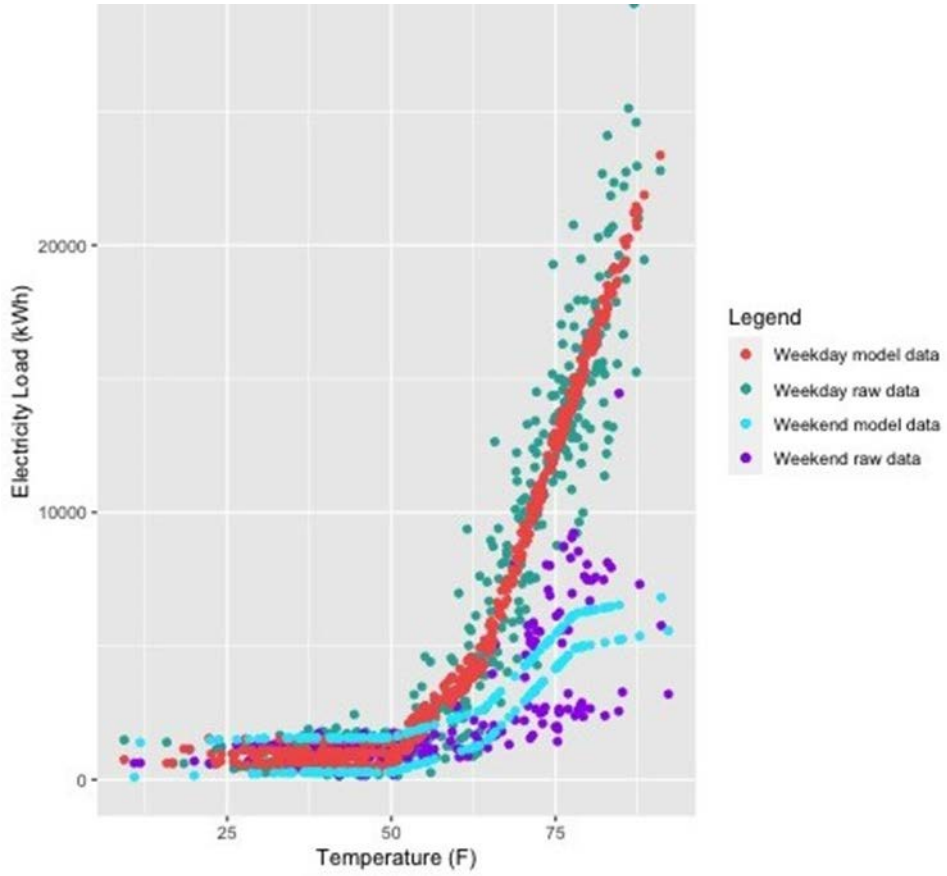
- Evaluated various regression approaches
  - Linear change-point regressions
  - Time-of-week and temperature (TOWT)

  R package by kW labs (https://github.com/kW-Labs/nmecr)

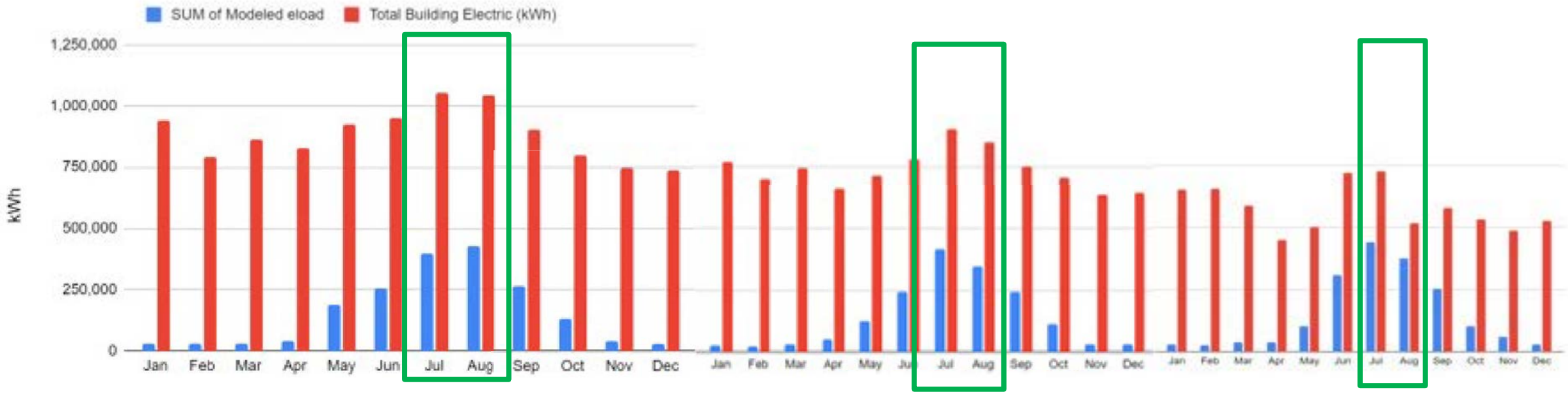


ToWT Results for a Chiller





ToWT Results for Chilled Water



July 2018
Average 79.4°F

Aug 2018
Average 80.3°F

July 2019
Average 81.1°F

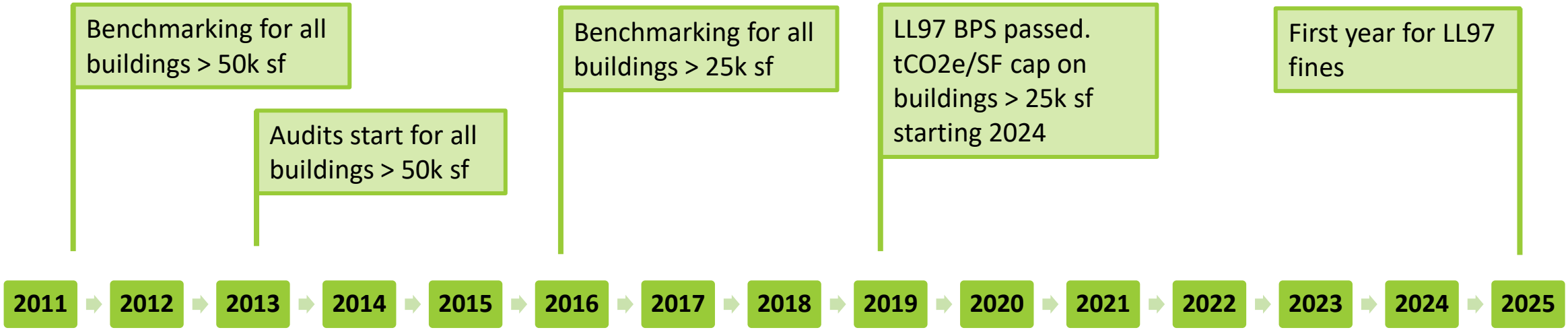
Aug 2019
Average 76.6°F

July 2020
Average 81.6°F

Aug 2020
Average 79.1°F

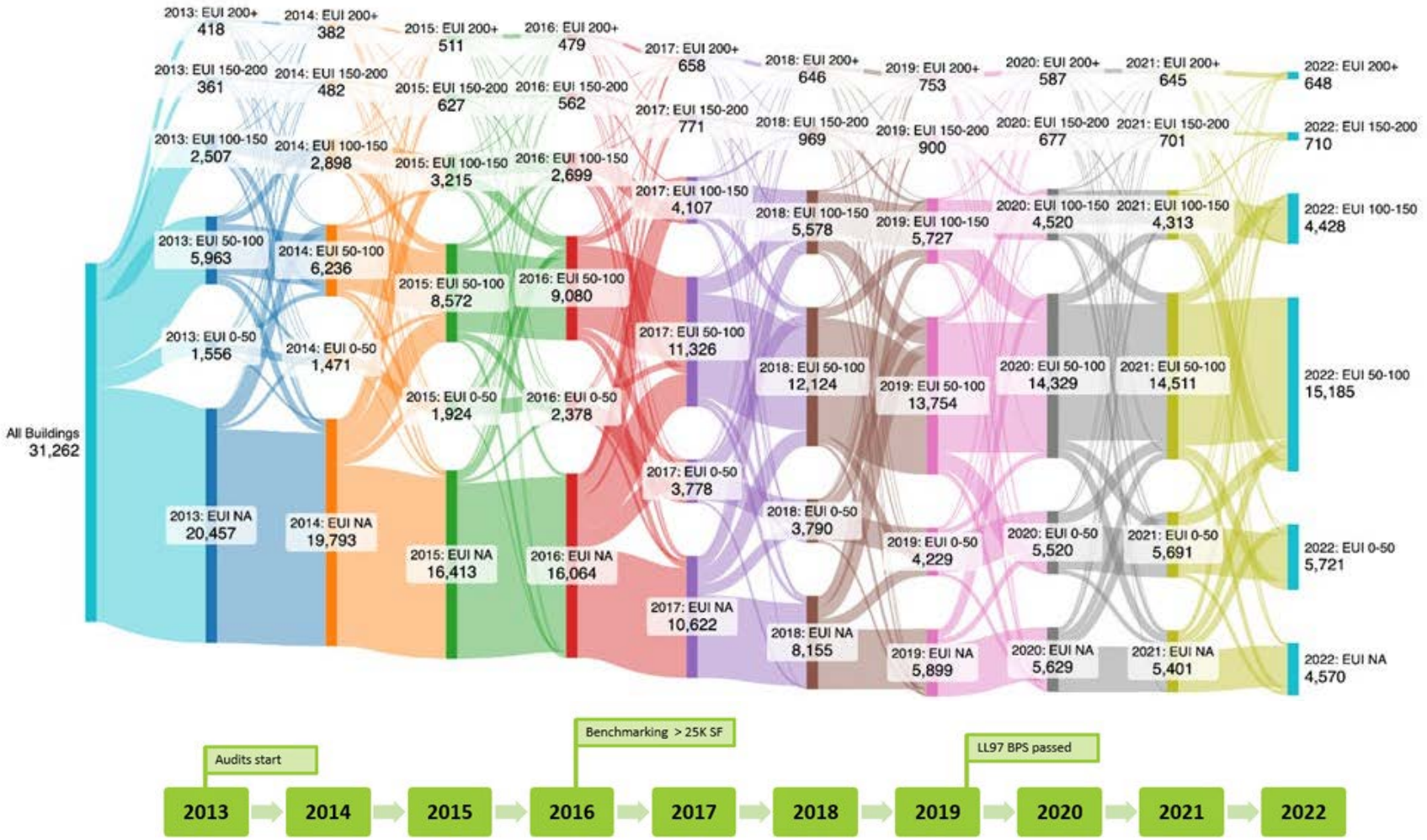
High-Level Data Analysis

- Looked at NYC Open Data from 2013 to 2022, as well some limited proprietary data
- Benchmarking, audits, permits, energy, drawing sets, and real-time energy management data
- Focused on four primary use groups – Multifamily, Office, K-12 Schools and Hotels



So, what did we find?

EUIs Change Over Time



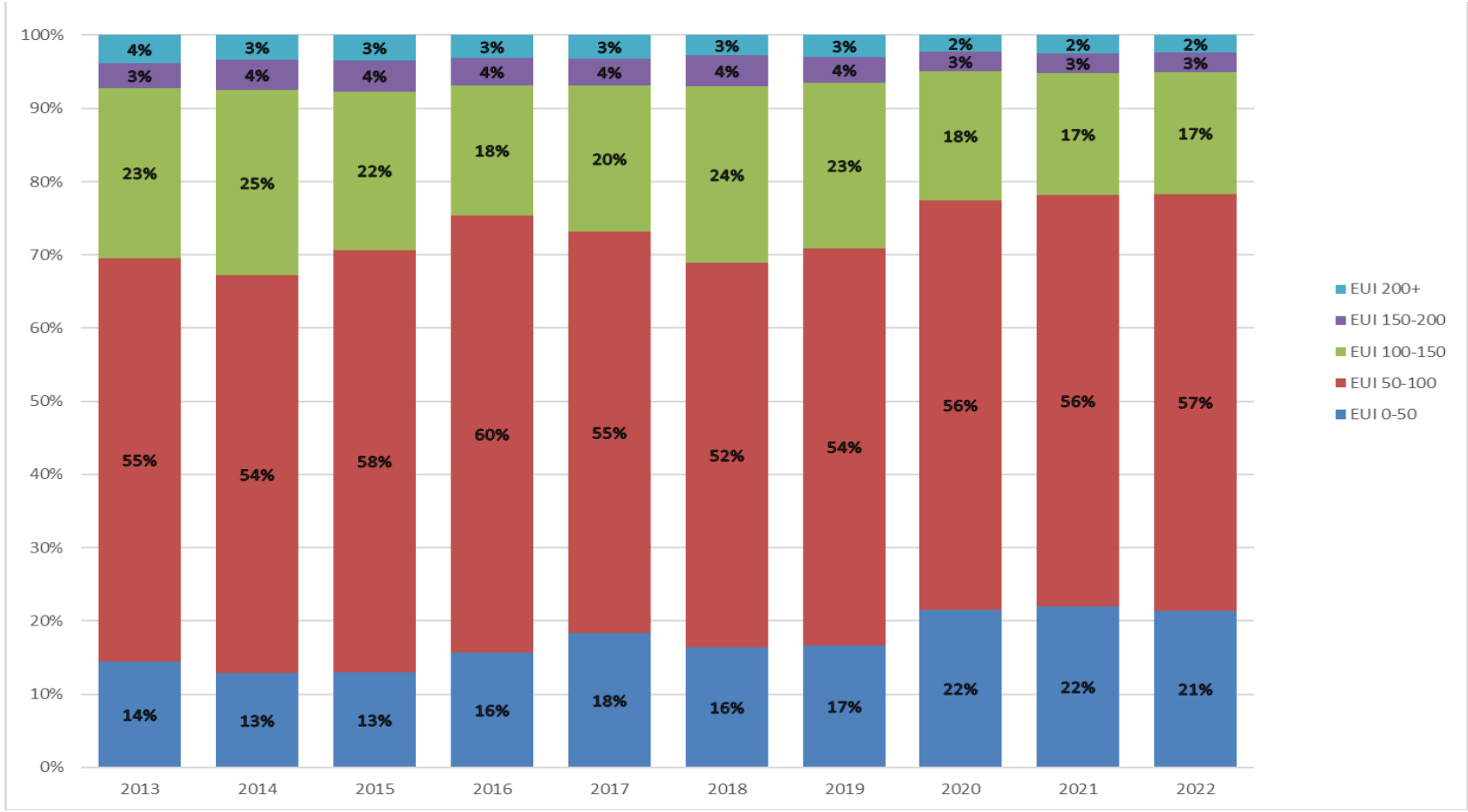
EUIs for All Buildings Change Over Time

EUIs stabilize in 2020

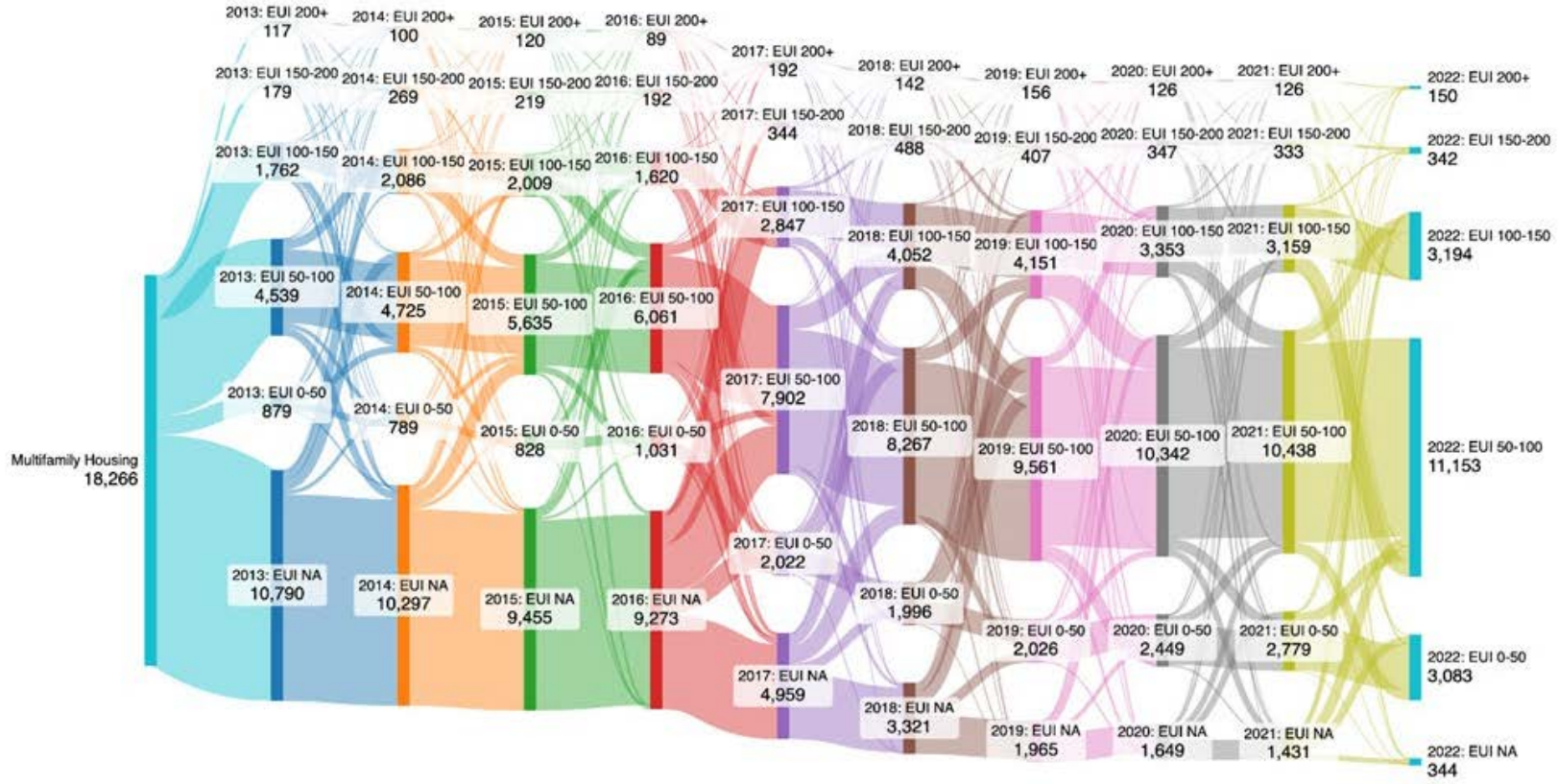
COVID?

