CAE 465/526 Building Energy Conservation Technologies

Fall 2022

October 5, 2020

Assignment feedback and building energy audits and commissioning

Built
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Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

RHINO/LBT OPENSTUDIO TRAINING

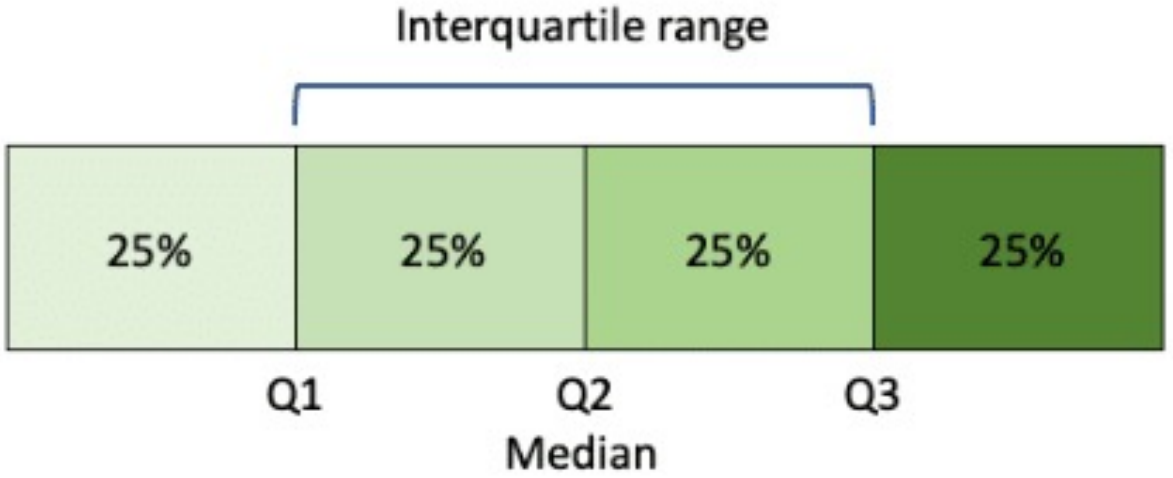
Rhino/LBT OpenStudio Training

- Download and install Rhino here: https://www.rhino3d.com/download/ (Trial version lasts for 90 days)
- Download Ladybug tools v1.5. You will need to make a login, but it is free to download. Follow the steps here: https://www.food4rhino.com/en/app/ladybug-tools

ASSIGNMENT 3 FEEDBACK

Assignment 3 Feedback

- Data outlier omission
  - Both very low and very high EUI numbers are questionable



Formula	Explanation
$IQR = Q3 - Q1$	• IQR = interquartile range • Q3 = 3rd quartile or 75th percentile • Q1 = 1st quartile or 25th percentile

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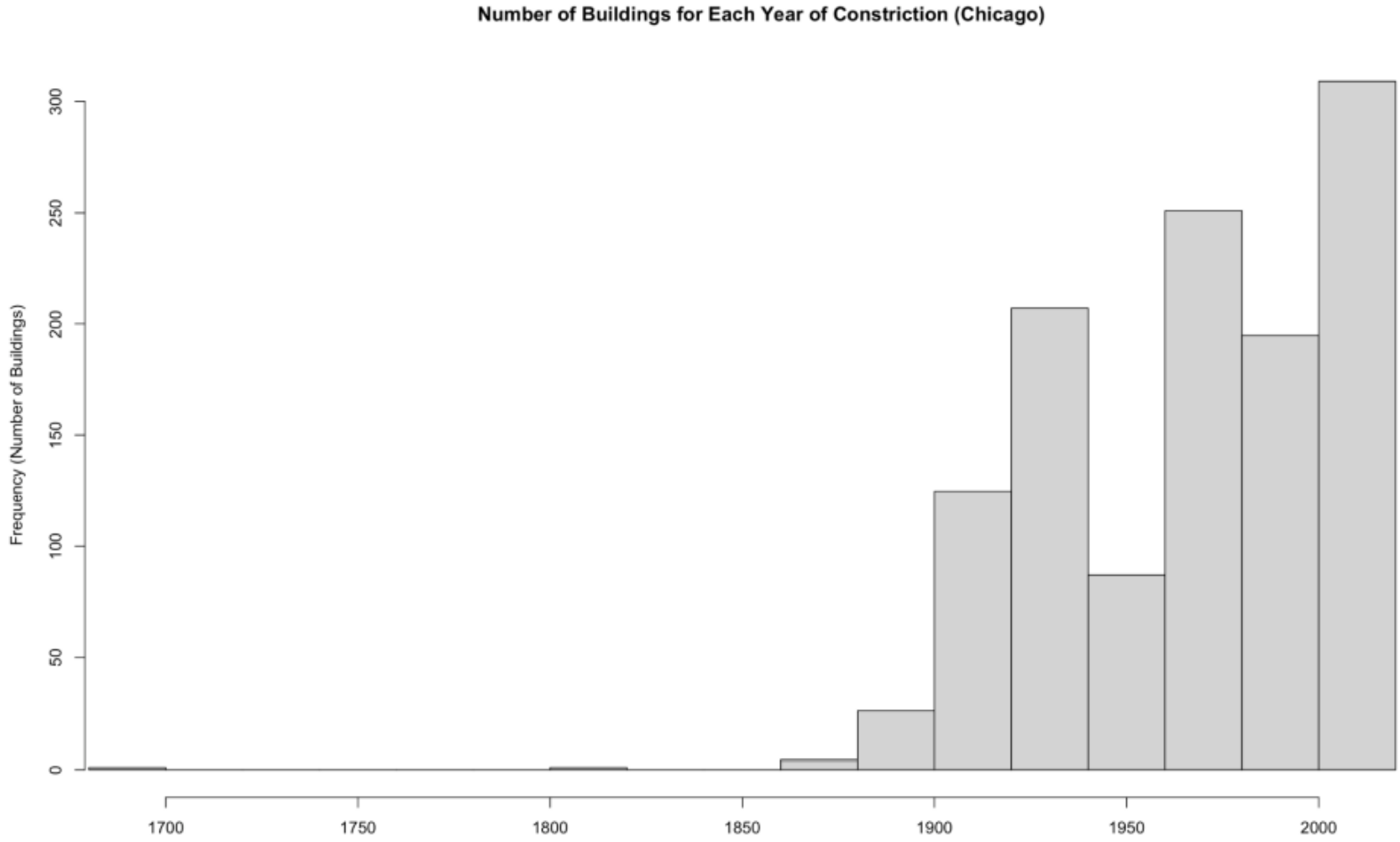

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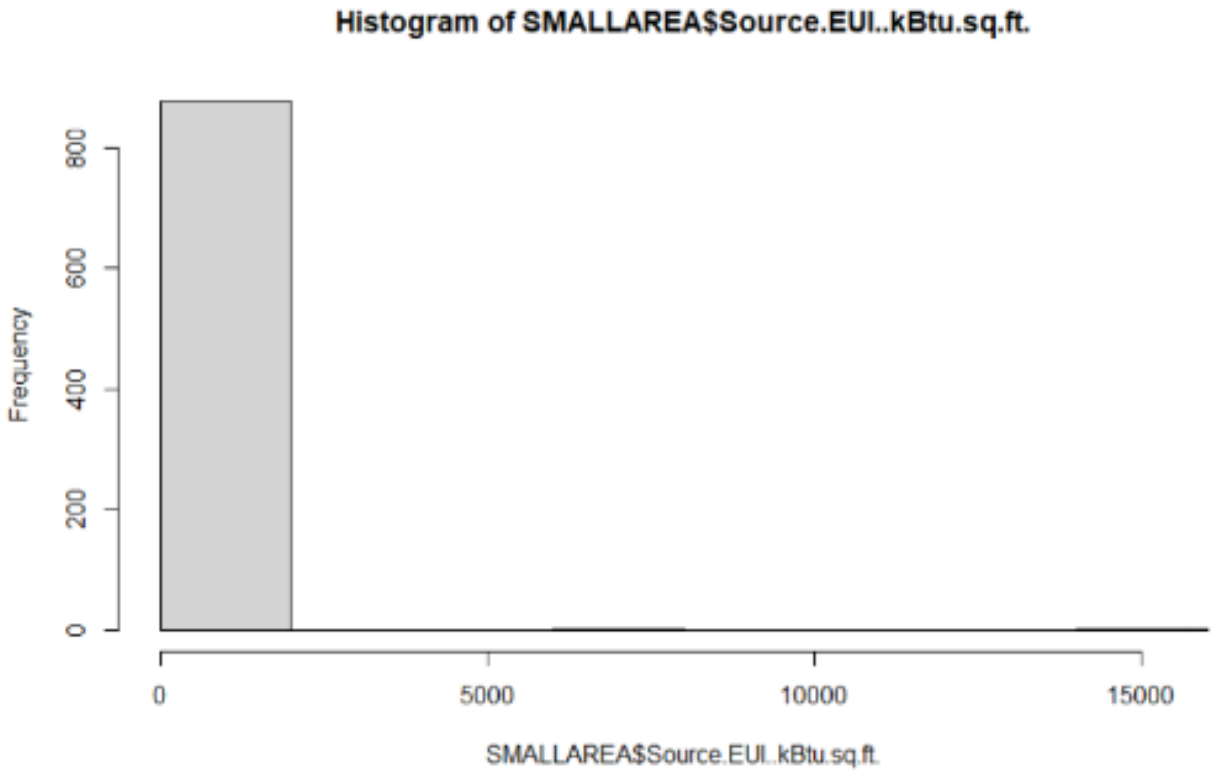

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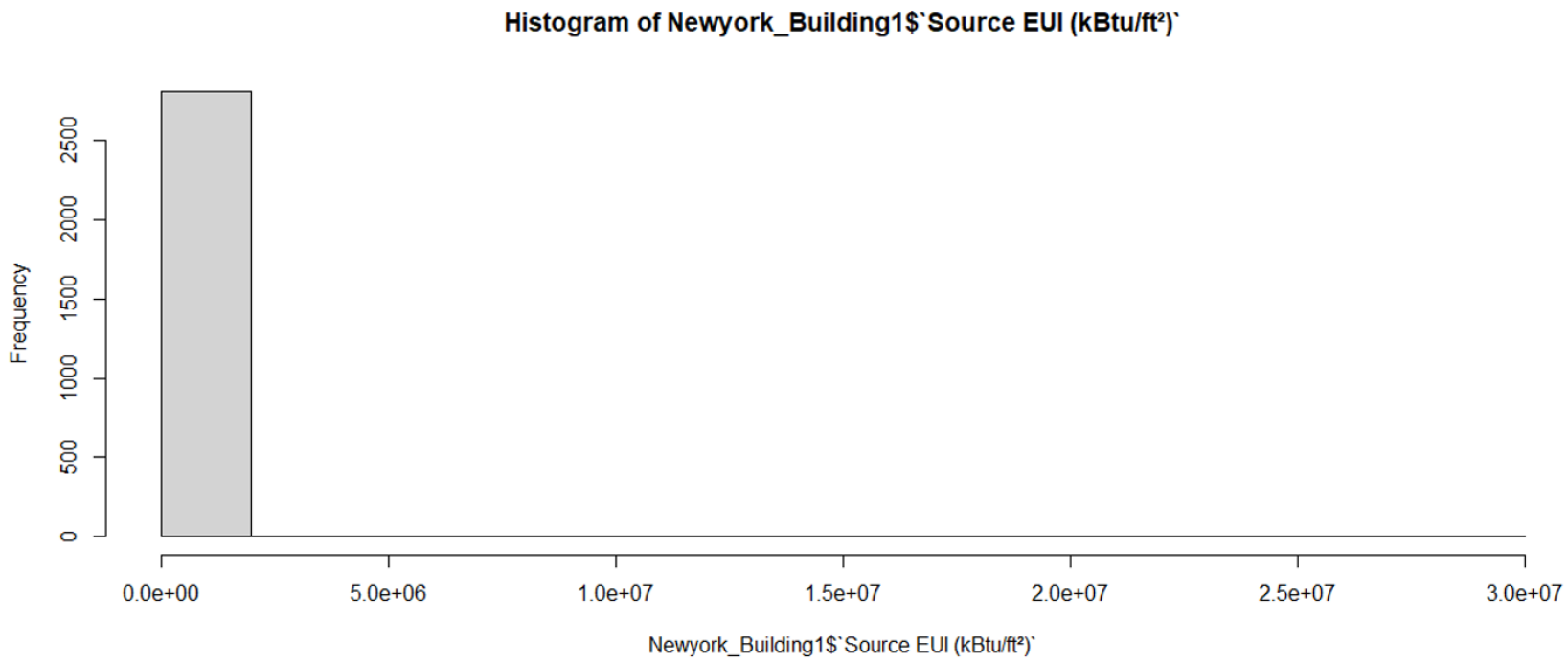

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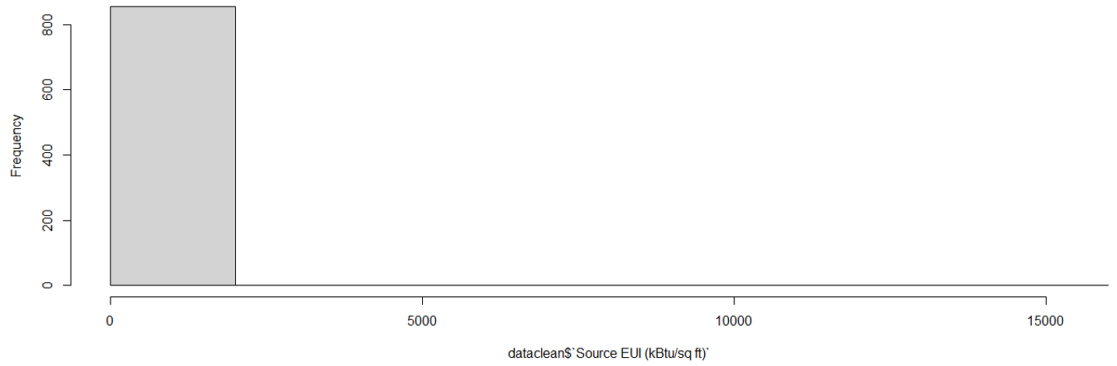

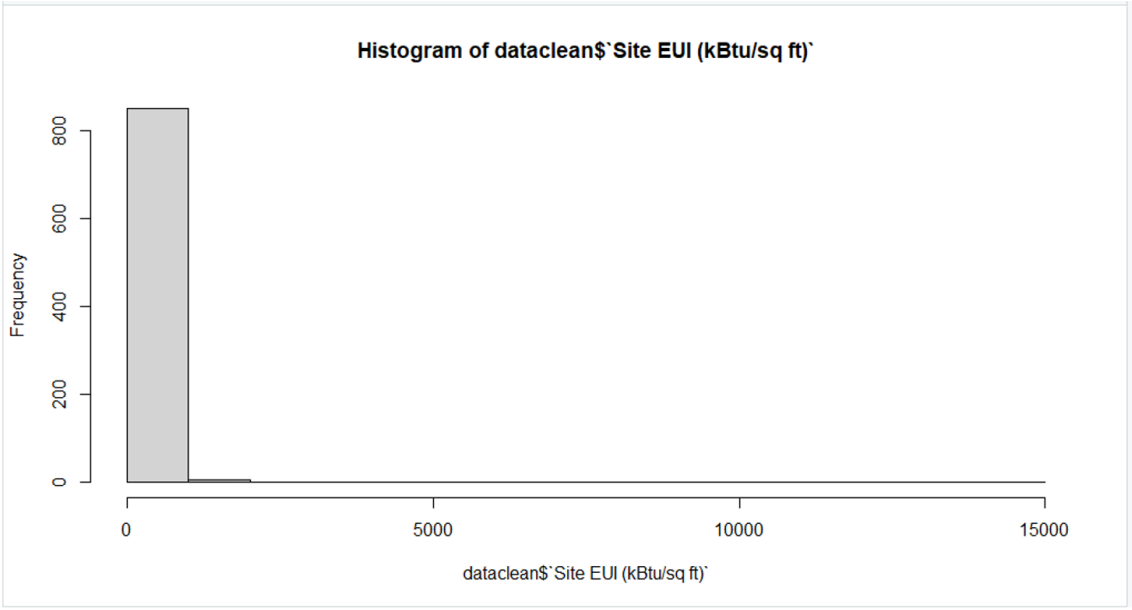

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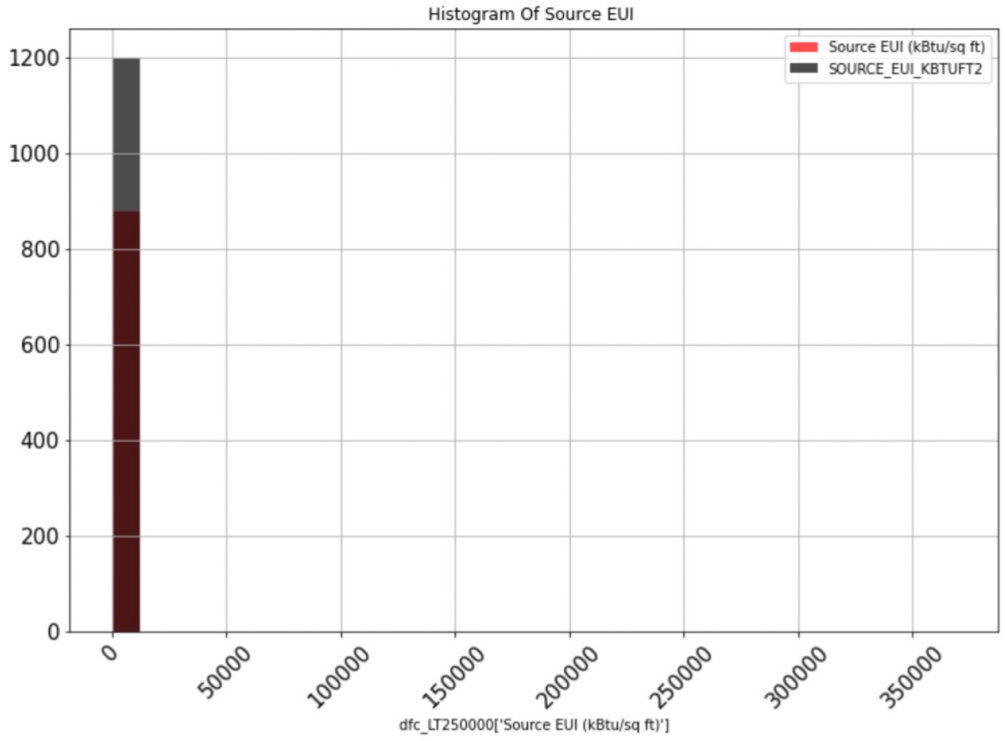
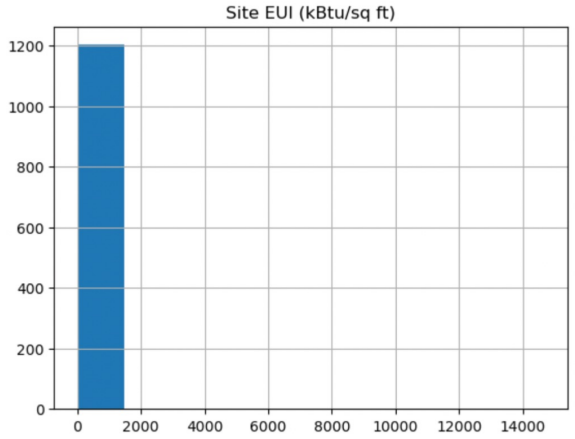
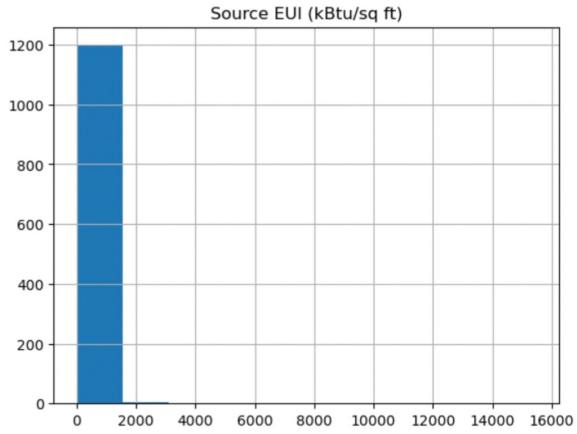


Caption



Chicago - Site EUI



Chicago - Source EUI

Assignment 3 Feedback

- If you see a number that does not make sense, try to find out if it is an outlier or not:

Year Built: Looking at the data for the construction year, we can observe that building with a larger area are on average newer structures (15 years difference when comparing the median values).

PLEASE NOTE: Also, I noticed that the minimum value for blds smaller than 250,000 ft^2 is 1692.I was surprised to see such an old building, and therefore I checked the data to find the address of that building. It turns out that this construction year is associated to a building located on 21 E Chestnut Street. I checked it on street view and it is not a historical building (I included a picture of the screenshot at the end of the report. I wonder if this is a typo (maybe it should be 1992?) **