LL97?

Coincidence?



Multifamily EUIs



Multifamily EUIs

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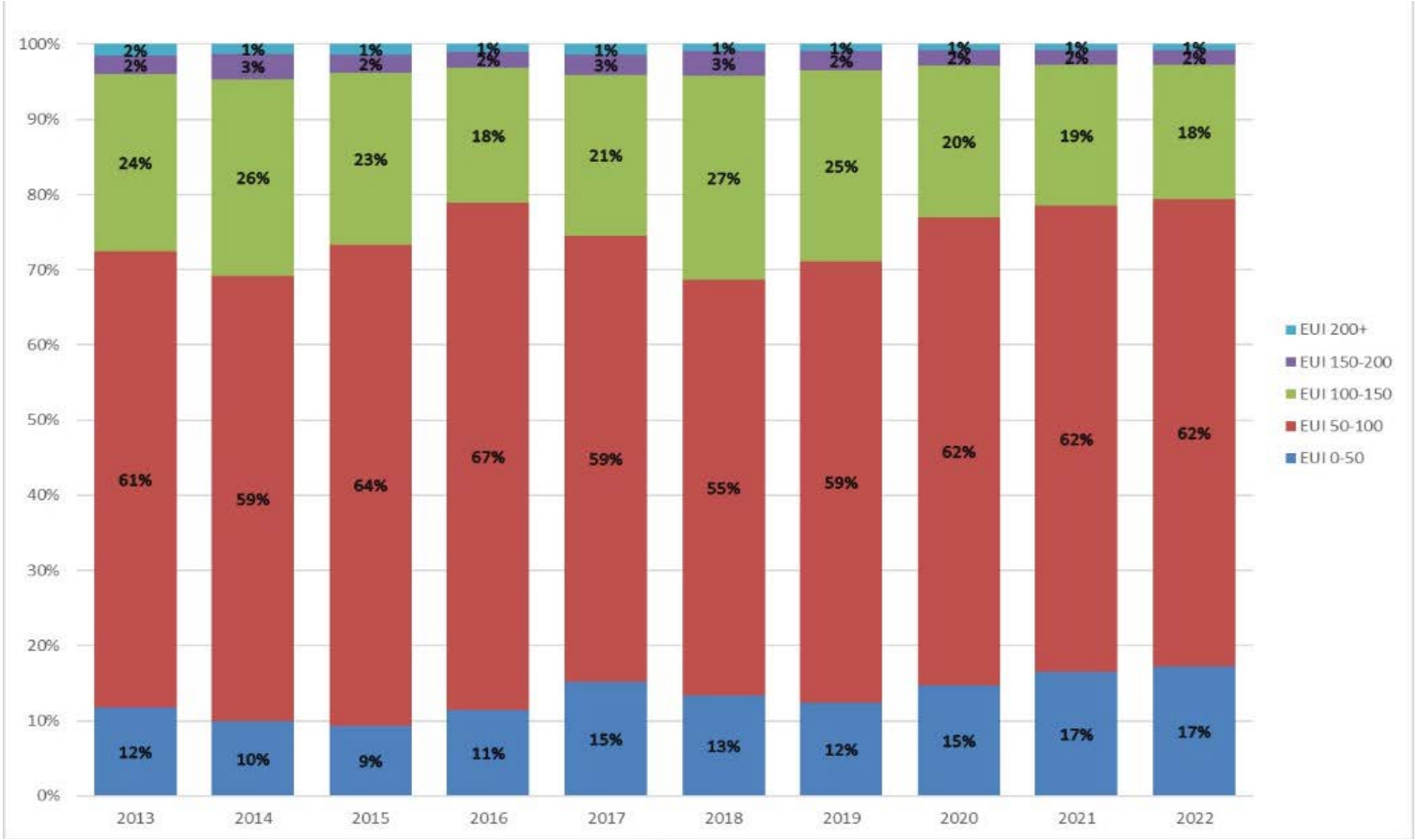
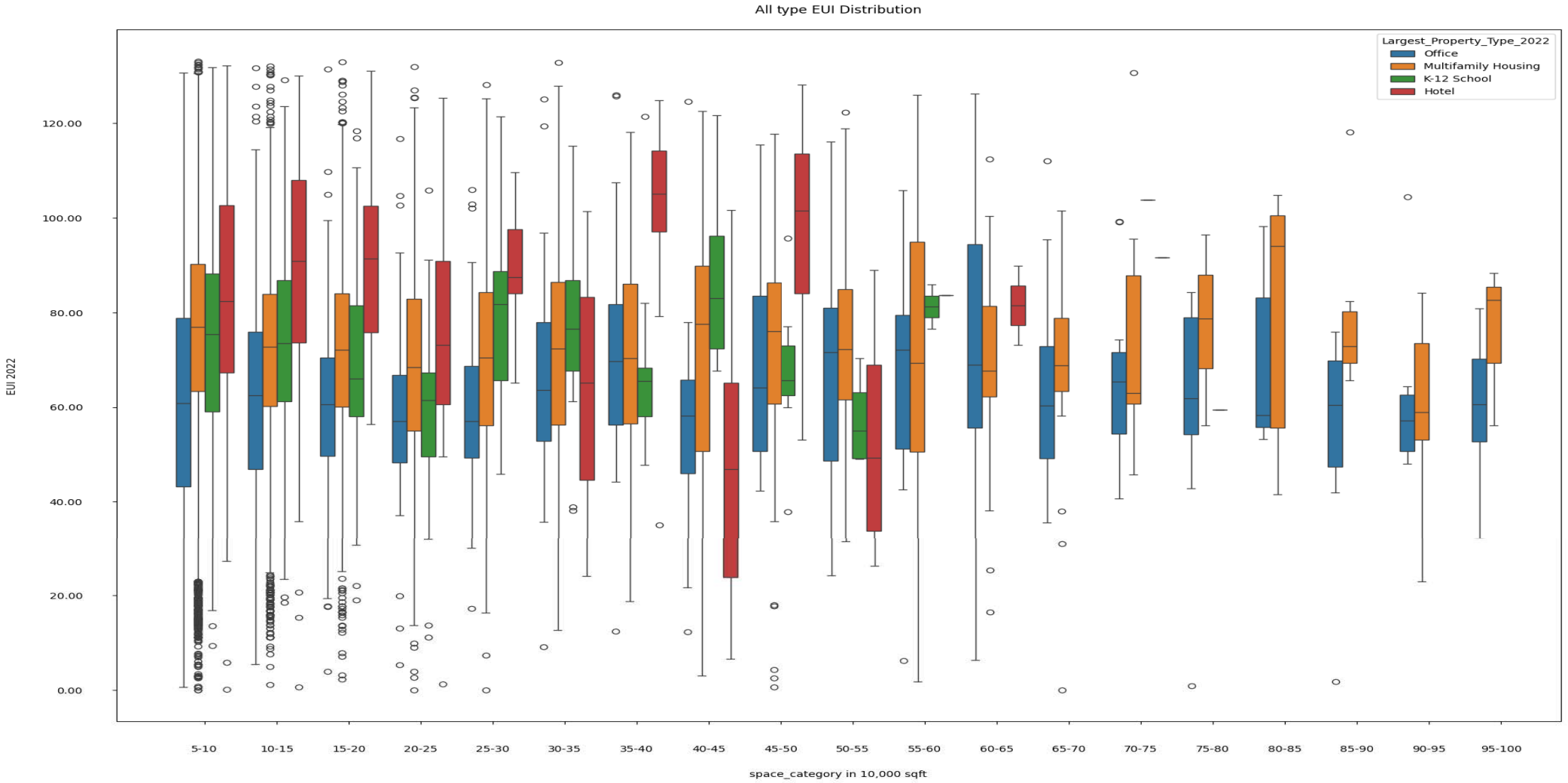
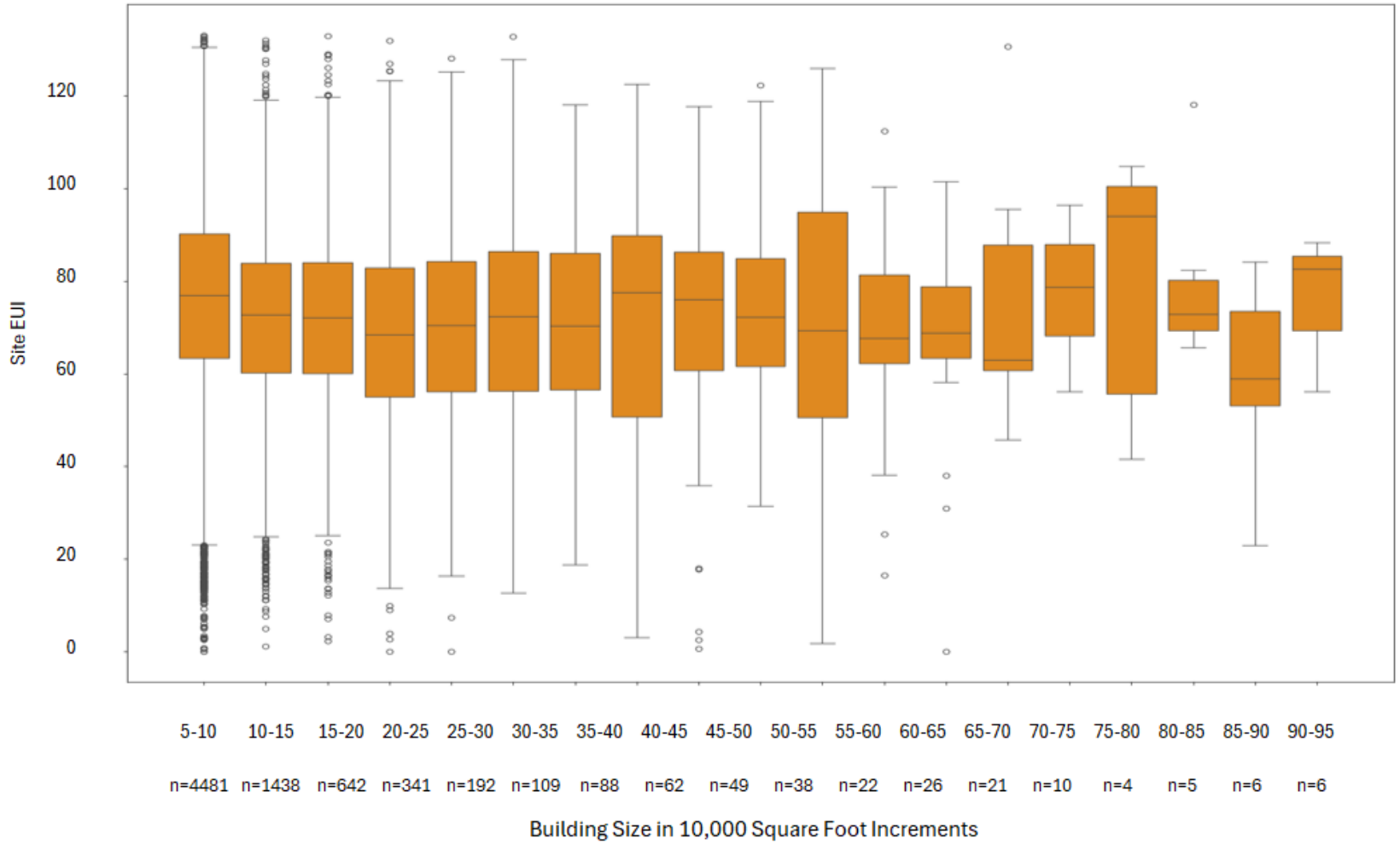