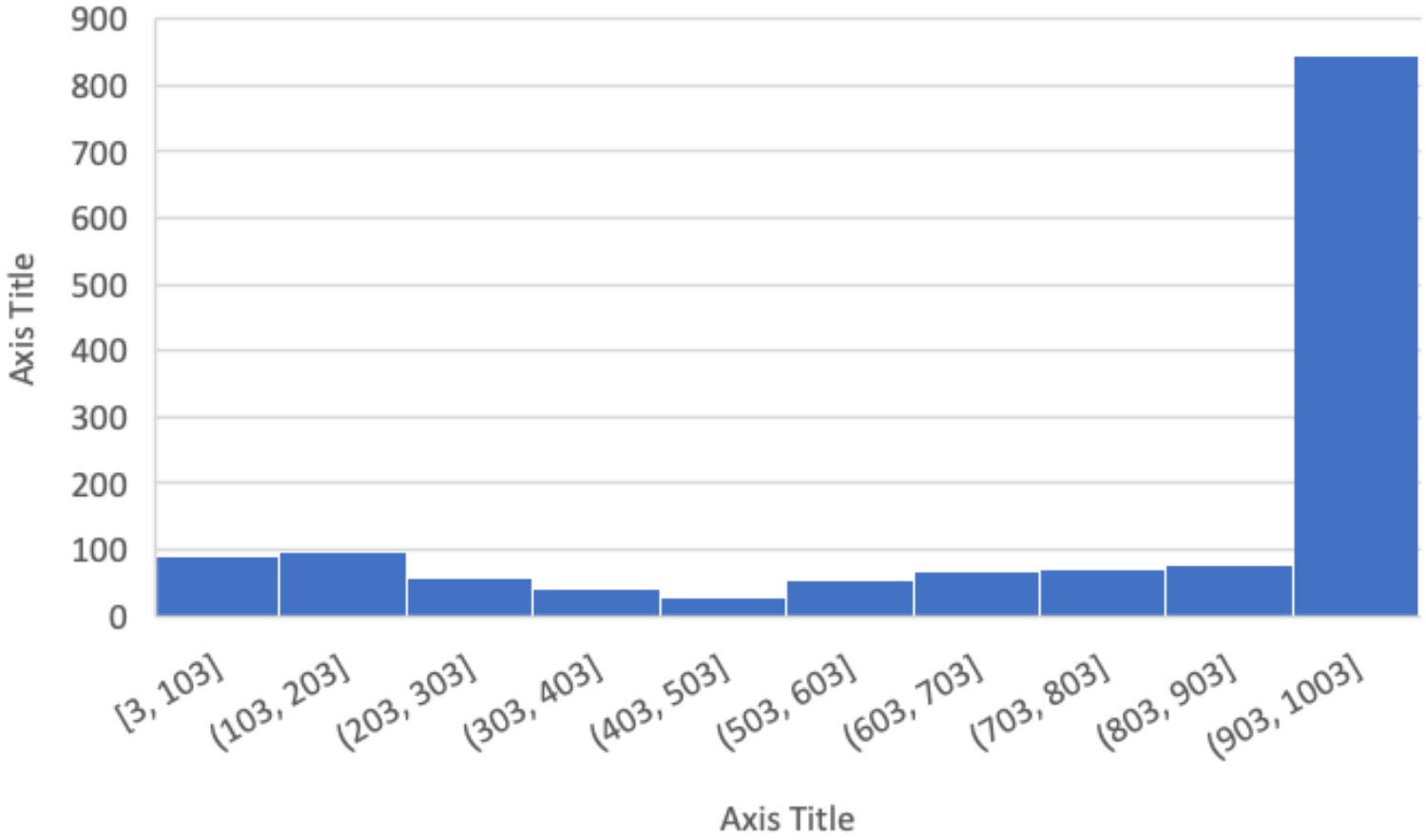
Assignment 3 Feedback

- If you see a number that does not make sense, try to find out if it is an outlier or not:

**Street view of building with construction year = 1692

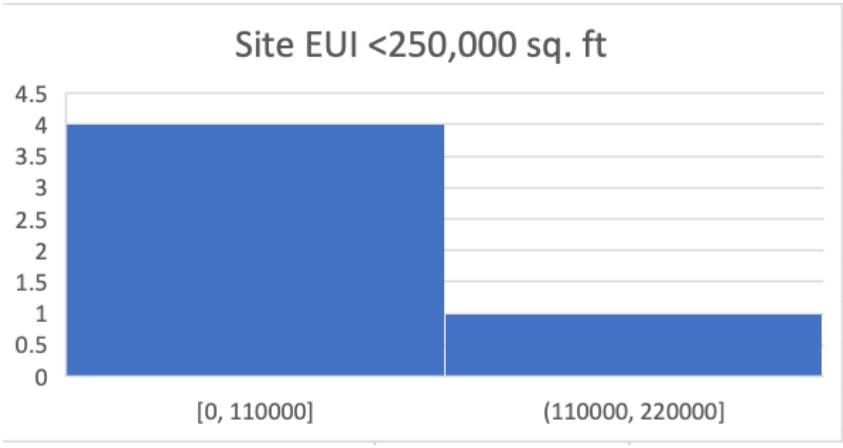
Assignment 3 Feedback

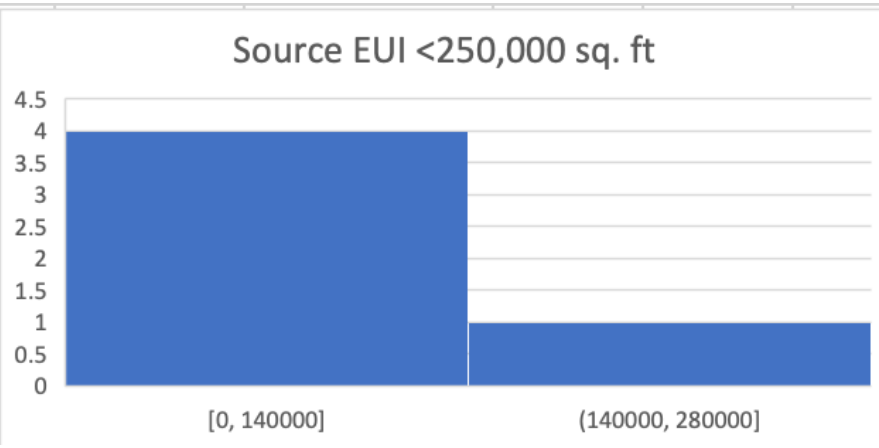
- If you see a number that does not make sense, try to find out if it is an outlier or not:
  - Question your numbers



Assignment 3 Feedback

- Data outlier omission
  - Having more bins would be helpful





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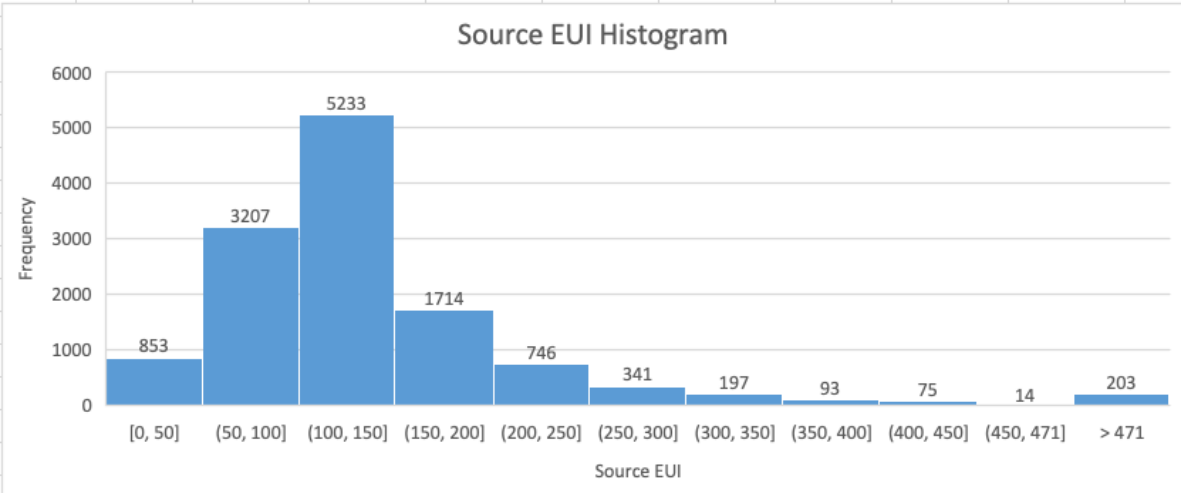

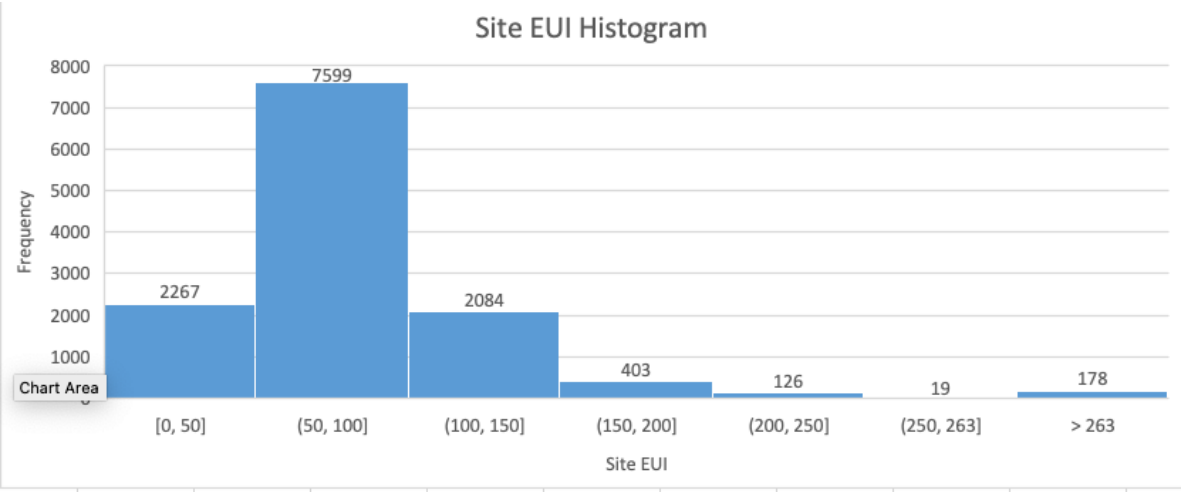

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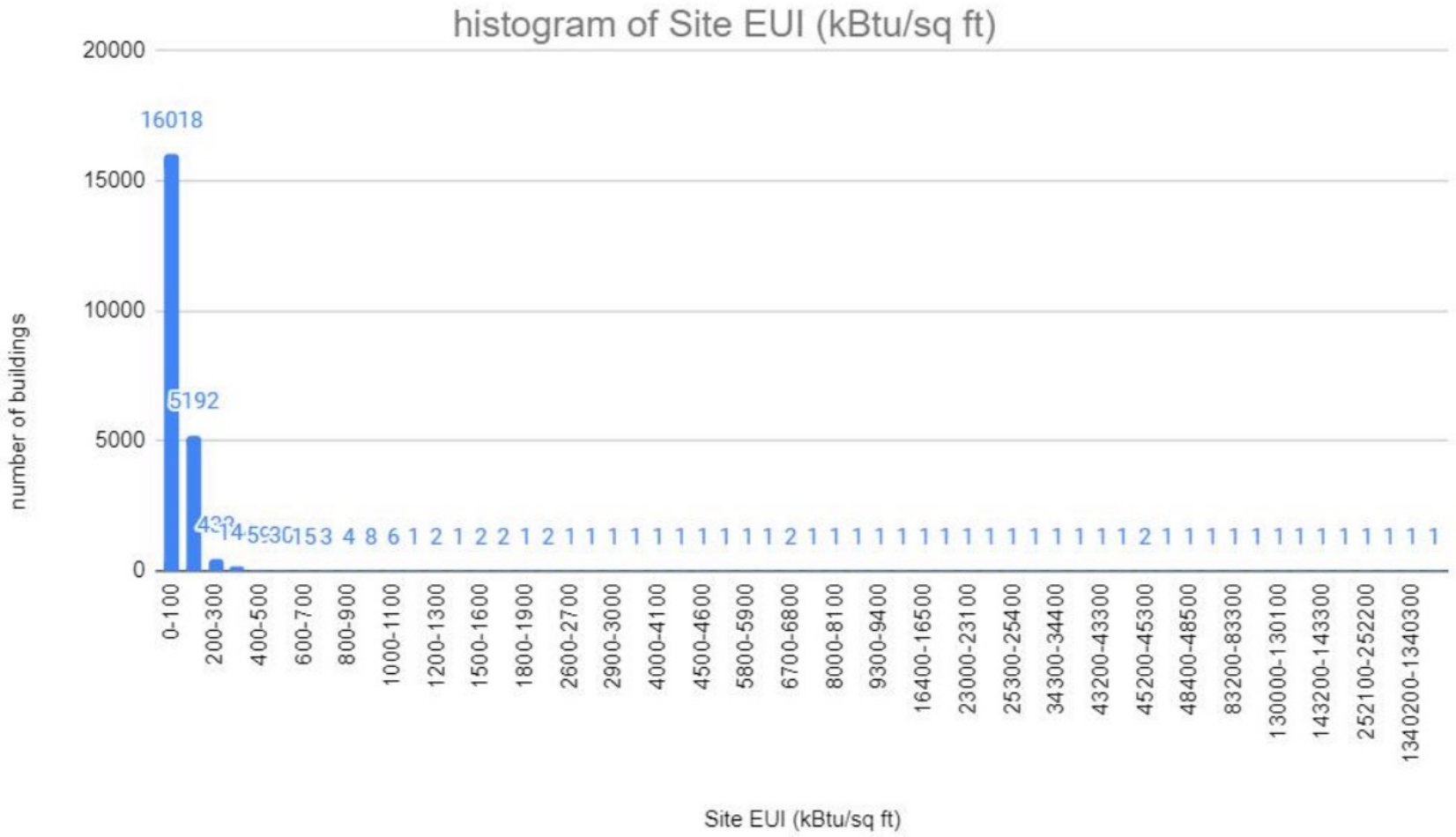
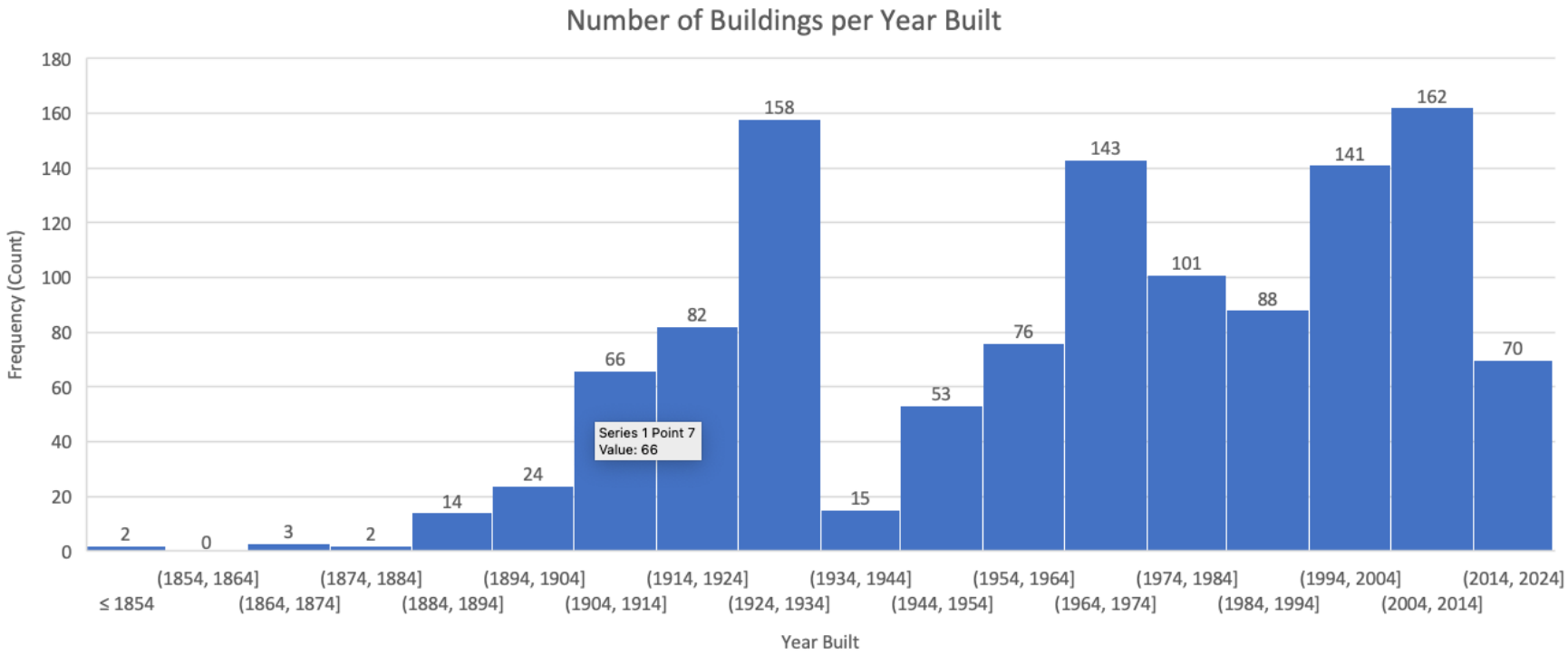


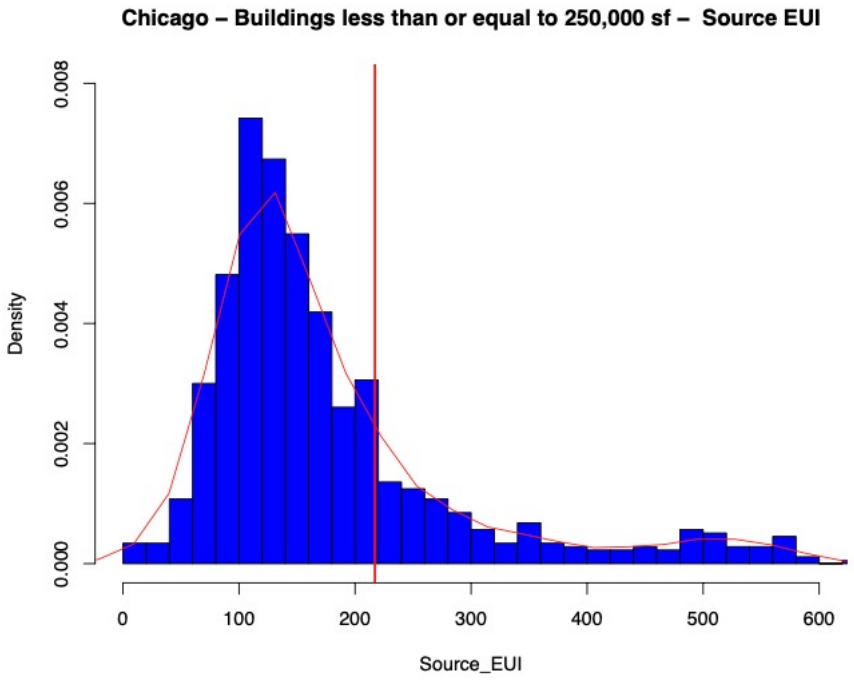
Assignment 3 Feedback

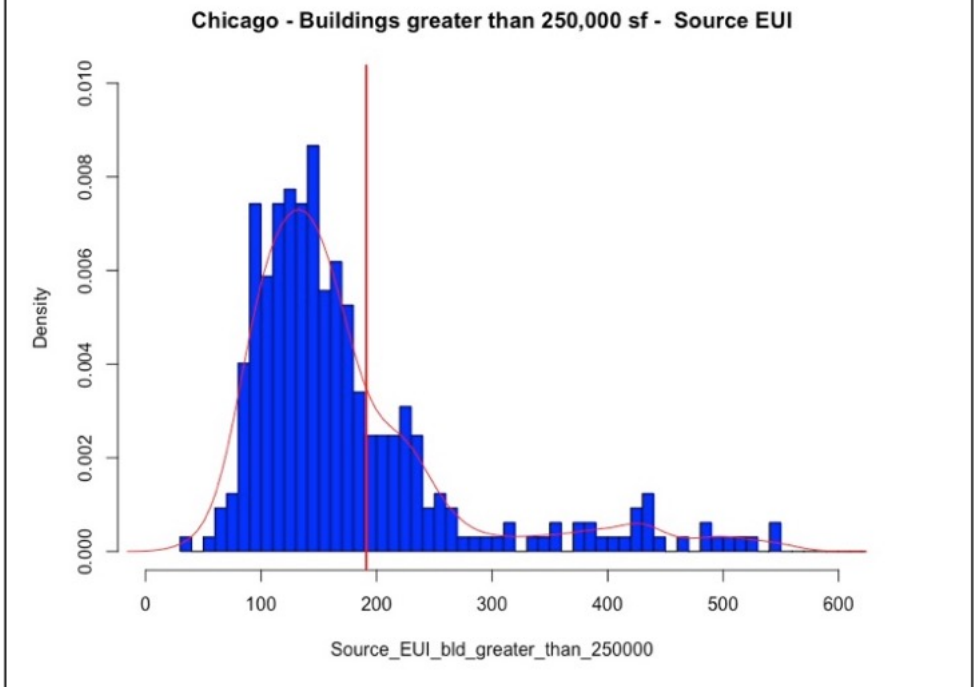
- Data outlier omission
  - You may want to factor the older buildings out