Quartile Analysis by Size



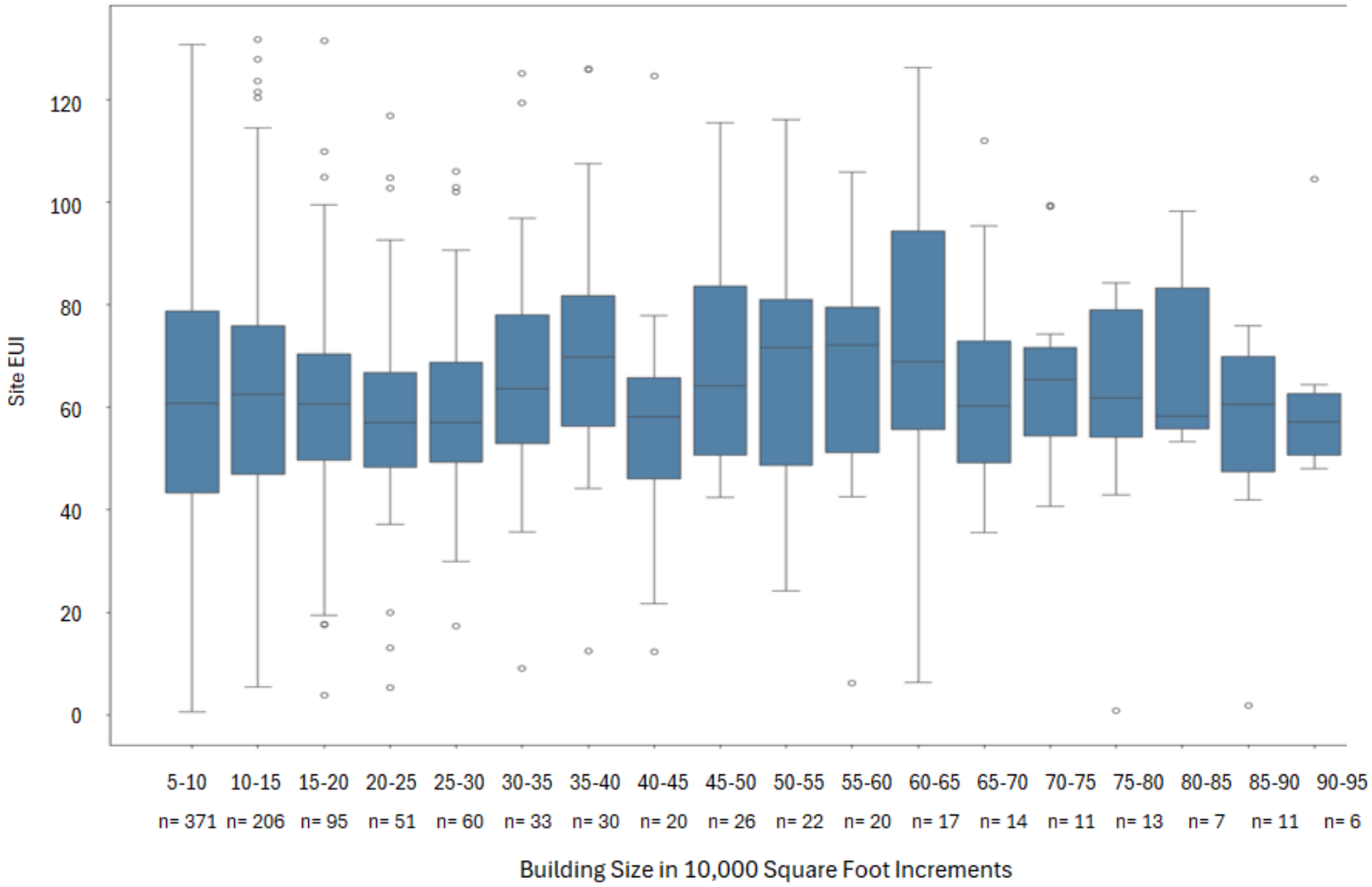
Multifamily Quartiles by Size

No clear trends

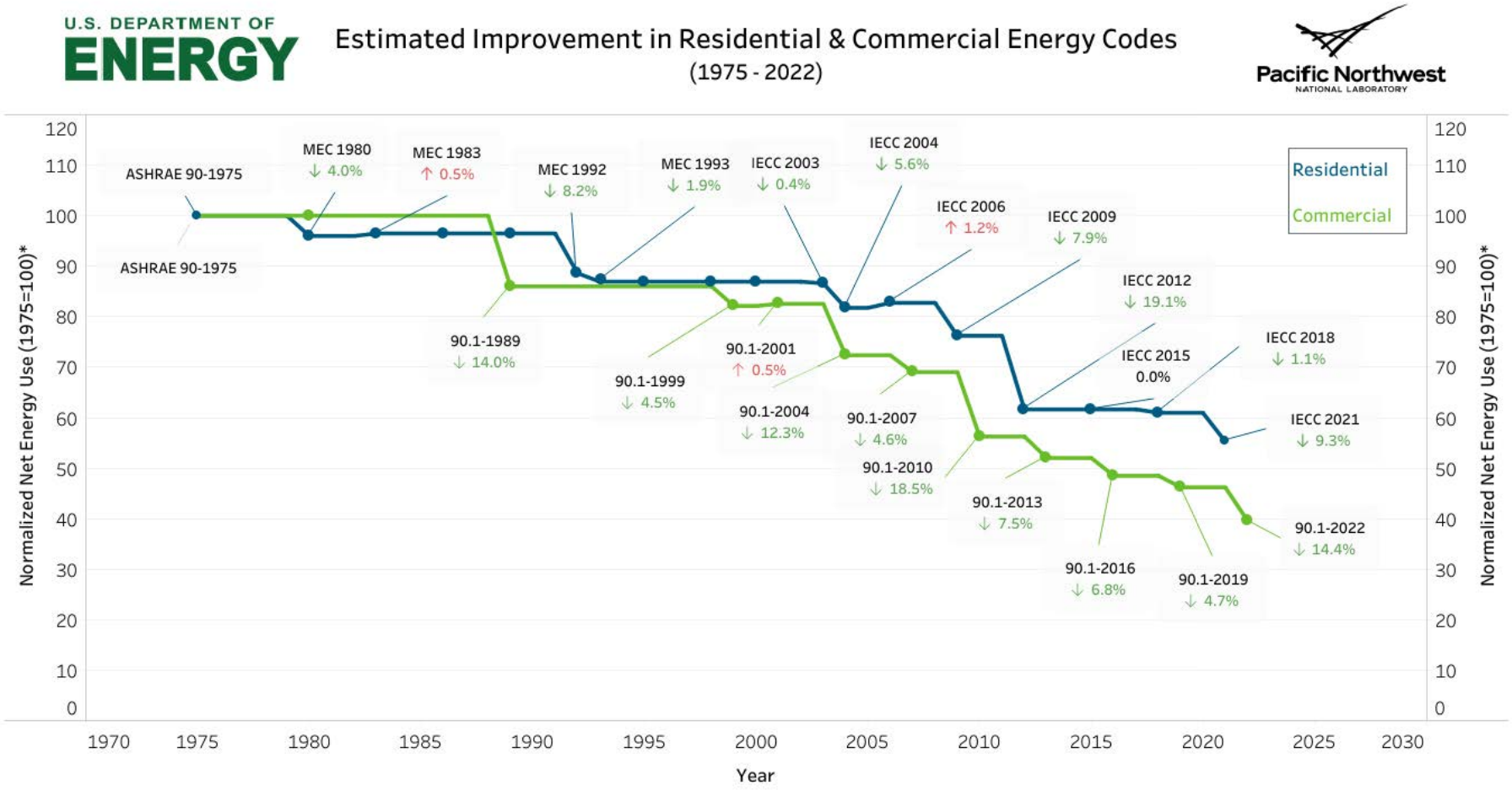


Office Quartiles by Size

No clear trends

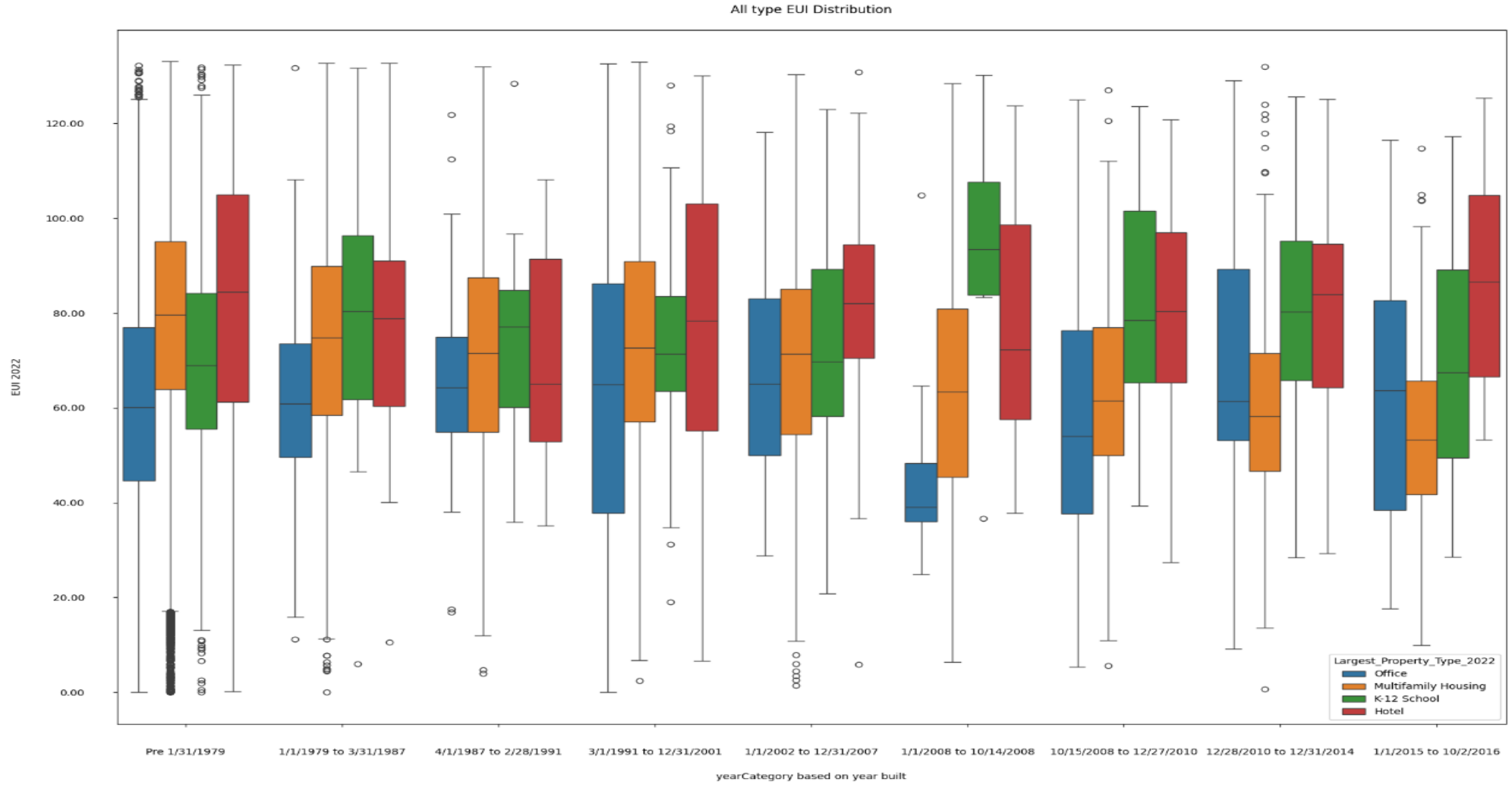


What About by Year Built?