Assignment 3 Feedback

- Good practice to show the median or mean

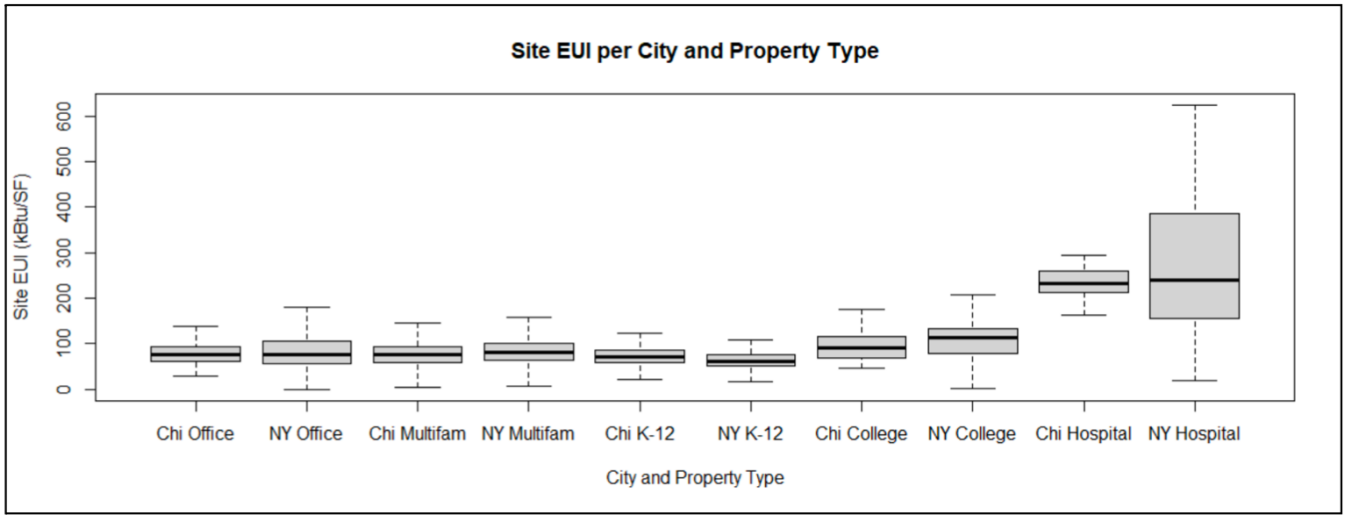


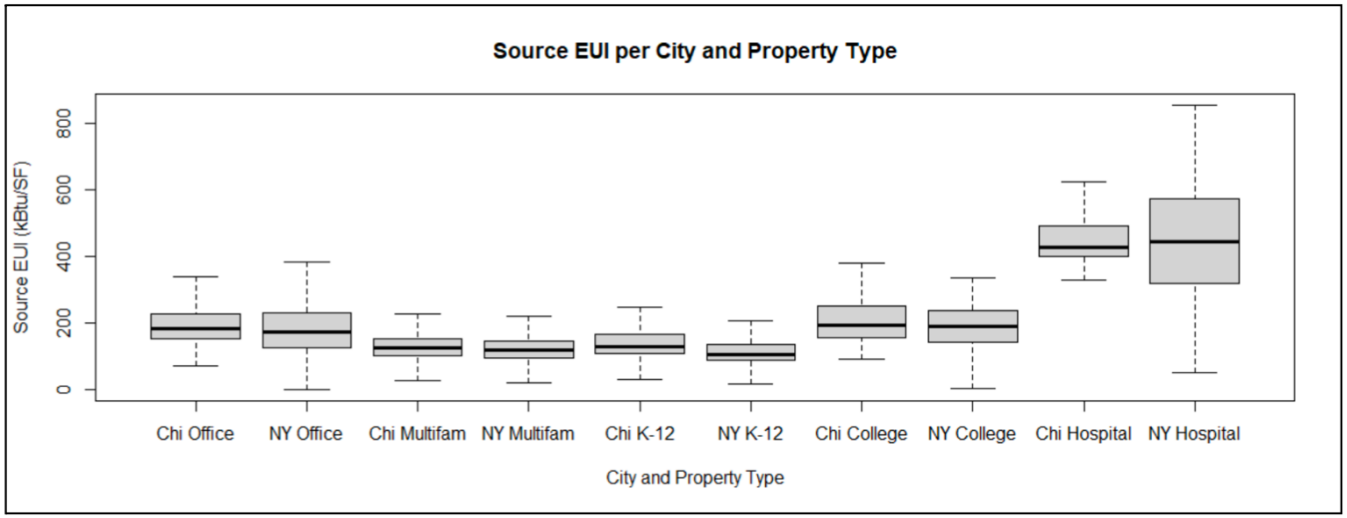


Source EUI: Same observations as for Site EUI.

Assignment 3 Feedback

- Try to avoid adding too many figures and merge the figures (especially when the aim is to compare two datasets)





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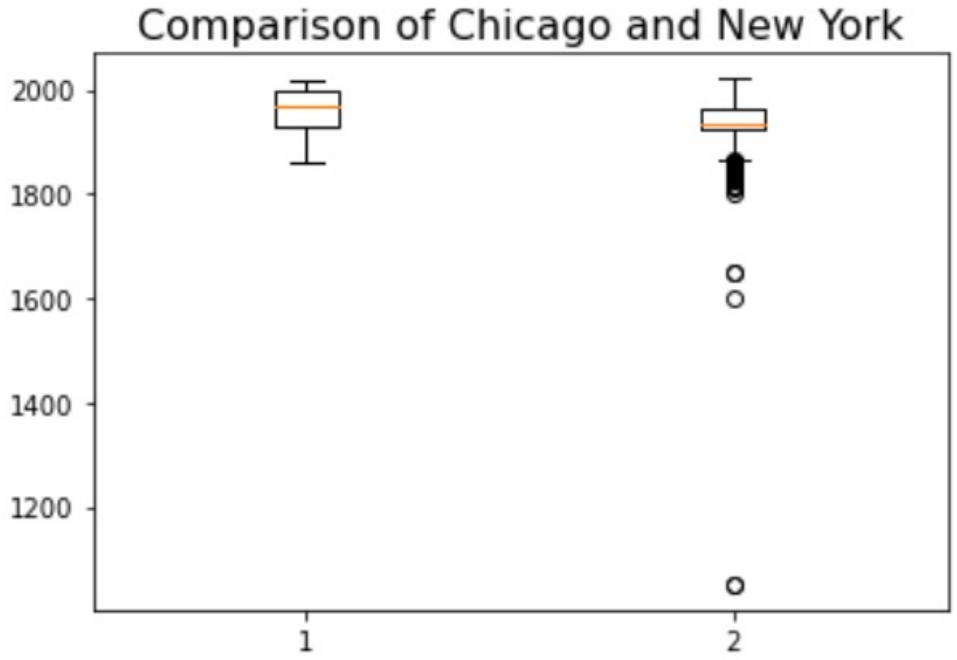

Figure 23 Box Plot of Year Built (Chicago, New York)

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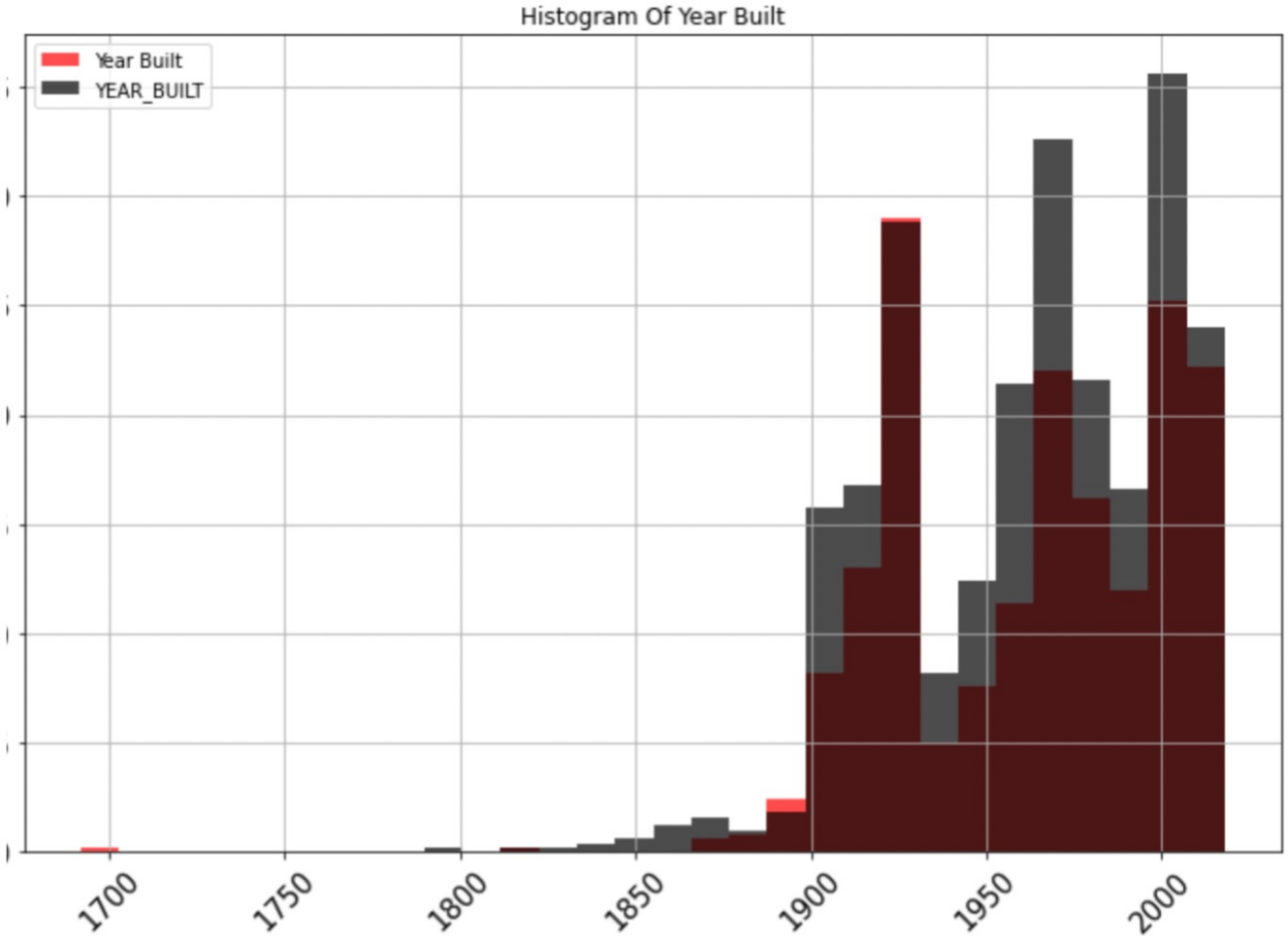

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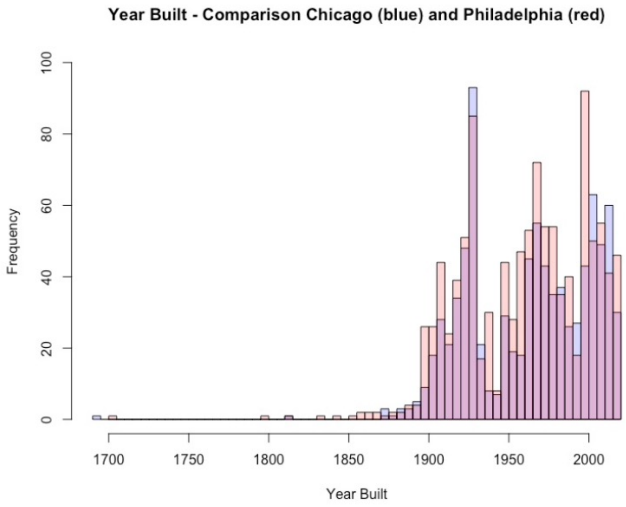
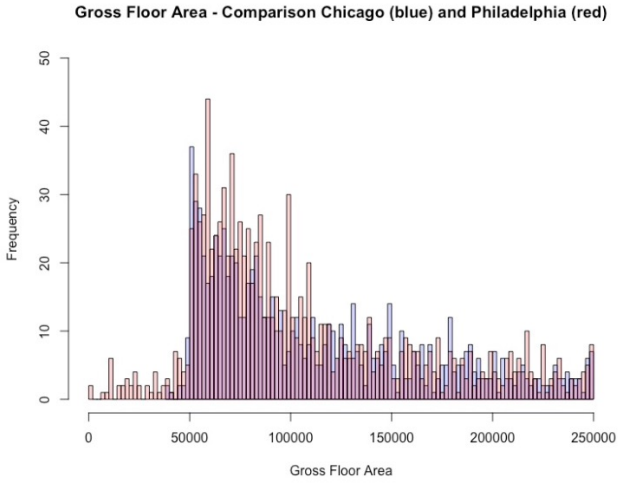
	The construction years for buildings smaller or equal to 250,000ft^2 is comparable in Philadelphia and Chicago.
	We can also observe similar distributions when comparing the gross floor areas of the two cities.

Assignment 3 Feedback

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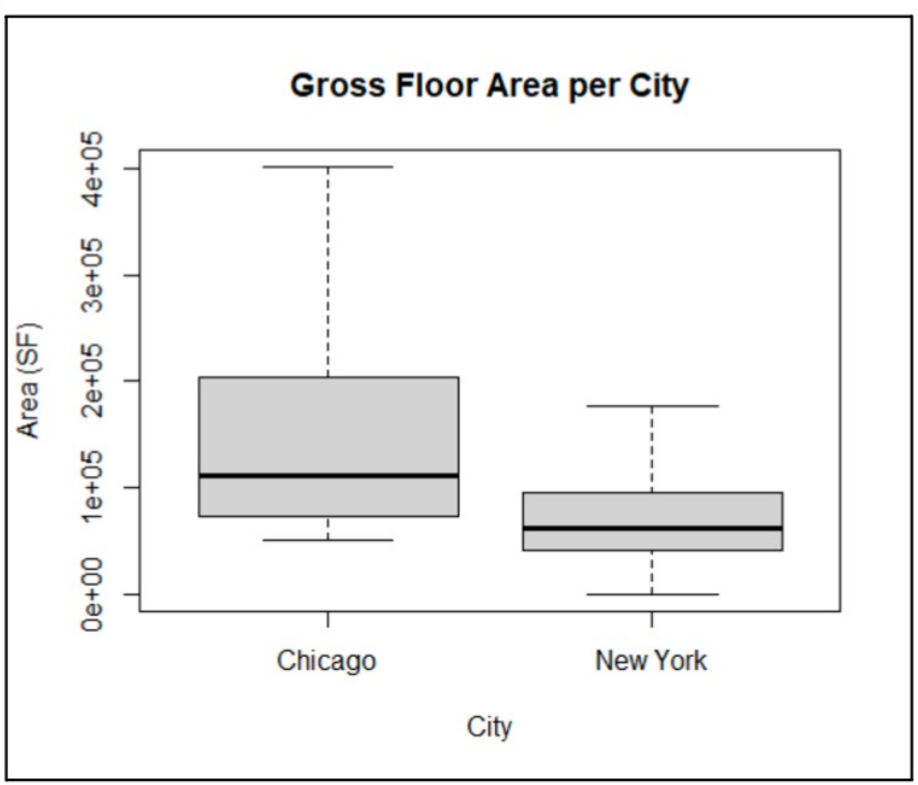

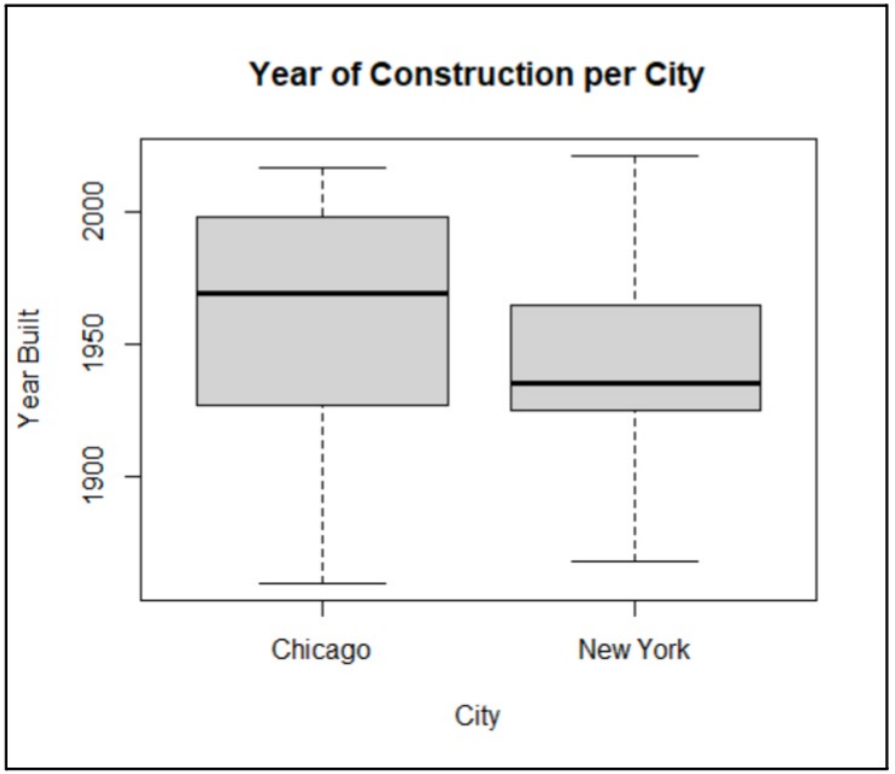

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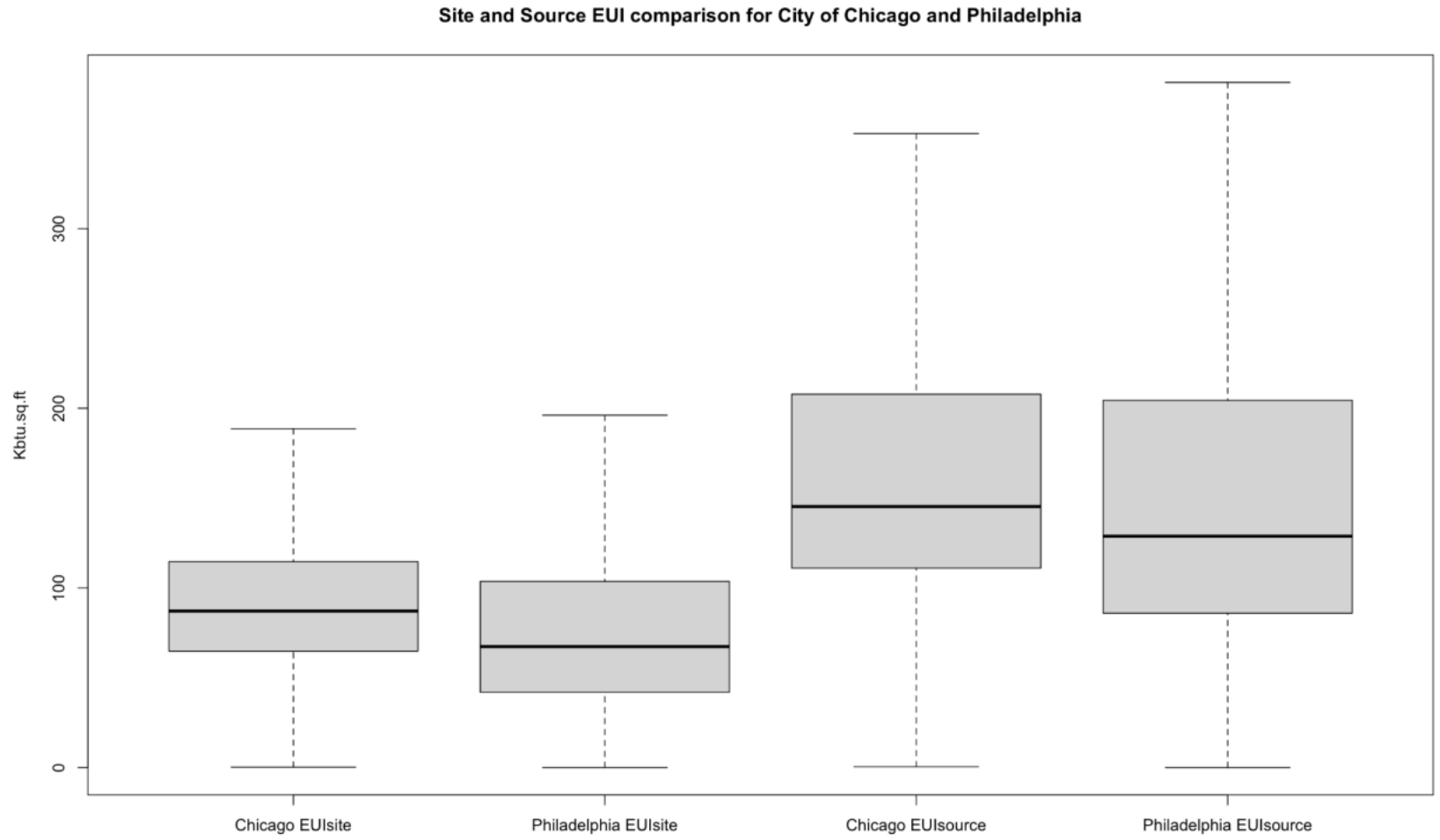

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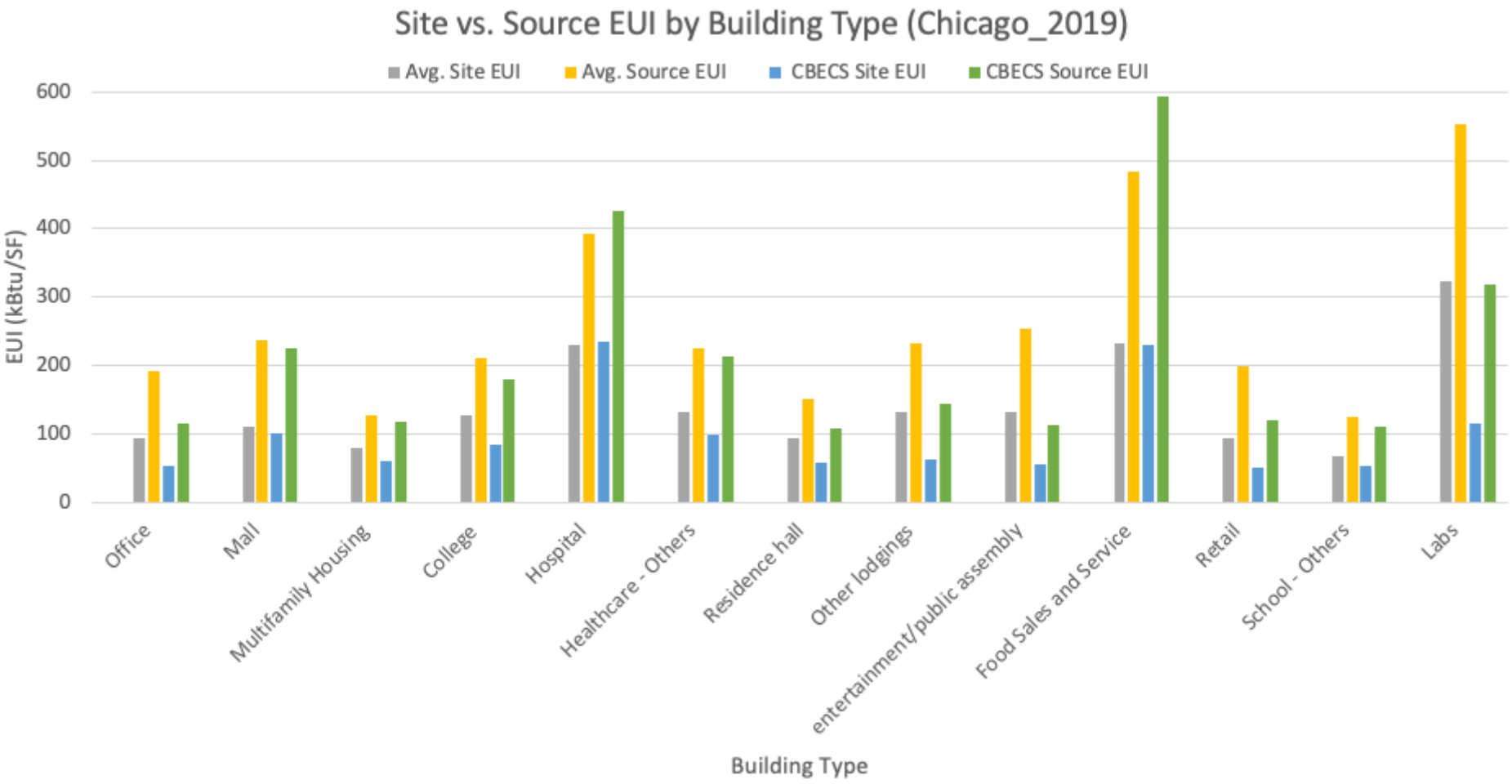