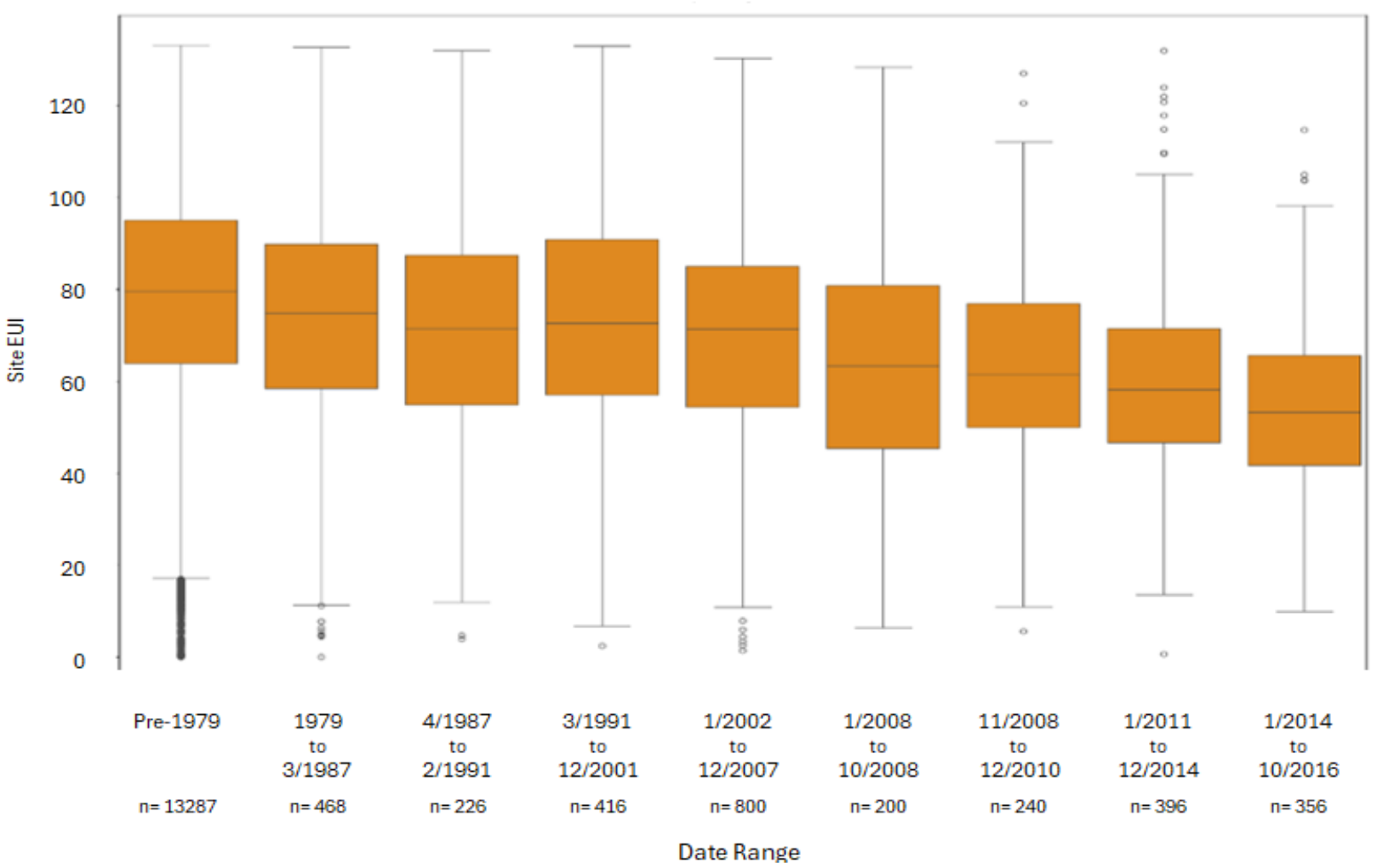


*Net energy use includes the contribution of renewable energy generation

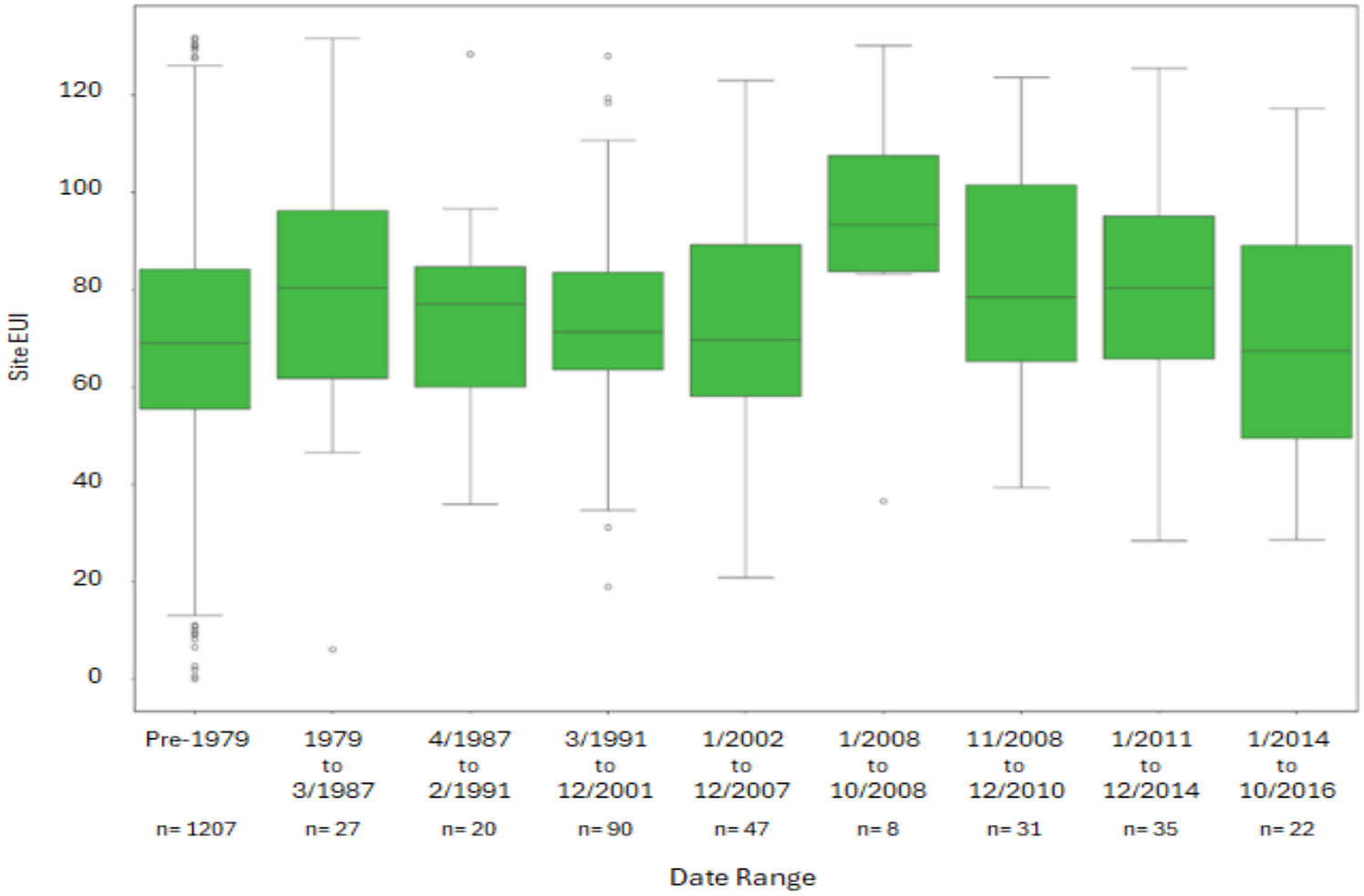
Quartiles by Vintage



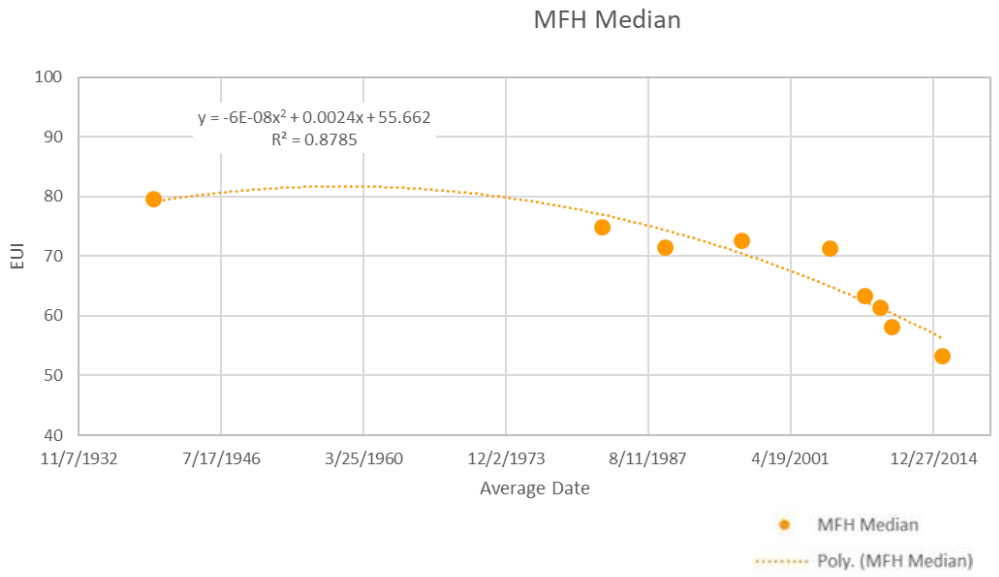
Multifamily by Vintage

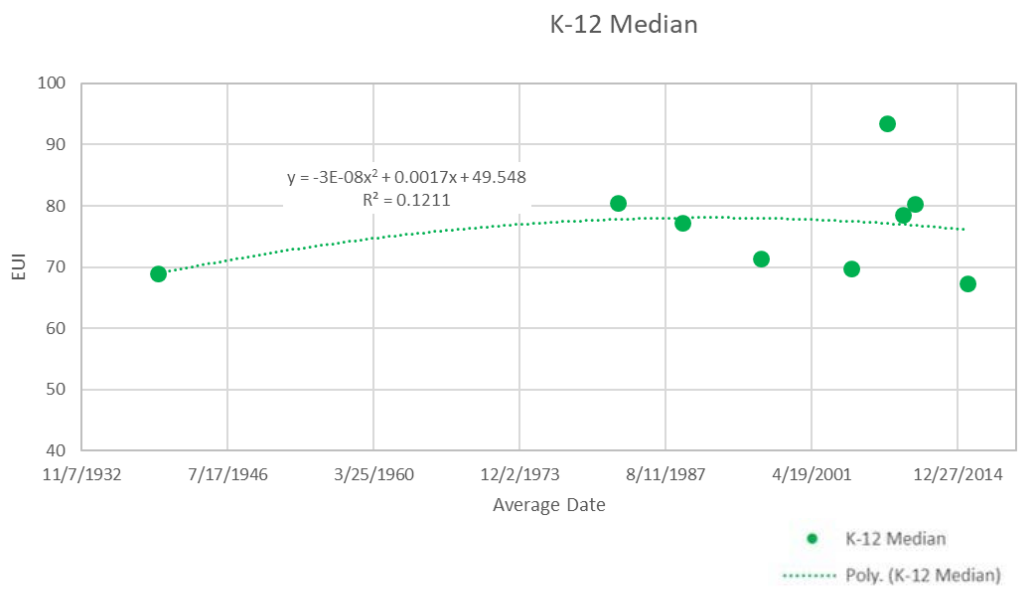


K-12 Schools by Vintage



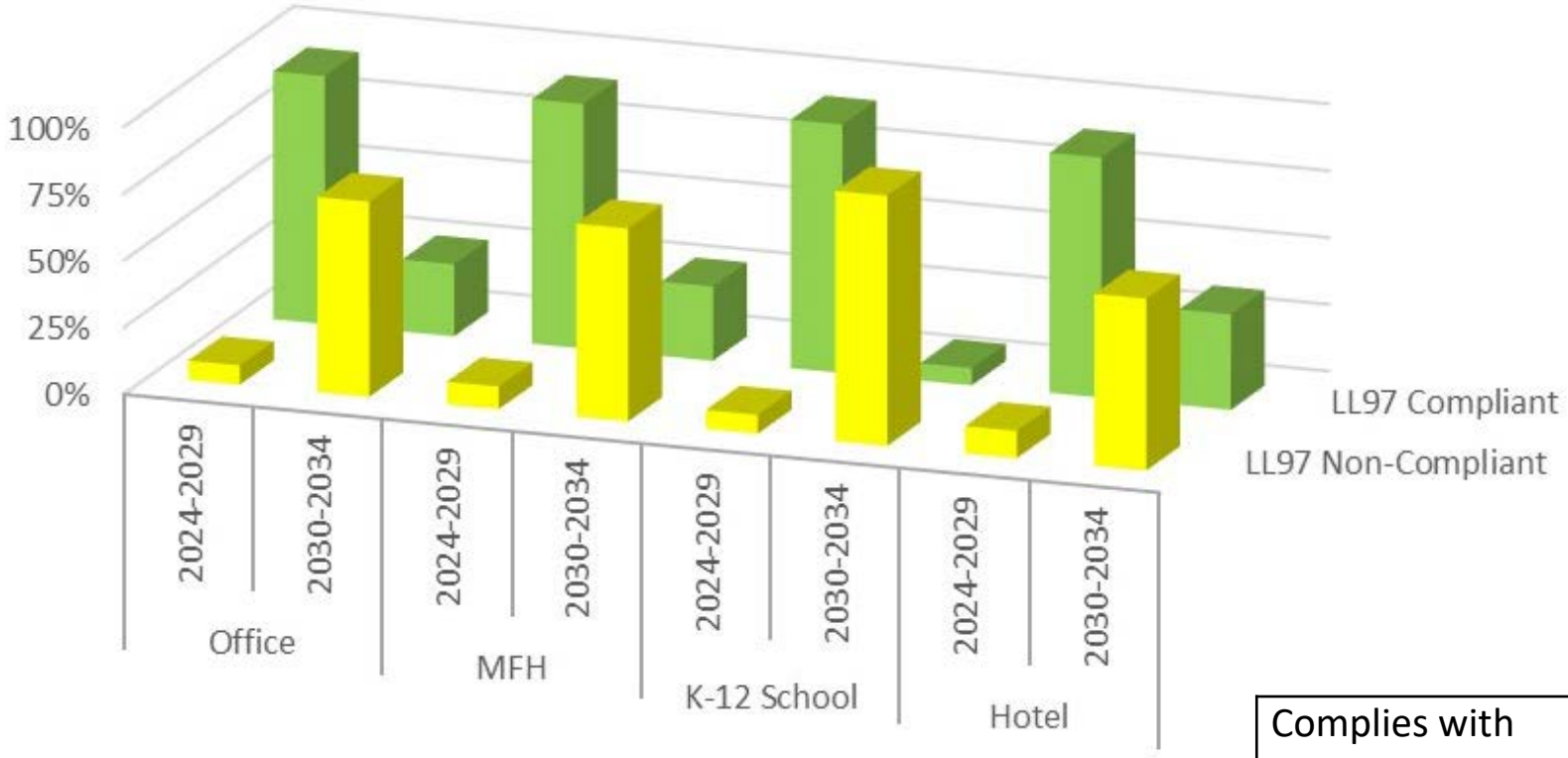
Multifamily and K-12 Trends





- Definite downward trends for Multifamily
- No similar trends seen in Office, K-12 Schools or Hotels

So How About LL97 Compliance?

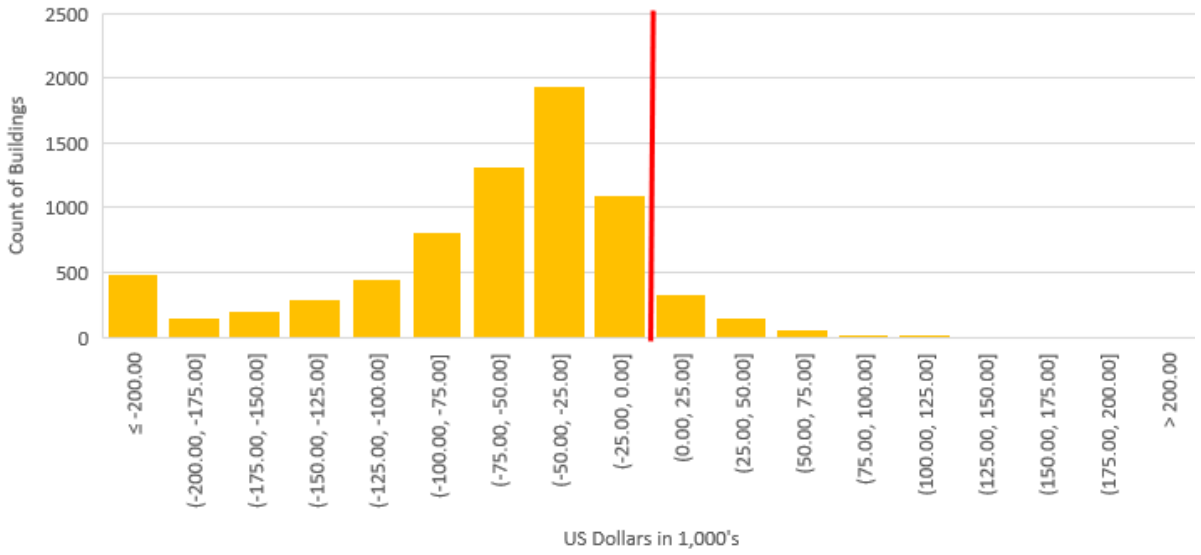


	Building Use Type				
	Office	Multifamily	K-12 School	Hotel	Total
Complies with 2024-29 tCO2e Cap	93%	92%	93%	90%	92%
Complies with 2030-34 tCO2e Cap	27%	28%	6%	36%	26%

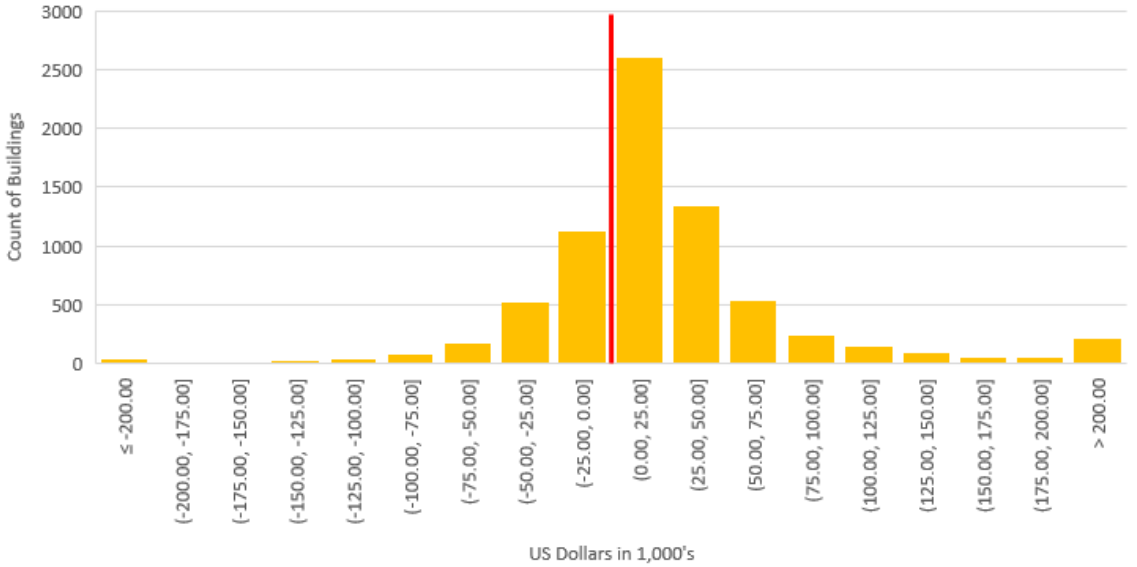
2024 vs. 2030 Carbon Caps

	tCO2e Cap per Square Foot		Percent Change
	2024 – 2029	2030 – 2034	
Office	0.00758	0.00269	65%
Multifamily Housing	0.00675	0.00335	50%
K-12 School	0.00675	0.00223	67%
Hotel	0.00987	0.00385	61%

What Will it Cost?



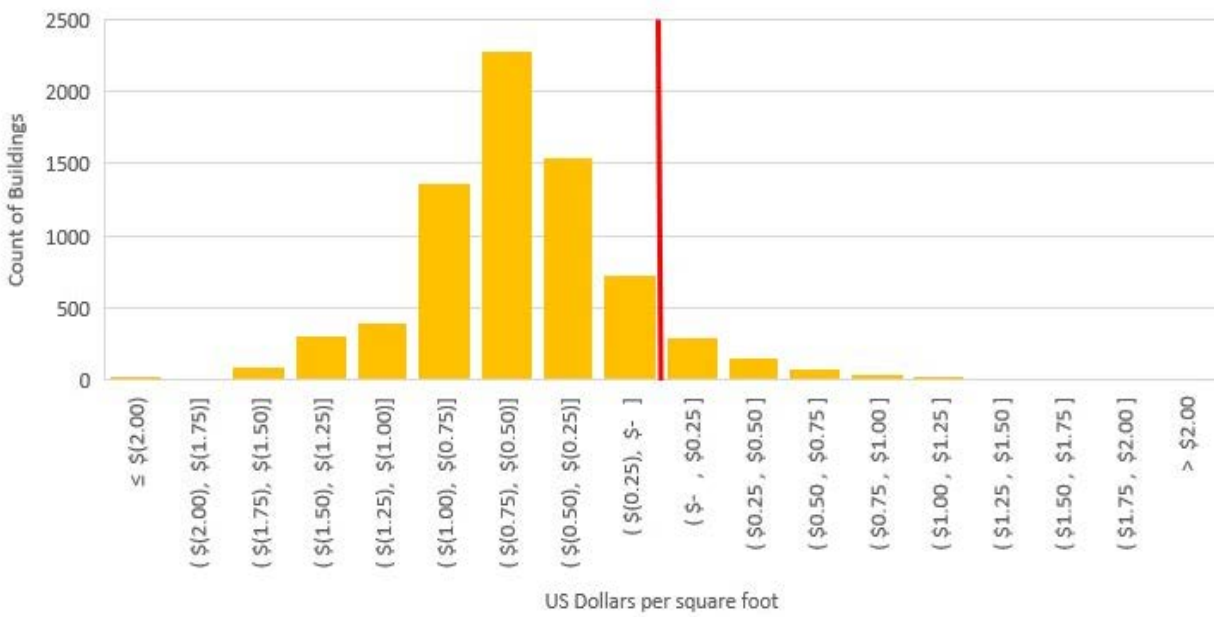
Multifamily – 2024-2029



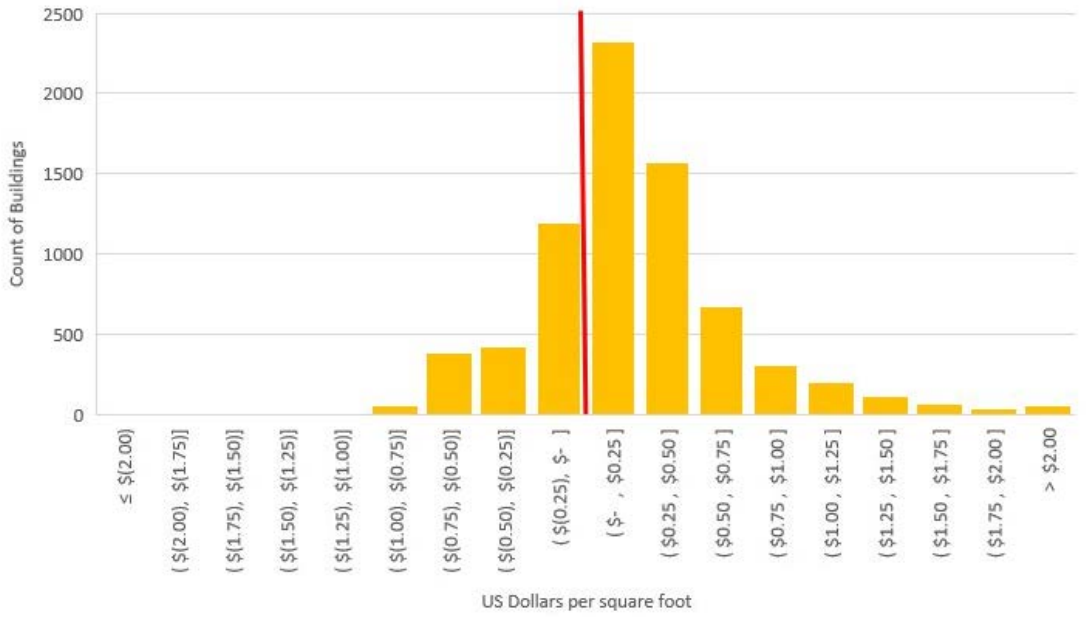
Multifamily – 2030-2034

Total fines in $1,000s USD
Assumes a cleaner electric grid in 2030-2034

And What Will it Cost per Square Foot?