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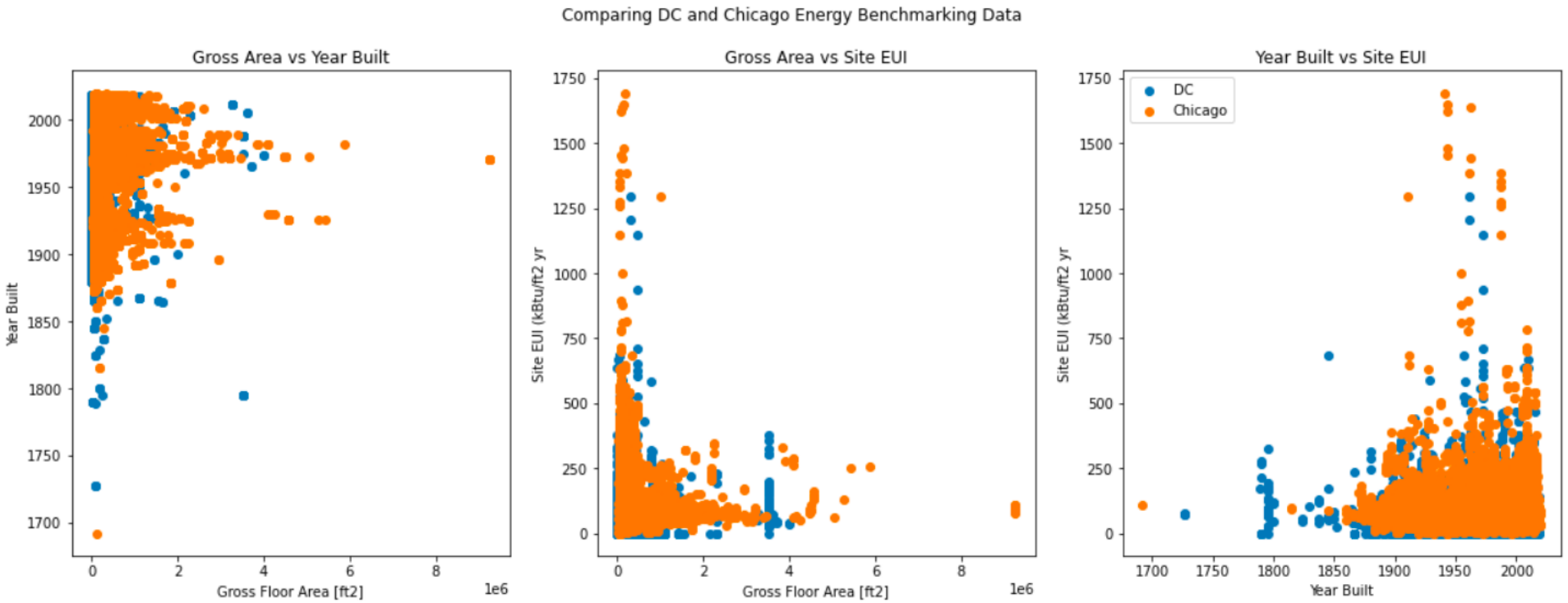

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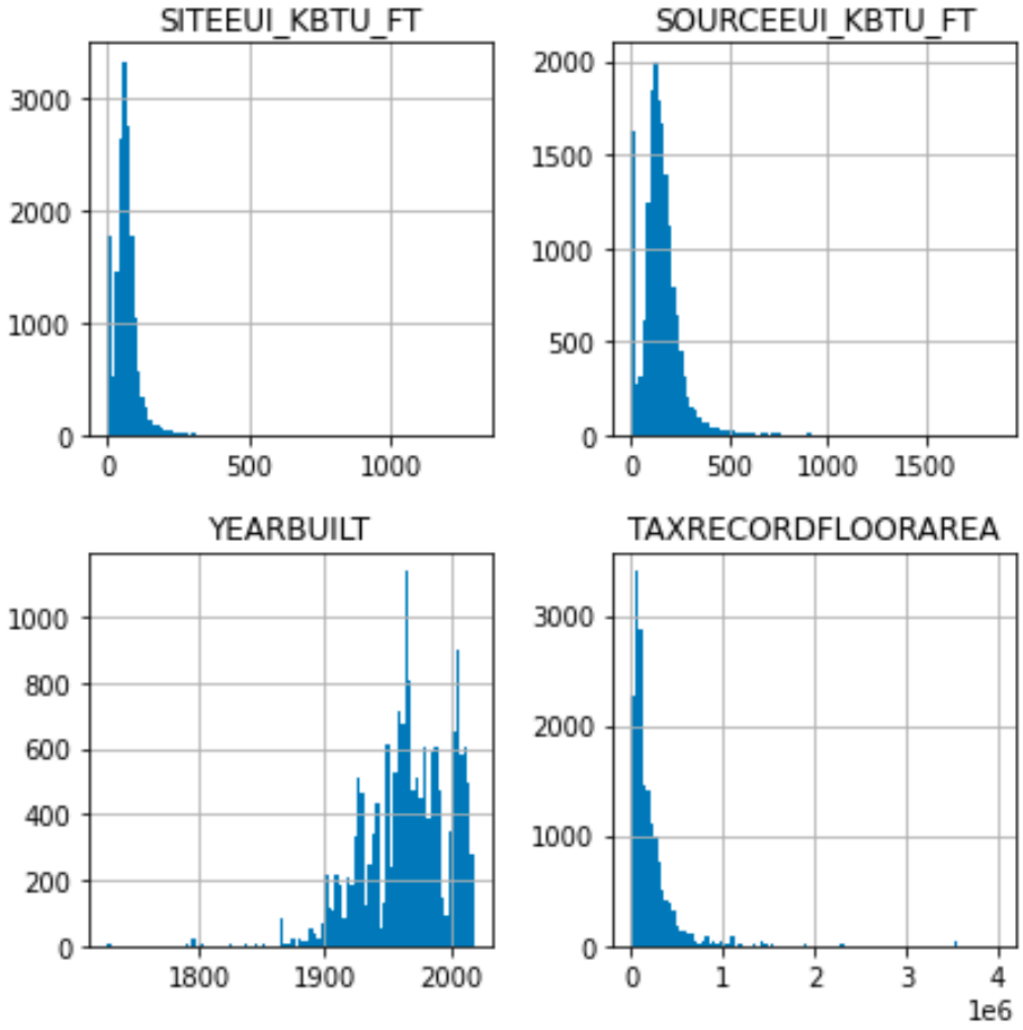
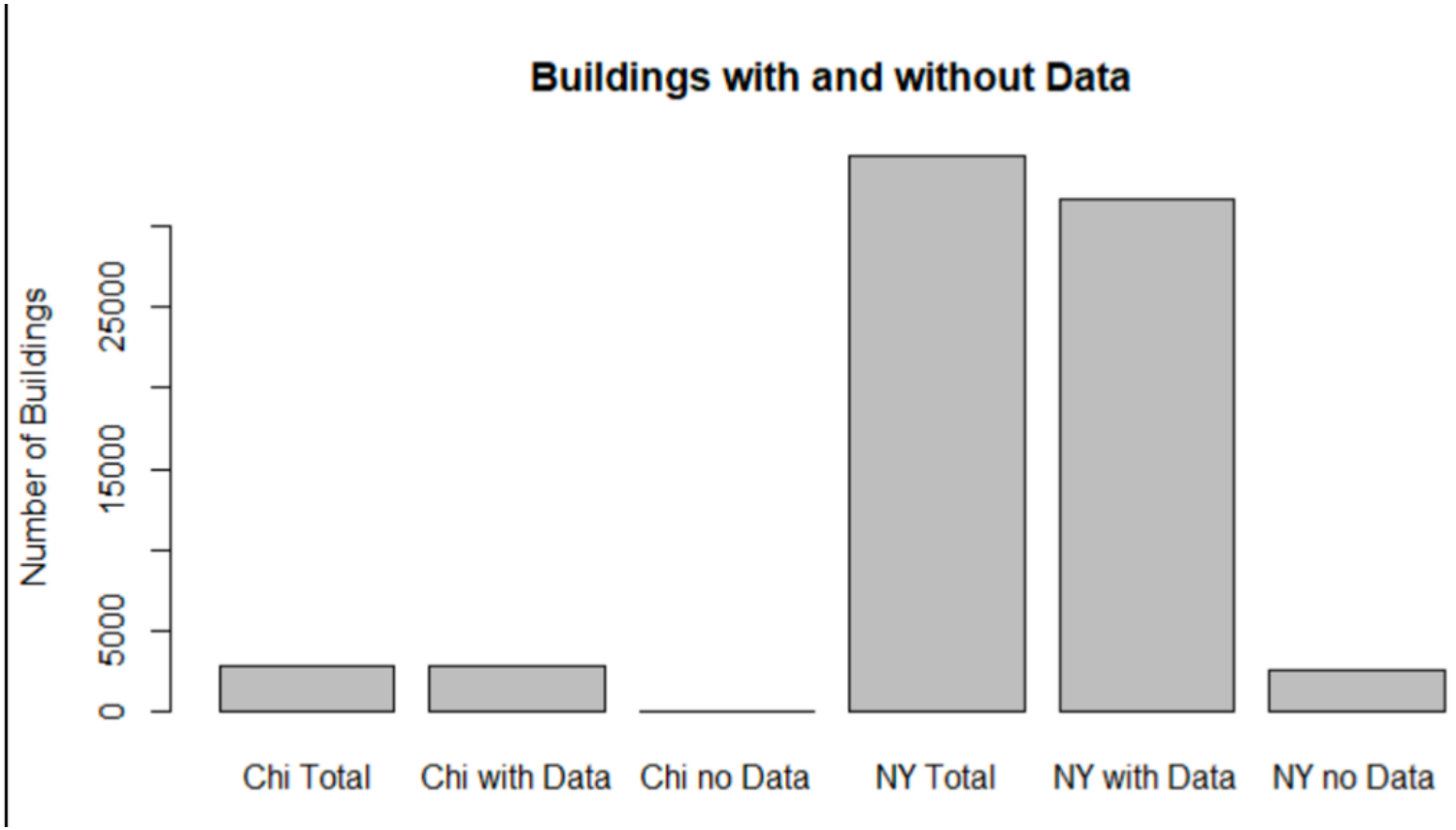


Assignment 3 Feedback

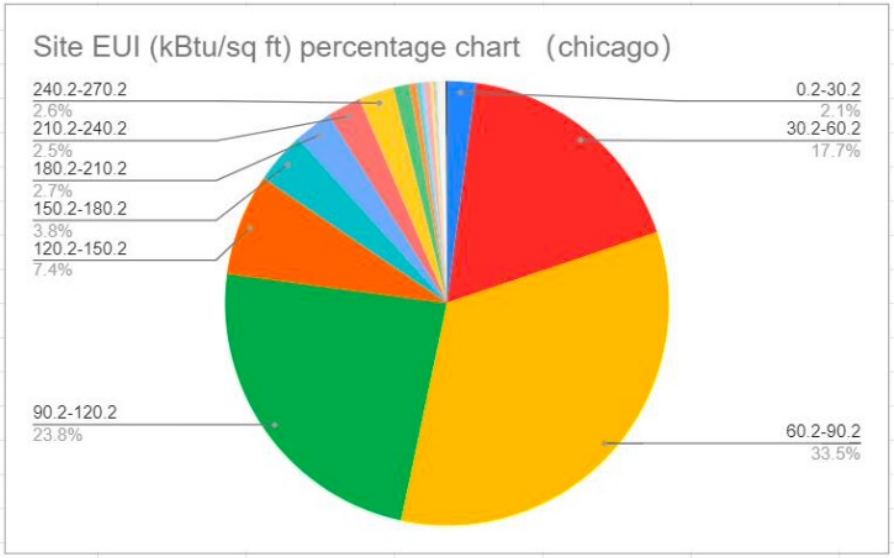
- Try to report the number of buildings or samples when you omit any data