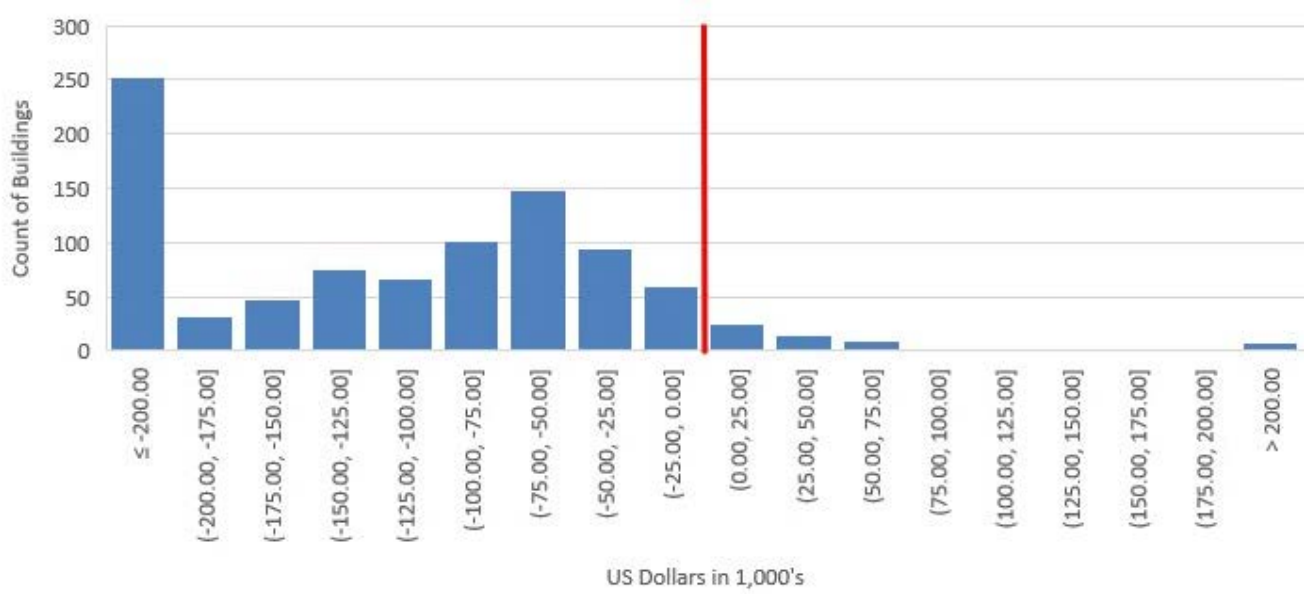
Multifamily – 2024-2029



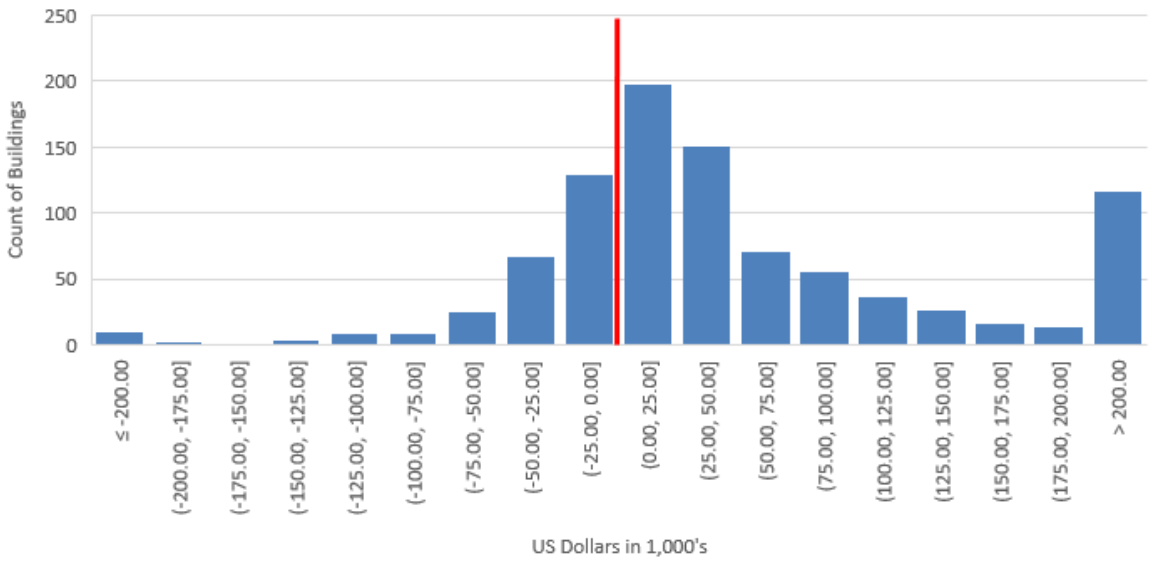
Multifamily – 2030-2034

Total fines in US dollars per square foot
Assumes a cleaner electric grid in 2030-2034
Generally, less than $1.00 per square foot

And What Will it Cost per Square Foot?



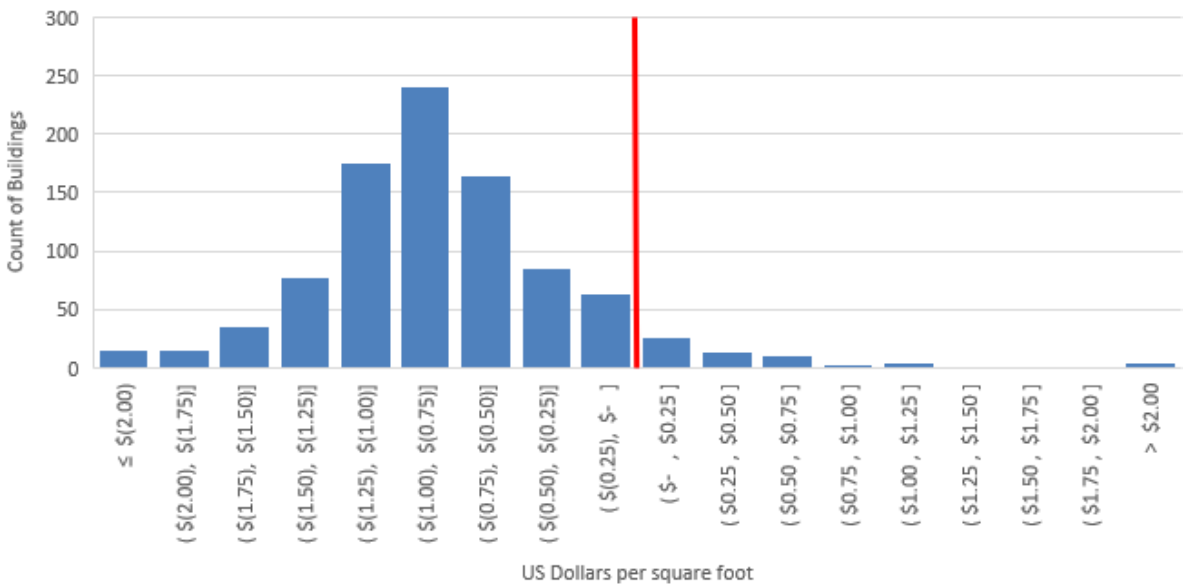
Office – 2024-2029



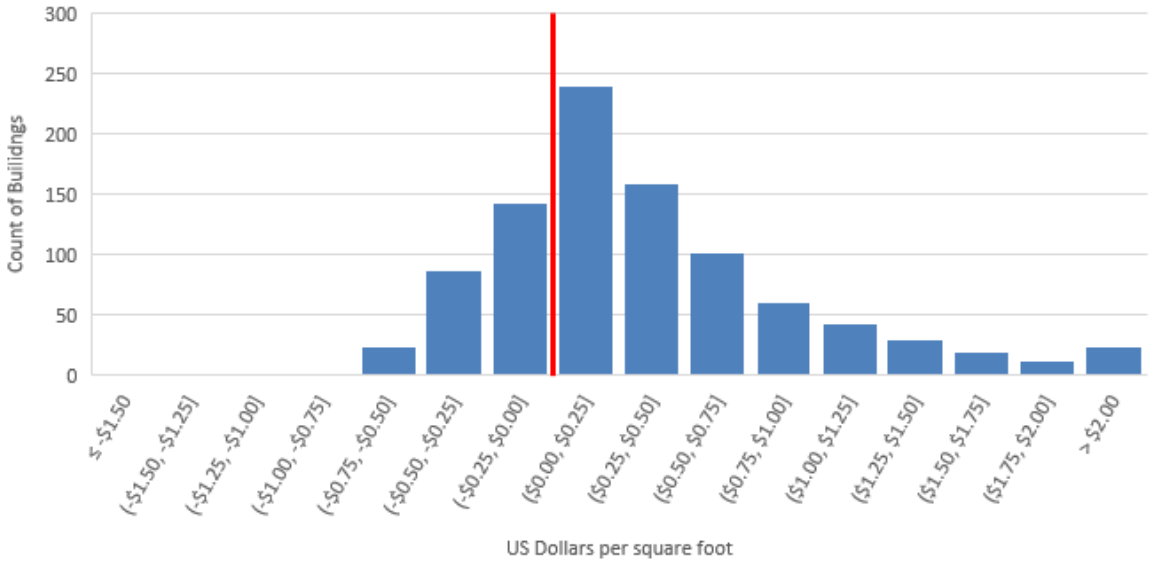
Office – 2030-2034

Total fines in $1,000s USD
Assumes a cleaner electric grid in 2030-2034

And What Will it Cost per Square Foot?



Office – 2024-2029

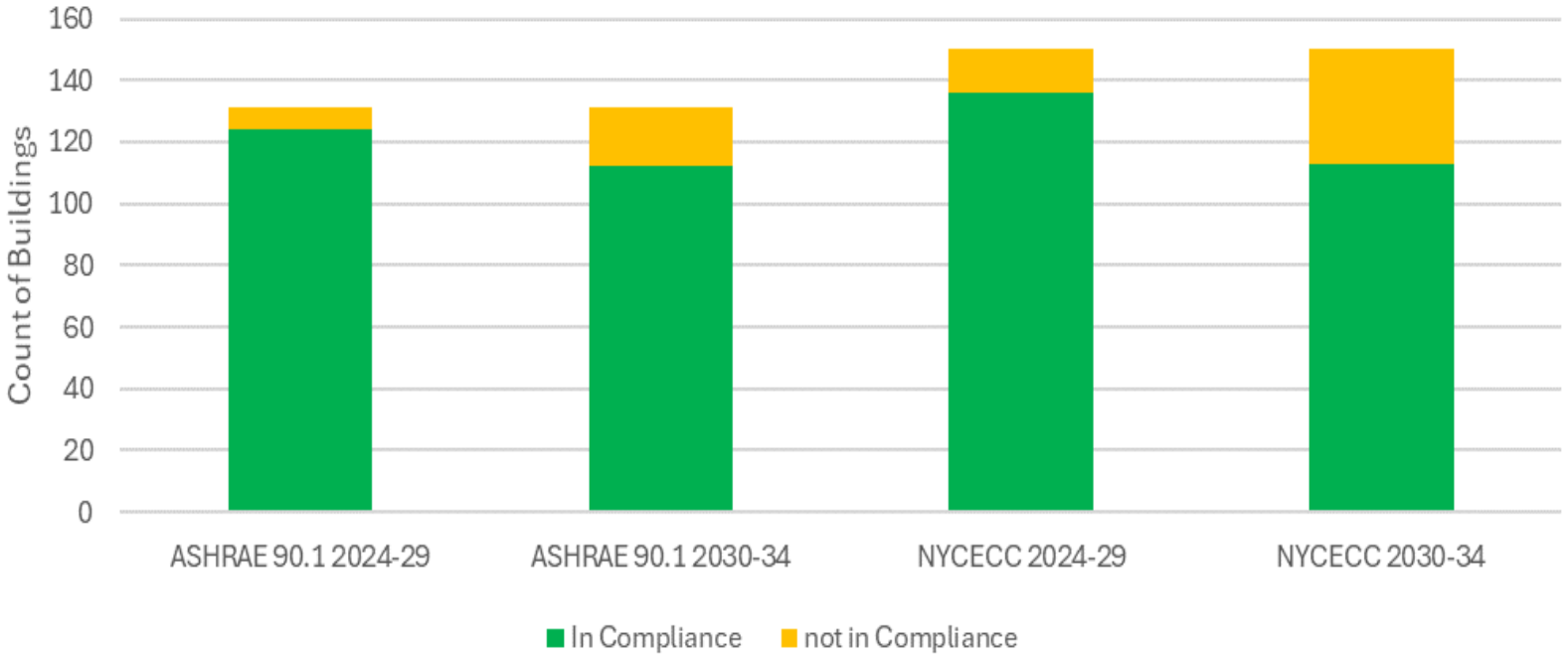


Office – 2030-2034

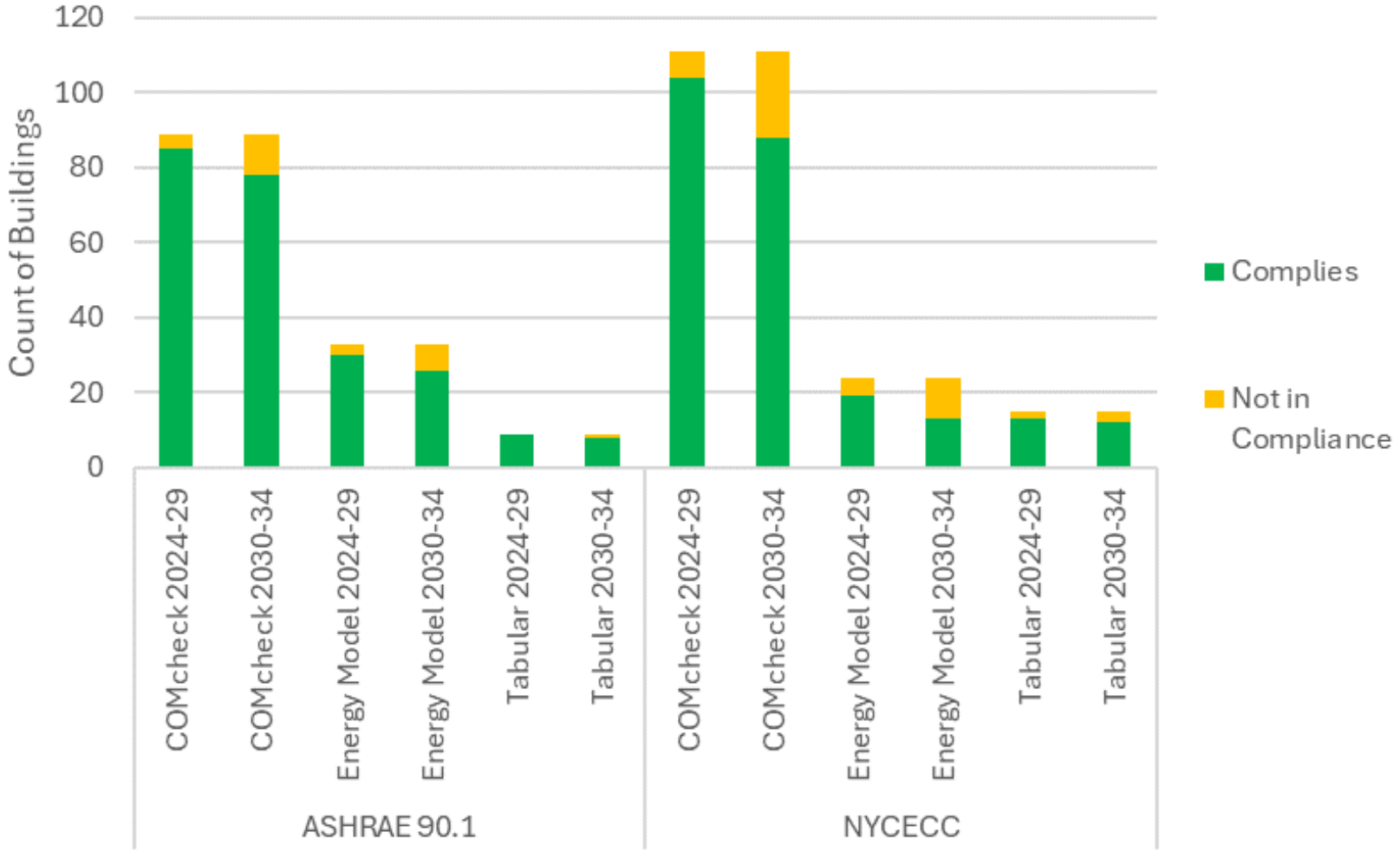
Total fines in US dollars per square foot
Assumes a cleaner electric grid in 2030-2034
Generally, less than $1.00 per square foot

What About New Construction and LL97?

- 281 buildings permitted since 2015 with 2022 LL84 benchmarking submission
- Codes: NYCECC or ASHARE 90.1
- Pathways: Tabular, COMcheck or Energy Modeling
- Calculated caps and emissions per NYC Rules

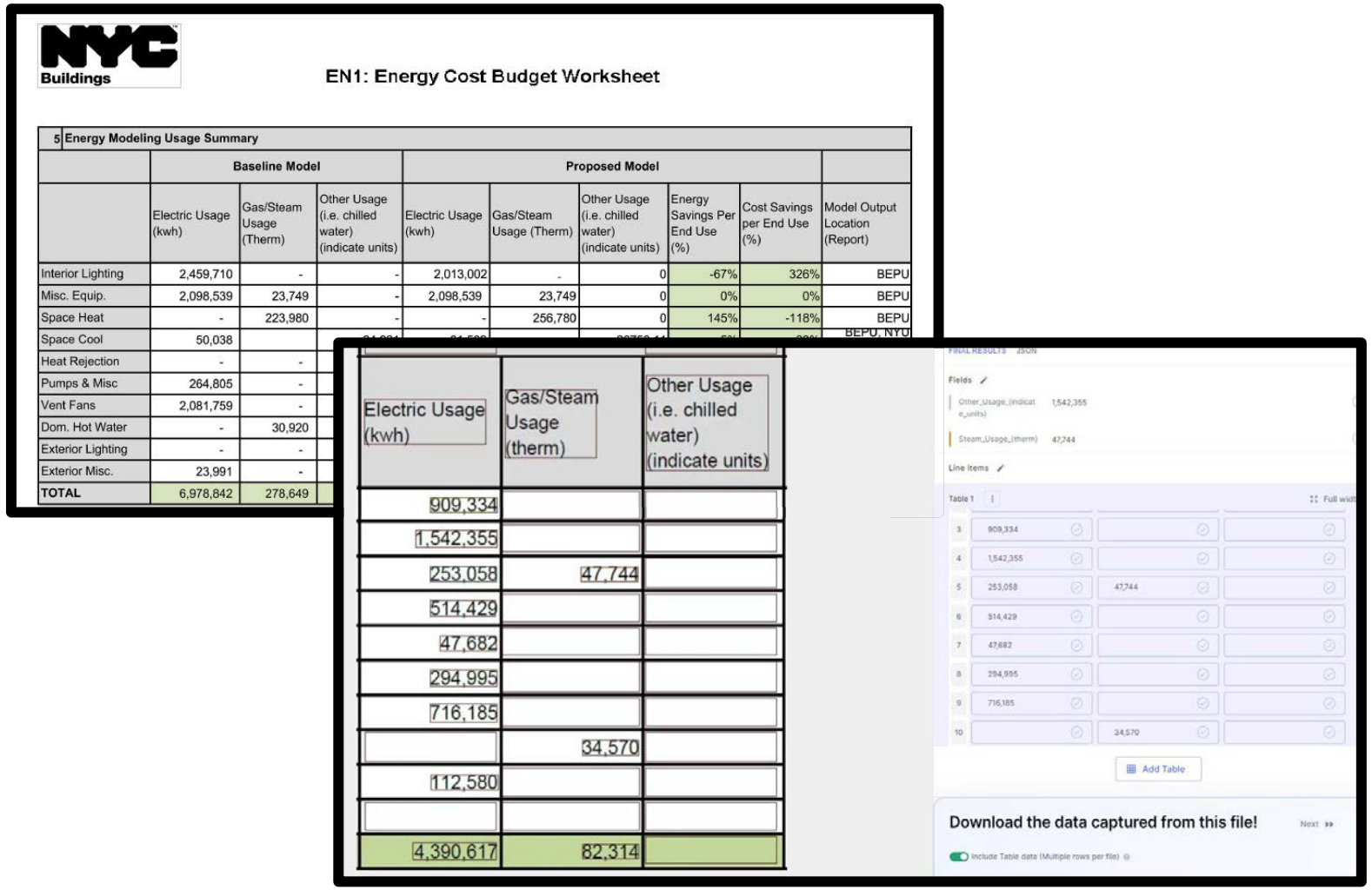


New Construction by Compliance Pathway



And Speaking of Energy Modeling…

- Analyzed drawing sets from Dept. of Buildings
- Extracted energy modeling results
- Baseline and proposed model results by end-use energy source
- Compared to 2022 LL84 benchmarking results
- Calculated GHG emissions



NYC Buildings

EN1: Energy Cost Budget Worksheet

5 Energy Modeling Usage Summary

	Baseline Model			Proposed Model					
	Electric Usage (kwh)	Gas/Steam Usage (Therm)	Other Usage (i.e. chilled water) (indicate units)	Electric Usage (kwh)	Gas/Steam Usage (Therm)	Other Usage (i.e. chilled water) (indicate units)	Energy Savings Per End Use (%)	Cost Savings per End Use (%)	Model Output Location (Report)
Interior Lighting	2,459,710	-	-	2,013,002	-	0	-67%	326%	BEPU
Misc. Equip.	2,098,539	23,749	-	2,098,539	23,749	0	0%	0%	BEPU
Space Heat	-	223,980	-	-	256,780	0	145%	-118%	BEPU
Space Cool	50,038								BEPU, NYU
Heat Rejection	-	-							
Pumps & Misc	264,805	-							
Vent Fans	2,081,759	-							
Dom. Hot Water	-	30,920							
Exterior Lighting	-	-							
Exterior Misc.	23,991	-							
TOTAL	6,978,842	278,649							

Electric Usage (kwh)	Gas/Steam Usage (therm)	Other Usage (i.e. chilled water) (indicate units)
909,334		
1,542,355		
253,058	47,744	
514,429		
47,682		
294,995		
716,185		
	34,570	
112,580		
4,390,617	82,314	

FINAL RESULTS JSON

Fields

Other_Usage_(indicate_units) 1,542,355

Steam_Usage_(therm) 47,744

Line Items

Table 1

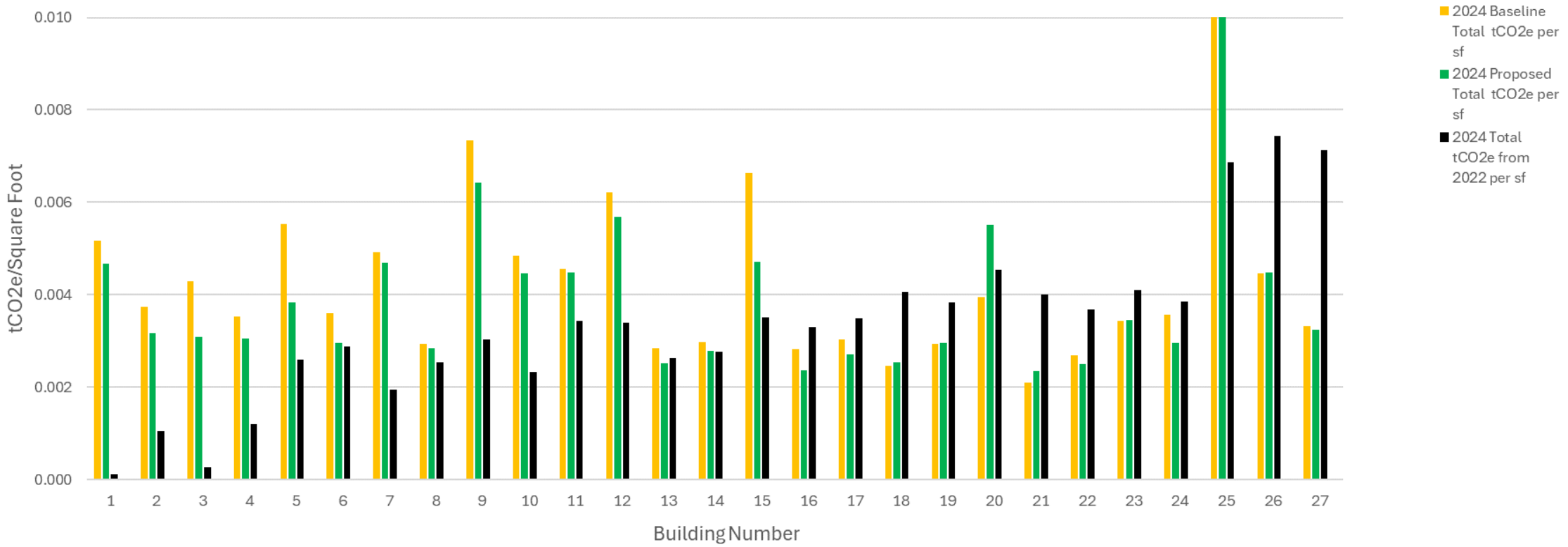
Add Table

Download the data captured from this file!

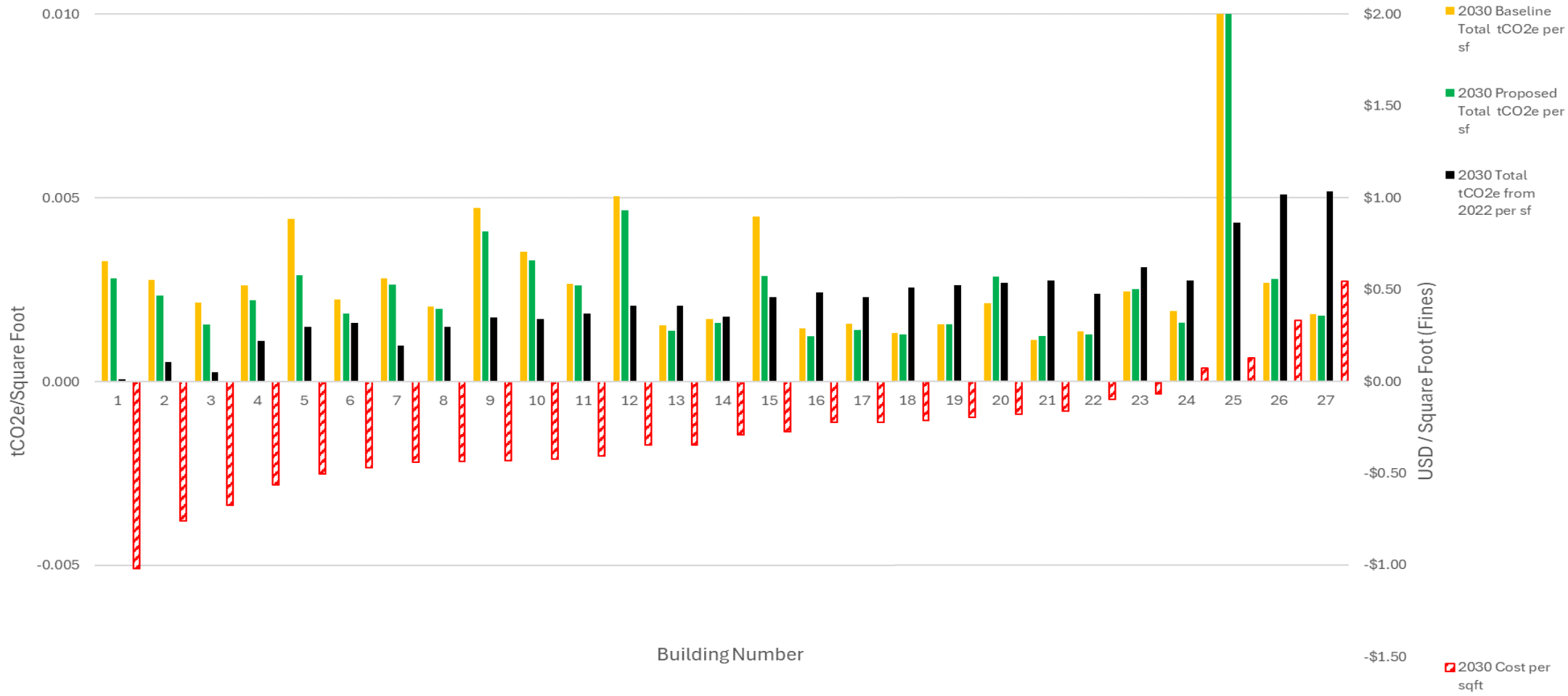
Next

Include Table data (Multiple rows per file)

2022 GHG Emissions vs. Models



Energy Modeling vs. LL97 2030 Compliance

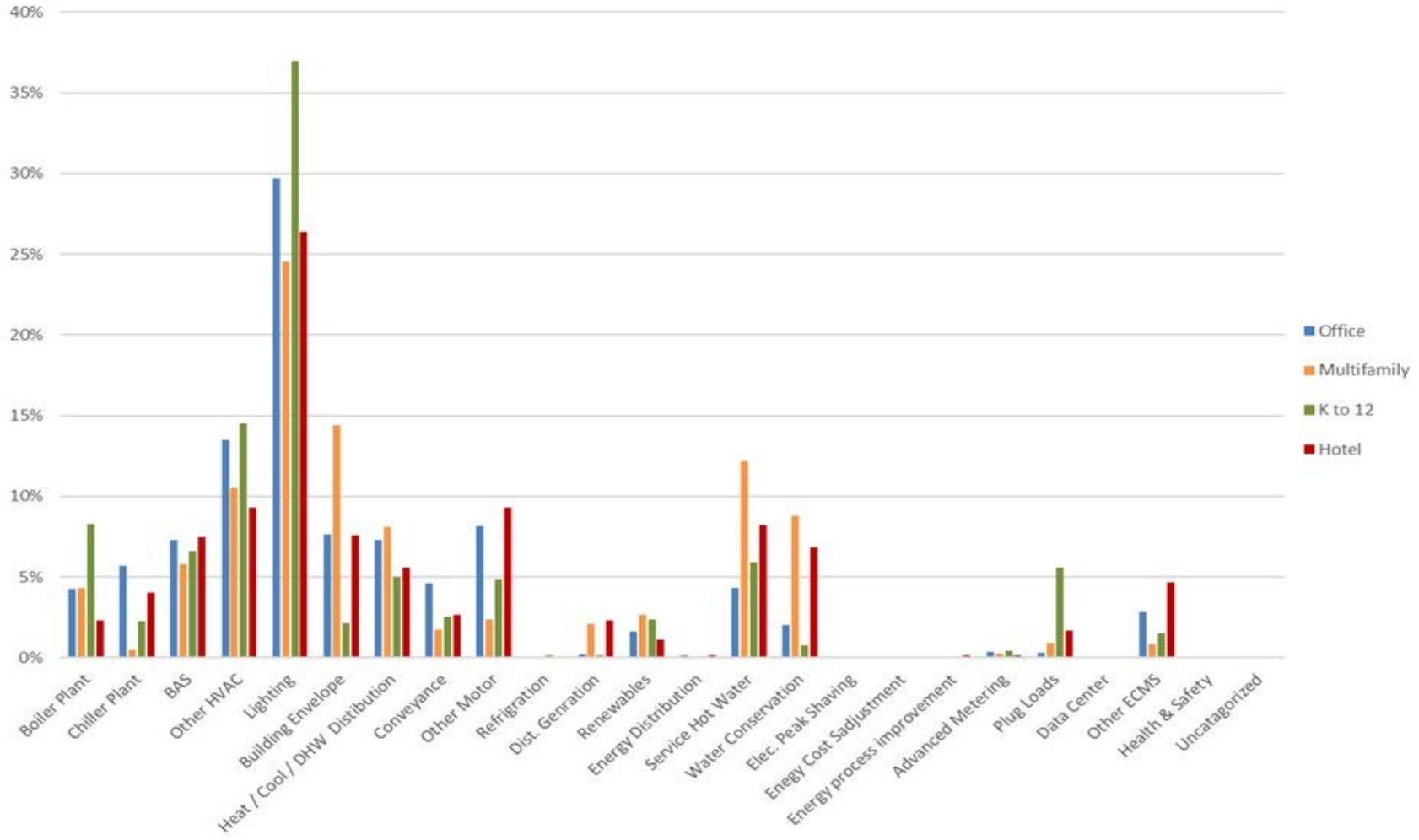


LL87 Audits

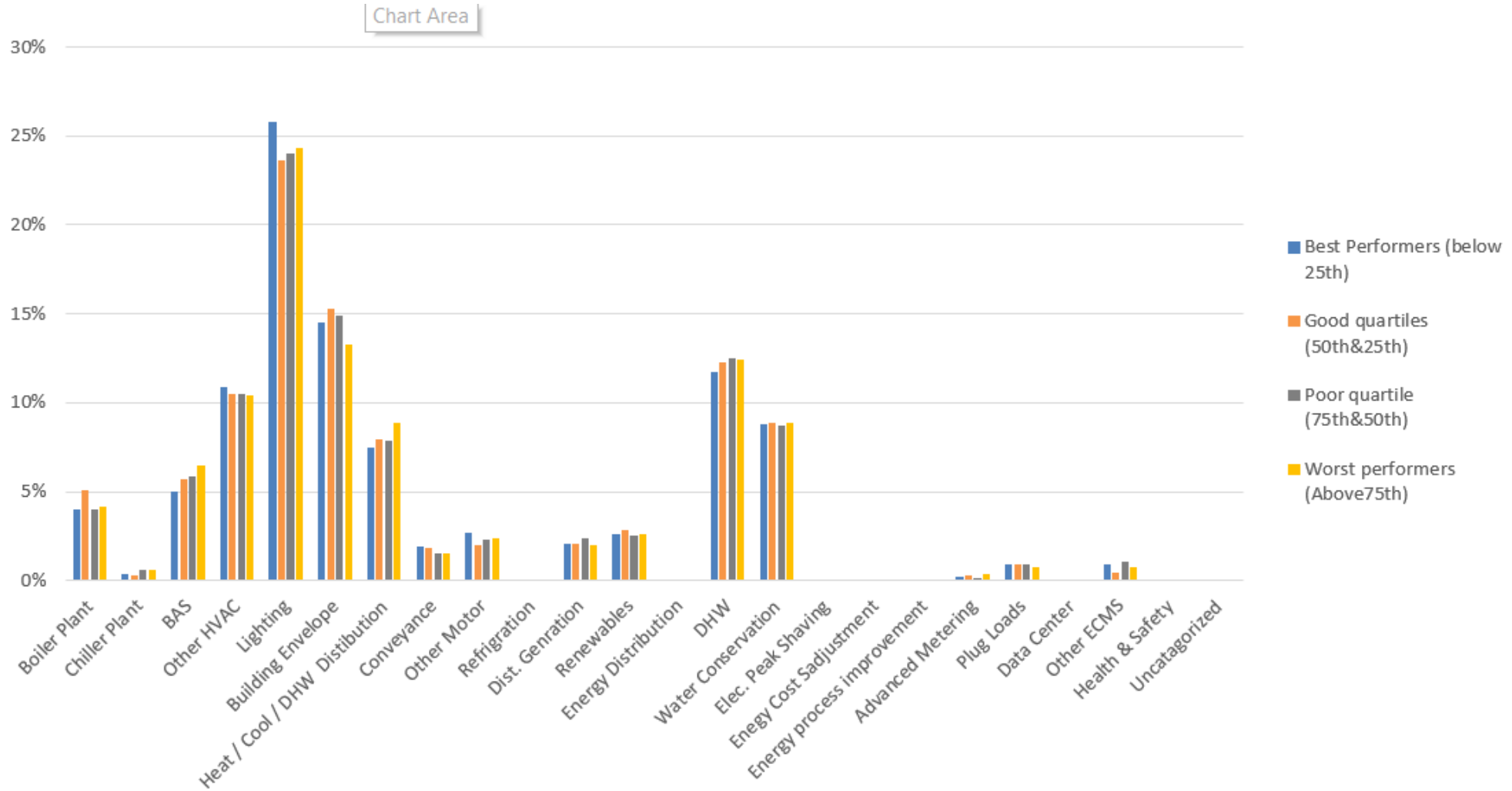
- Properties with a LL84 (benchmarking) submission in 2018-2019
- Properties greater than 50,000 sf and less than 1,000,000 sf
- Properties with an EUI greater than 5 and less than 1,000
- Properties with LL84 submissions with at least 12 months of utility data
- The four property use types with the largest number of buildings
- Accessed BSXML files from USDOE Audit Template website

Use Group	Total number of BINs in overall dataset	Number of BINS after filtering	Number of BINs with BSXML files	Percentage of filtered BINs with BSXML file
Multifamily	15,264	7,492	3,761	50%
Office	1,875	1,015	364	36%
K-12 School	1,362	921	384	42%
Hotel	480	232	48	21%
Total	18,981	9,660	4,557	47%

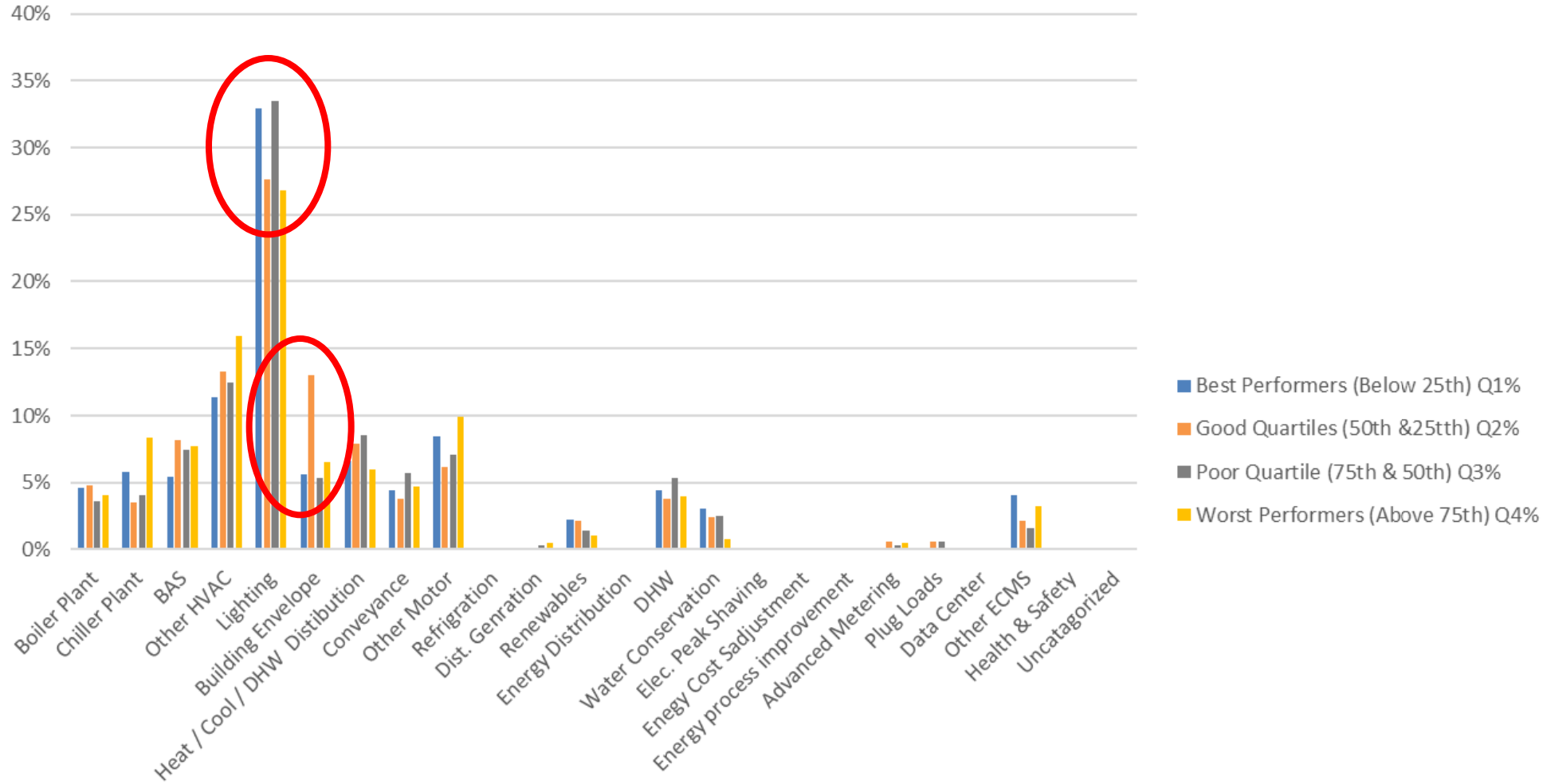
Percentage Recommended ECM by Category



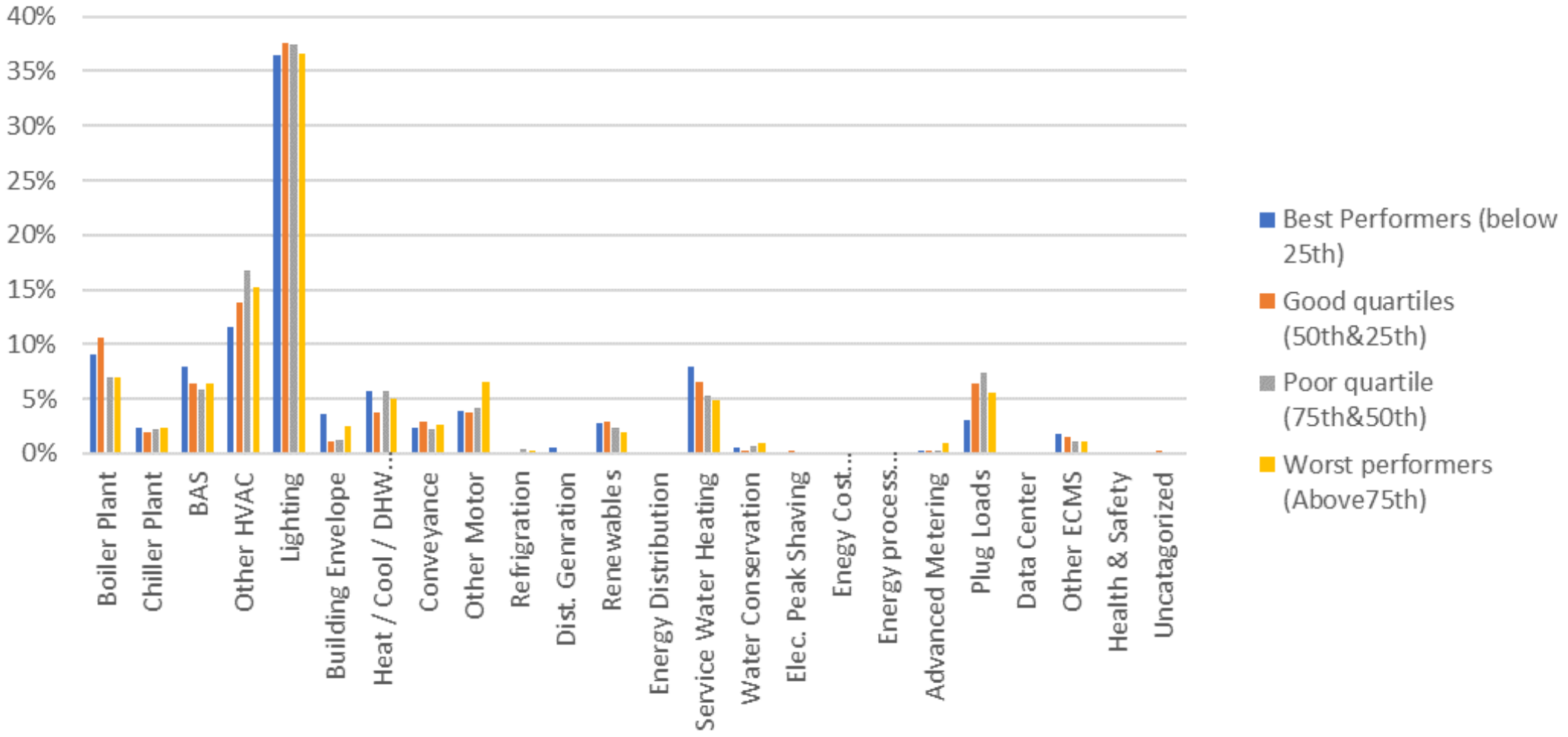
Multifamily – Percentage ECM by Category



Office – Percentage ECM by Category



K-12 Schools – Percentage ECM by Category



Measures with over 5% recommendations for at least three building use groups

Measure	K to 12		Office		Hotel		MF		Average % Recommend
	Count of BIN	% of BIN	Count of BIN	% of BIN	Count of BIN	% of BIN	Count of BIN	% of BIN	
Retrofit with light emitting diode technologies	171	45%	236	65%	34	71%	2626	70%	63%
Add or upgrade BAS/EMS/EMCS	36	9%	107	29%	14	29%	1164	31%	25%
Add occupancy sensors	82	21%	79	22%	20	42%	515	14%	25%
Add pipe insulation	34	9%	85	23%	8	17%	1373	37%	21%
Add VSD motor controller	30	8%	86	24%	20	42%	365	10%	21%
Other lighing	85	22%	84	23%	7	15%	789	21%	20%
Separate SHW from heating	26	7%	21	6%	5	10%	1513	40%	16%
Other heating	40	10%	57	16%	4	8%	726	19%	13%
Air seal envelope	8	2%	47	13%	4	8%	1089	29%	13%
Upgrade operating protocols, calibration, and/or sequencing	16	4%	50	14%	6	13%	636	17%	12%
Upgrade motors	36	9%	53	15%	5	10%	270	7%	10%
Other chiller	26	7%	46	13%	8	17%	49	1%	9%
Replace windows	5	1%	35	10%	3	6%	712	19%	9%
Replace boiler	43	11%	30	8%	3	6%	362	10%	9%
Other SHW	27	7%	18	5%	5	10%	345	9%	8%
Install demand control ventilation	43	11%	20	5%	3	6%	50	1%	6%

- Red shading = greater than 10% of buildings received this measure recommendation
- Yellow shading between 5% and 10% of buildings received this recommendation
- White shading = fewer than 5% of buildings received this recommendation

Are Auditors Biased?

Auditor	Count of Distinct BINs	Auditor	Count of Distinct BINs	Auditor	Count of Distinct BINs	Auditor	Count of Distinct BINs
MFH Auditor 01	142	Office Auditor 01	24	Hotel Auditor 01	5	K-12 Auditor 01	92
MFH Auditor 02	132	Office Auditor 02	18	Hotel Auditor 02	4	K-12 Auditor 02	81
MFH Auditor 03	107	Office Auditor 03	11	Hotel Auditor 03	3	K-12 Auditor 03	68
MFH Auditor 04	56	Office Auditor 04	9	Hotel Auditor 04	3	K-12 Auditor 04	45
MFH Auditor 05	56	Office Auditor 05	9	Hotel Auditor 05	2	K-12 Auditor 05	33
MFH Auditor 06	56	Office Auditor 06	8	Hotel Auditor 06	2		
MFH Auditor 07	51	Office Auditor 07	8	Hotel Auditor 07	2		
MFH Auditor 08	43	Office Auditor 08	7	Hotel Auditor 08	2		
MFH Auditor 09	41	Office Auditor 09	6	Hotel Auditor 09	2		
MFH Auditor 10	39	Office Auditor 10	5	Hotel Auditor 10	1		

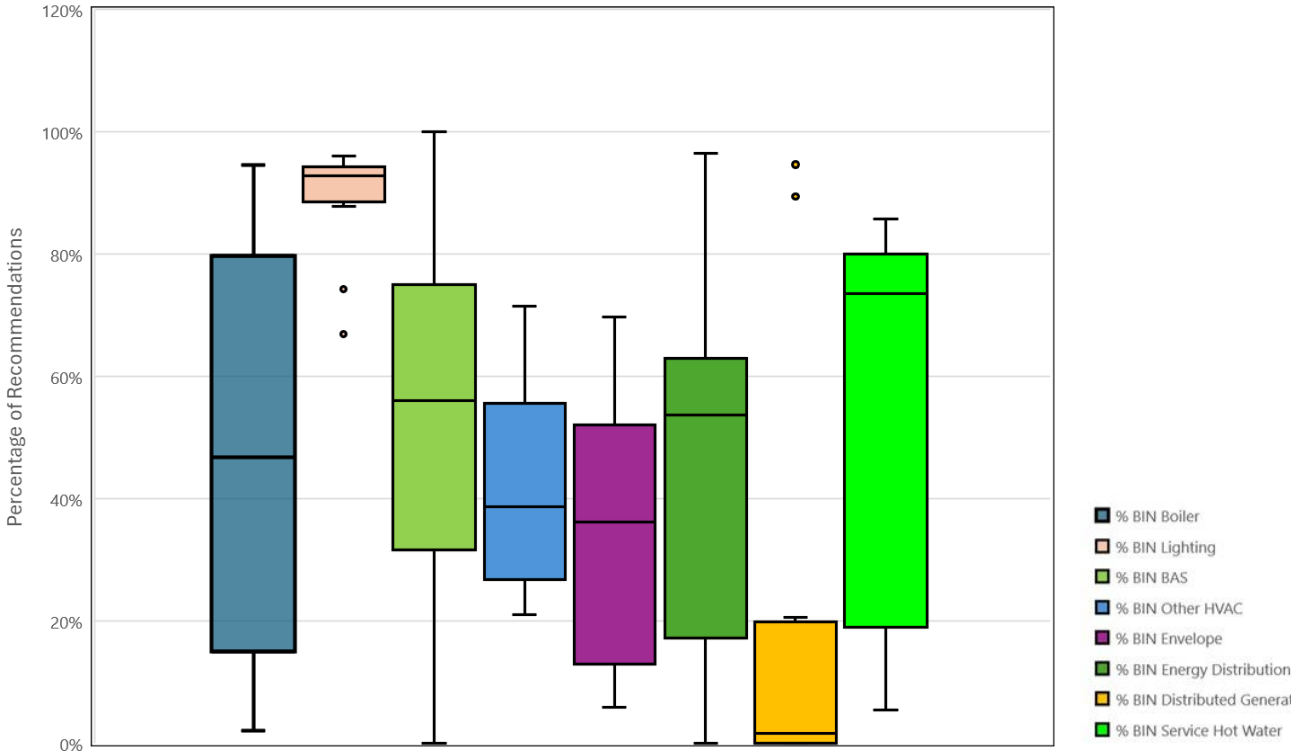
Multifamily

Auditor	% BIN Boiler	% BIN Chiller	% BIN BAS	% BIN Other HVAC	% BIN Lighting	% BIN Envelope	% BIN CW/HW & Steam	% BIN Conveyance	% BIN Other electric motors and drives	% BIN Refrigeration	% BIN Distributed Generation	% BIN Renewable Energy Systems	% BIN Energy Distribution Systems	% BIN Service Hot Water	% BIN Water Sewer Conservation	% BIN Electrical peak shaving load shifting	% BIN Energy cost reduction through adjustments	% BIN Energy Related Process Improvements	% BIN Advanced Metering System	% BIN Plug Load Reductions	% BIN Data Center Improvements	% BIN Future Other ECMs	% BIN Health and Safety	% BIN Uncategorized	Count of Distinct BINs
MFH Auditor 1	5%	0%	39%	38%	67%	33%	10%	1%	0%	0%	1%	58%	1%	76%	8%	0%	0%	0%	0%	0%	0%	2%	0%	0%	142
MFH Auditor 2	85%	0%	57%	54%	74%	96%	66%	0%	7%	0%	89%	0%	0%	81%	93%	0%	0%	0%	0%	0%	0%	1%	0%	0%	132
MFH Auditor 3	52%	3%	85%	26%	91%	51%	53%	12%	21%	0%	21%	4%	0%	71%	65%	0%	0%	0%	4%	3%	0%	7%	0%	0%	107
MFH Auditor 4	41%	0%	70%	68%	93%	38%	48%	0%	32%	2%	18%	32%	0%	5%	88%	0%	0%	5%	11%	29%	0%	5%	0%	0%	56
MFH Auditor 5	30%	2%	11%	39%	93%	0%	13%	0%	61%	0%	0%	86%	0%	82%	4%	0%	0%	0%	0%	0%	0%	9%	0%	2%	56
MFH Auditor 6	95%	0%	55%	71%	95%	96%	70%	0%	0%	25%	95%	96%	0%	86%	4%	0%	0%	0%	0%	73%	0%	11%	0%	0%	56
MFH Auditor 7	2%	0%	0%	24%	96%	55%	6%	6%	0%	0%	0%	65%	0%	39%	37%	0%	0%	0%	0%	0%	0%	0%	0%	0%	51
MFH Auditor 8	65%	0%	77%	21%	93%	19%	14%	0%	19%	5%	0%	53%	2%	7%	0%	0%	0%	0%	0%	5%	0%	9%	0%	0%	43
MFH Auditor 9	10%	0%	29%	56%	88%	41%	41%	0%	10%	0%	2%	12%	2%	12%	44%	0%	0%	0%	7%	7%	0%	2%	0%	0%	41
MFH Auditor 10	85%	0%	100%	23%	95%	0%	31%	10%	79%	0%	0%	54%	0%	77%	97%	0%	0%	15%	0%	0%	0%	3%	0%	0%	39
Min	2%	0%	0%	21%	67%	0%	6%	0%	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Max	95%	3%	100%	71%	96%	96%	70%	12%	79%	25%	95%	96%	2%	86%	97%	0%	0%	15%	11%	73%	0%	11%	0%	2%	
Median	47%	0%	56%	39%	93%	39%	36%	0%	14%	0%	2%	54%	0%	74%	41%	0%	0%	0%	0%	1%	0%	4%	0%	0%	

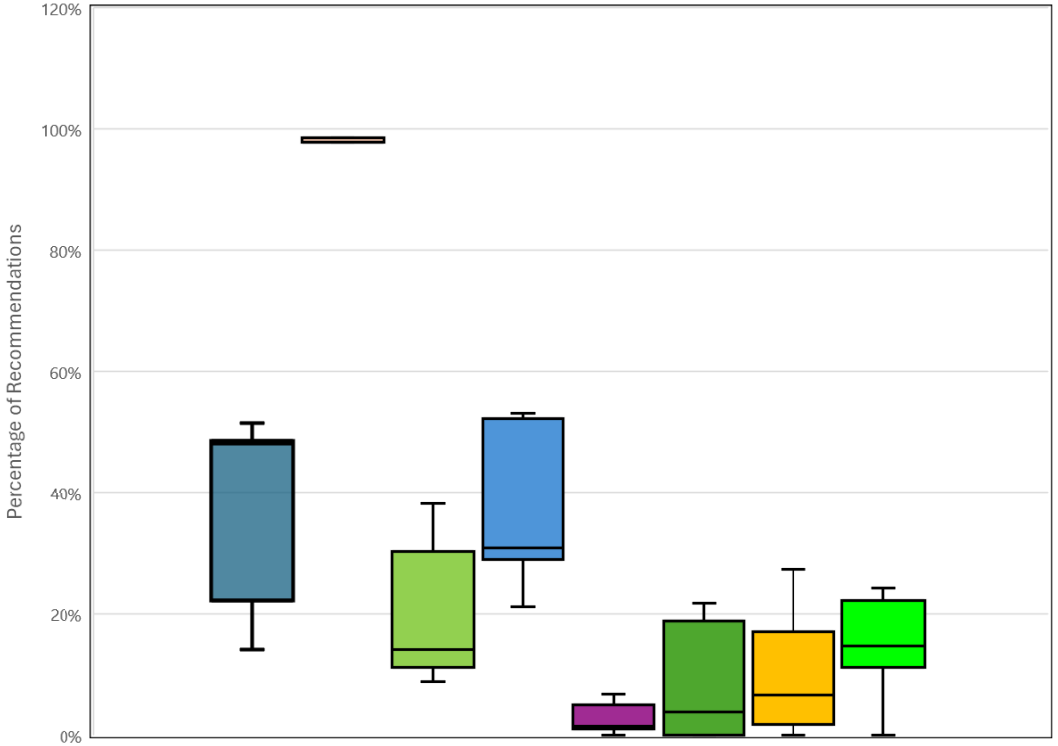
K-12 Schools

Auditor	% BIN Boiler	% BIN Chiller	% BIN BAS	% BIN Other HVAC	% BIN Lighting	% BIN Envelope	% BIN CW/HW & Steam	% BIN Conveyance	% BIN Other electric motors and drives	% BIN Refrigeration	% BIN Distributed Generation	% BIN Renewable Energy Systems	% BIN Energy Distribution Systems	% BIN Service Hot Water	% BIN Water Sewer Conservation	% BIN Electrical peak shaving load shifting	% BIN Energy cost reduction through adjustments	% BIN Energy Related Process Improvements	% BIN Advanced Metering System	% BIN Plug Load Reductions	% BIN Data Center Improvements	% BIN Future Other ECMs	% BIN Health and Safety	% BIN Uncategorized	Count of BINs
K-12 Auditor 1	14%	22%	14%	52%	98%	4%	20%	35%	4%	0%	0%	7%	0%	13%	3%	0%	0%	0%	0%	13%	0%	7%	0%	0%	92
K-12 Auditor 2	48%	4%	38%	53%	95%	1%	25%	1%	37%	4%	0%	14%	0%	11%	1%	1%	0%	0%	0%	27%	0%	7%	0%	0%	81
K-12 Auditor 3	51%	0%	9%	31%	99%	1%	0%	6%	22%	0%	0%	0%	0%	15%	1%	0%	0%	0%	0%	59%	0%	0%	0%	0%	68
K-12 Auditor 4	22%	18%	11%	29%	98%	7%	9%	4%	7%	0%	0%	2%	0%	22%	0%	0%	0%	0%	18%	29%	0%	4%	0%	0%	45
K-12 Auditor 5	48%	0%	30%	21%	100%	0%	3%	0%	0%	0%	0%	27%	0%	24%	0%	0%	0%	0%	0%	6%	0%	12%	0%	0%	33
Min	14%	0%	9%	21%	95%	0%	0%	0%	0%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	6%	0%	0%	0%	0%	
Max	51%	22%	38%	53%	100%	7%	25%	35%	37%	4%	0%	27%	0%	24%	3%	1%	0%	0%	18%	59%	0%	12%	0%	0%	
Median	48%	4%	14%	31%	98%	1%	9%	4%	7%	0%	0%	7%	0%	15%	1%	0%	0%	0%	0%	27%	0%	7%	0%	0%	

Spread in Recommendations

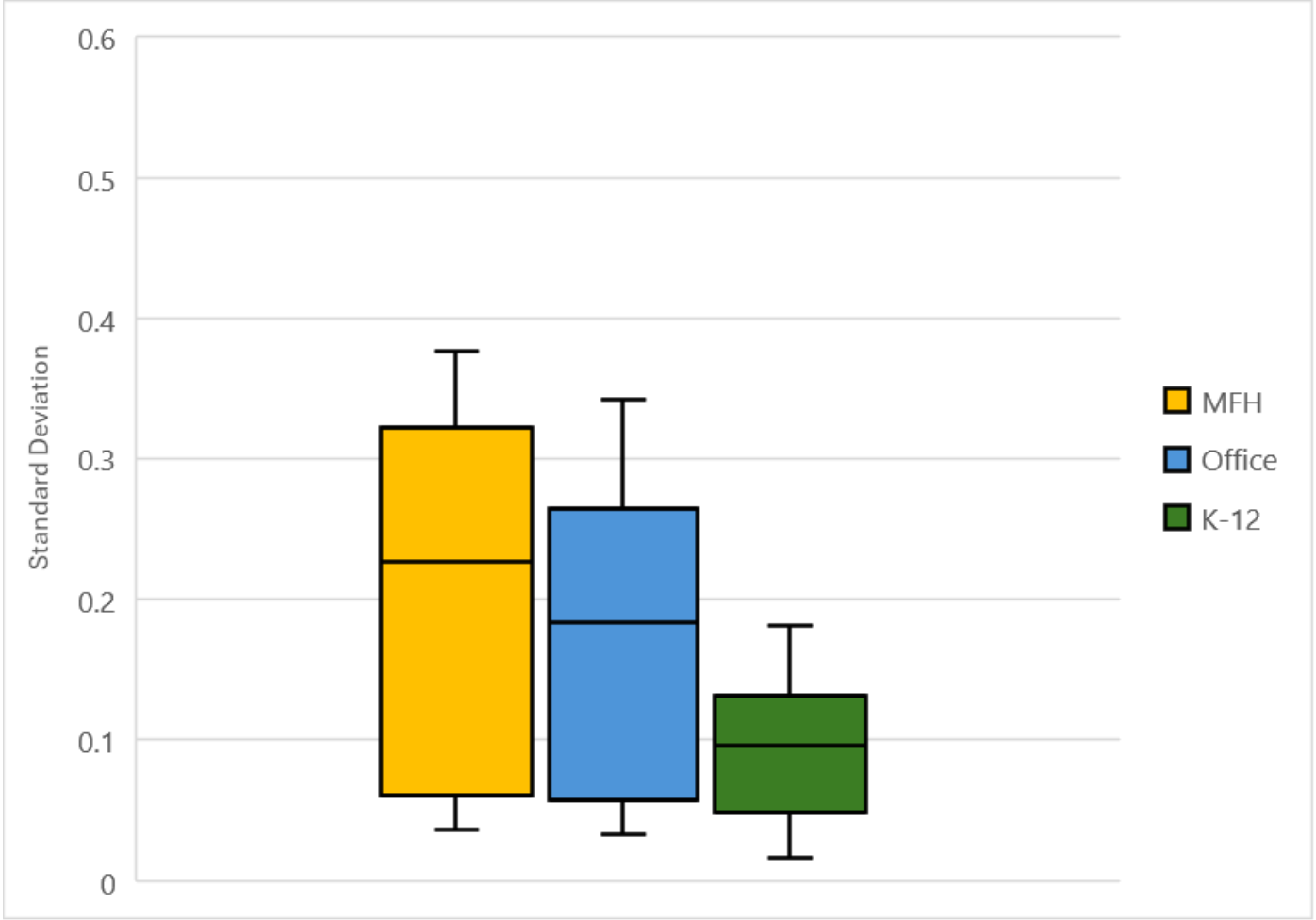


Multifamily



K-12 Schools

Standard Deviation

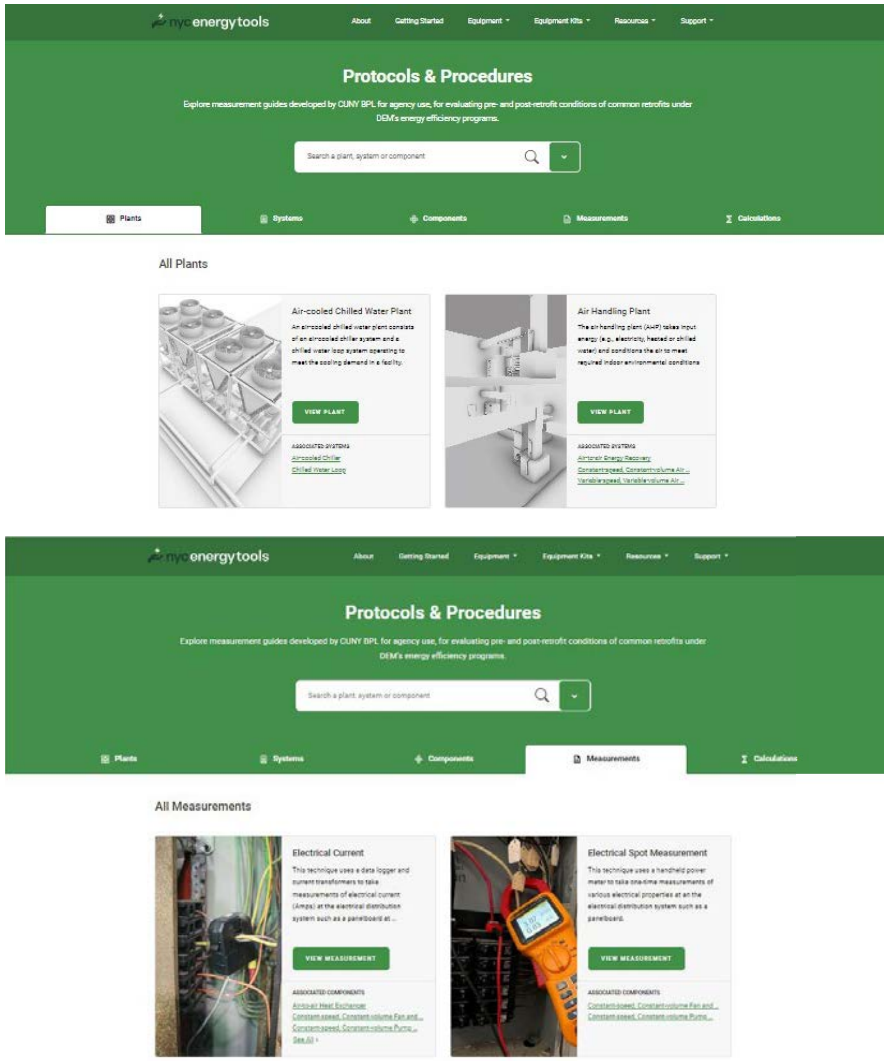


Other Random Acts of Research

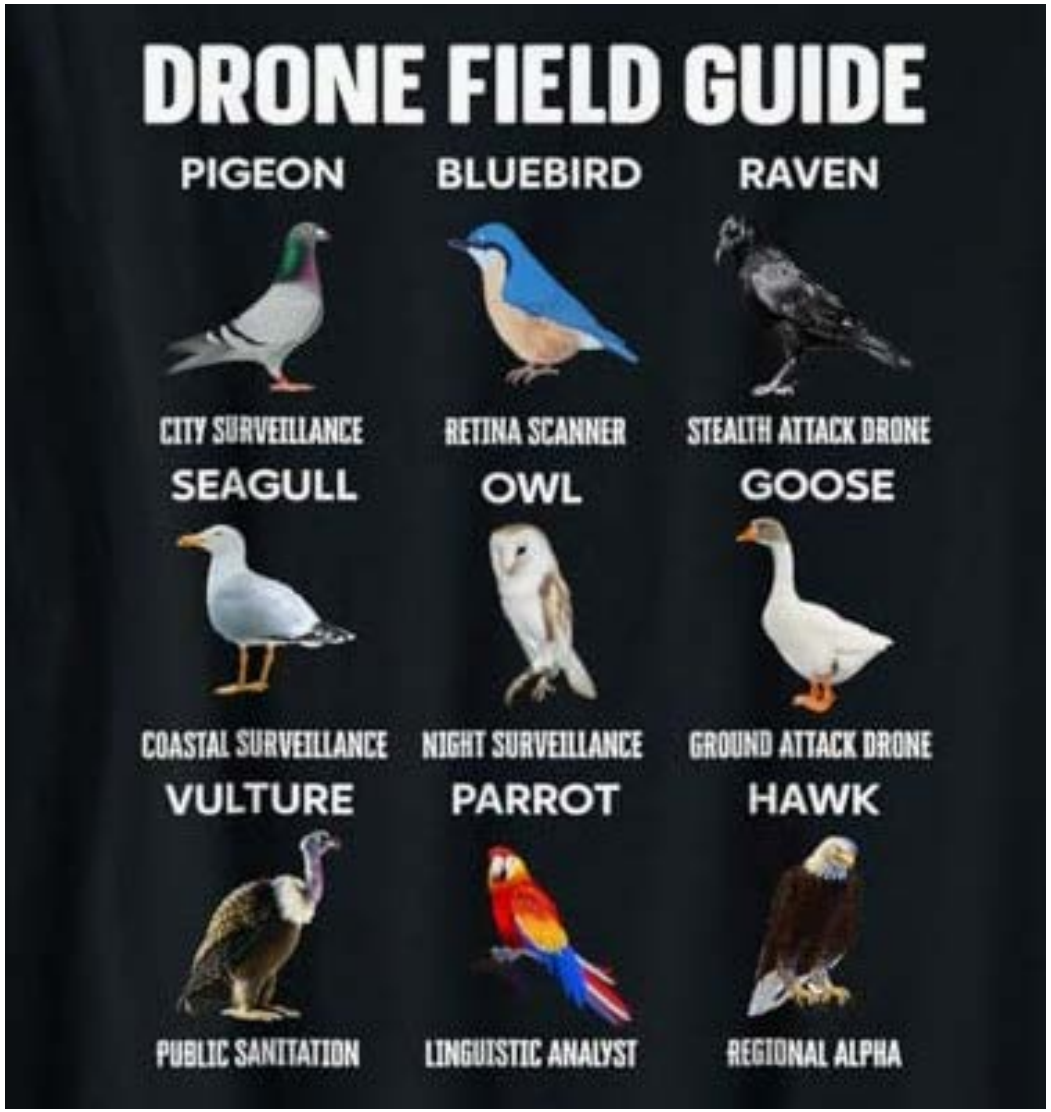
- Measuring large air hander airflow and outside air – 5,000 to 50,000 CFM
- BAS standards for long-term M&V
- Calculation and measurement standards for common commercial building retrofits

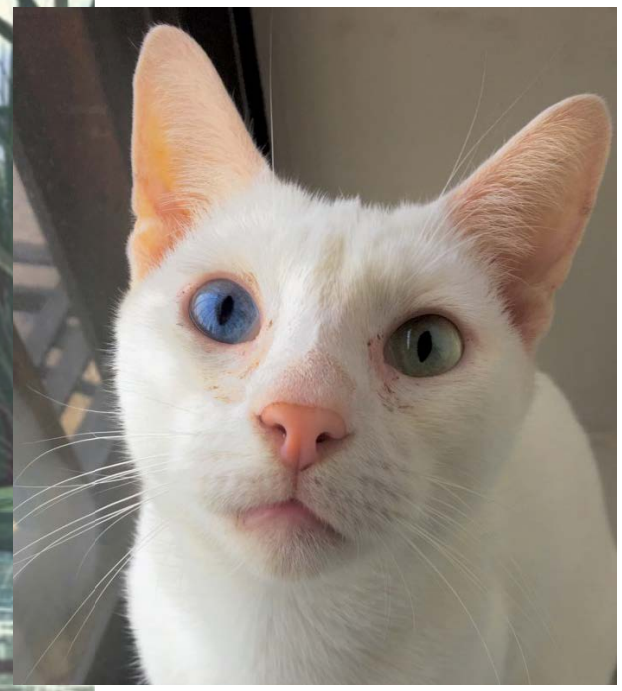
CUNY BPL M&V Protocols & Procedures

- Developed for DCAS DEM, city agency and consultant personnel
- Website documenting major Plants, Systems and Components in commercial buildings
- Provide standard measurement and energy calculation guidance
- Coupled with an extensive library of measurement tools
- www.nycenergytools.com



Parting Thoughts…





Thank You

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