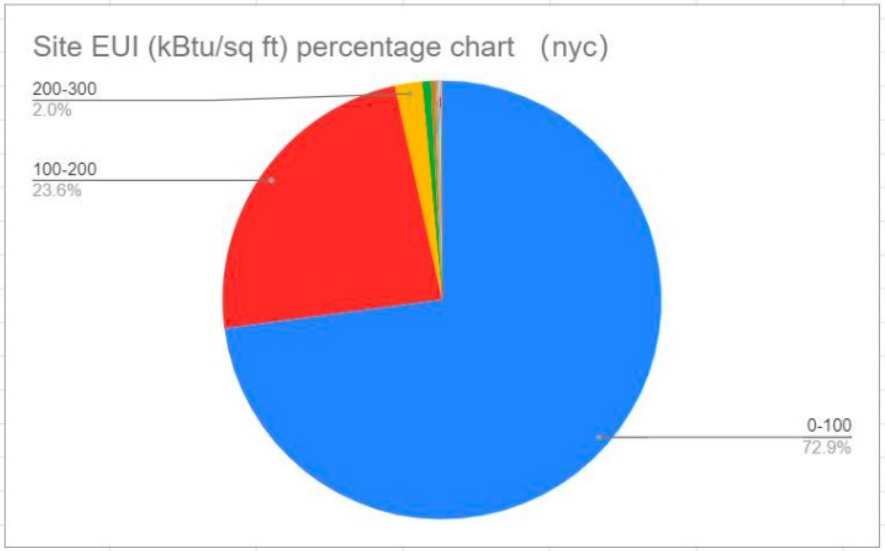


Assignment 3 Feedback

- Try to avoid using pie charts!

Compare site EUI:





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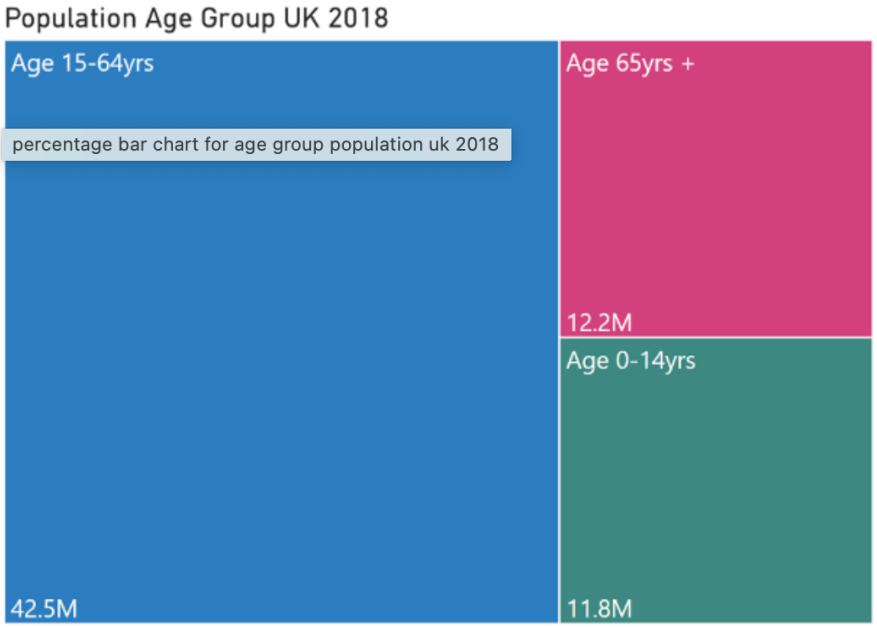
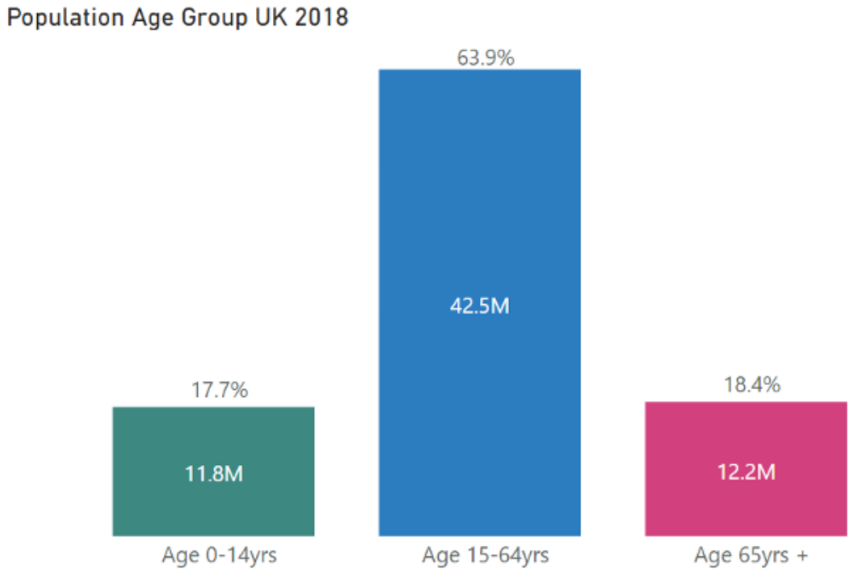
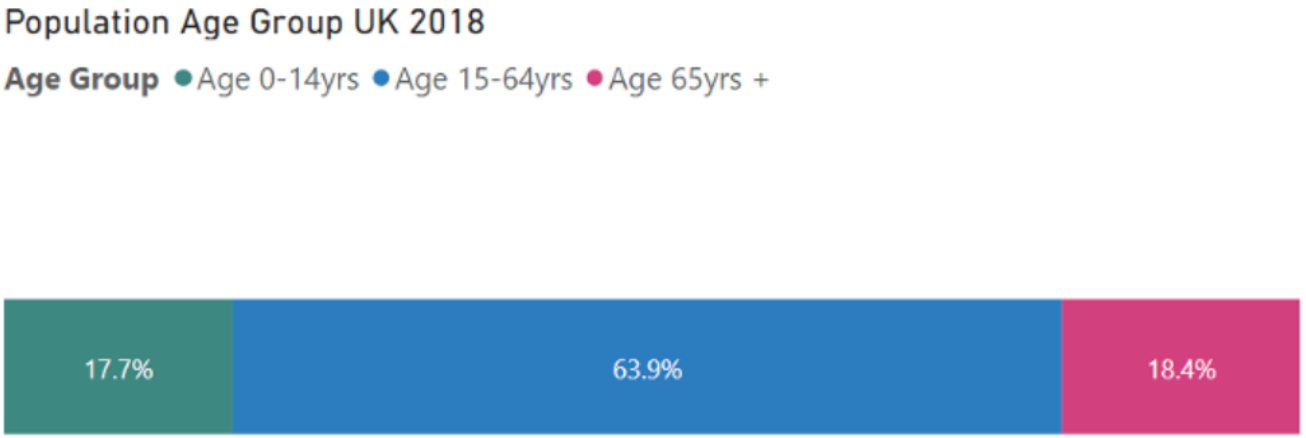
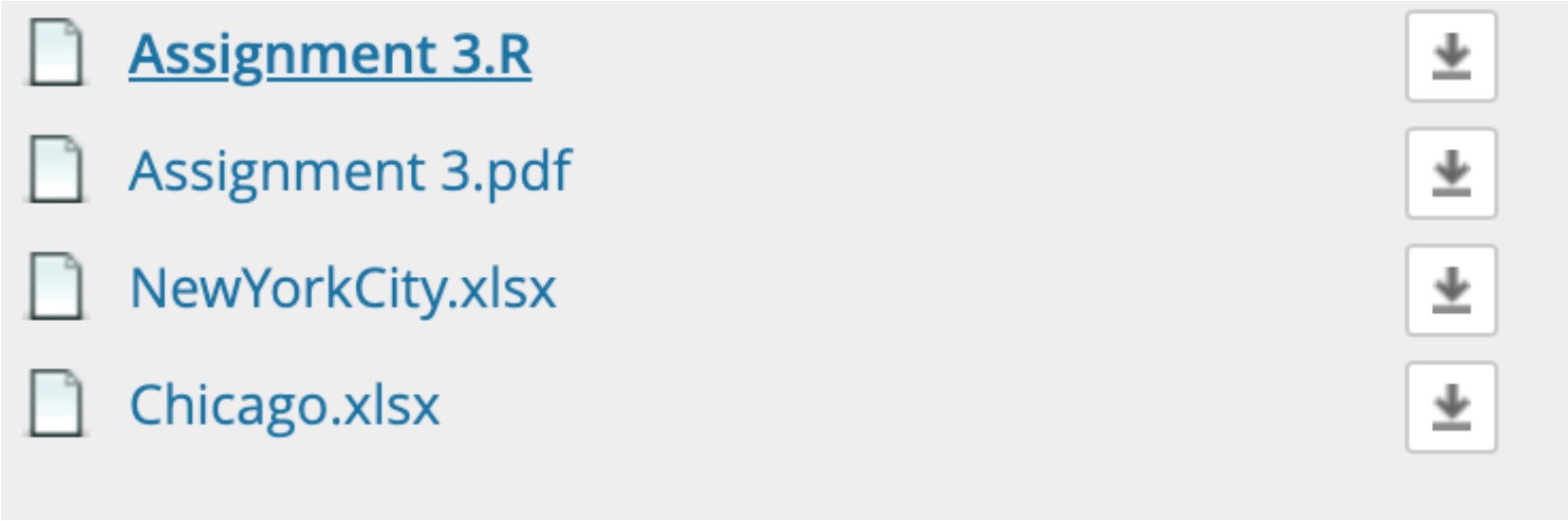






Assignment 3 Feedback

- A lot of times, in addition to your code, it is helpful to share the data source file:



Assignment 3 Feedback

- A good practice is to comment your code:

```
#                   Mean   : 80.71   Mean   :126.8
#                   3rd Qu.: 96.80   3rd Qu.:146.0
#                   Max.   :240.50   Max.   :466.1

summary(data2NoNA[data2NoNA$Type=='College/University', ])
#Type              EUIsite           EUIsource
#Length:54          Min.   :    0.20   Min.   :    0.4
#Class :character   1st Qu.:   75.92   1st Qu.:  151.3
#Mode  :character   Median :  111.80   Median :  209.8
#                   Mean   :  472.31   Mean   :  562.4
#                   3rd Qu.:  175.00   3rd Qu.:  284.9
#                   Max.   :14680.60   Max.   :15480.9

########## For Philadelphia
Pdata2<-Pr
names(Pdat
Pdata2NoNA


summary(Pd
#PType
#Length:18
#Class :ch
#Mode  :ch
#
#
#
```

```
################################################################################
#import Chicago_Energy_Benchmarking_._2019_Data_Reported_in_2020 cvs file
#create new data from the dataframe called "data"
#rename the columns in the data
data<-Chicago_Energy_Benchmarking_._2019_Data_Reported_in_2020[,c(11,12,21,22)]
names(data)<-c("Area","YearBuilt","EUIsite","EUIsource")

#Problem 1a, calculating num of building with missing Area, Year of construction, SiteEUI and SourceEUI values
sum(is.na(data$Area)) # answer is 1361 buildings
sum(is.na(data$YearBuilt)) #answer is 1358 buildings
sum(is.na(data$EUIsite)) #answer is 1195 buildings
sum(is.na(data$EUIsource)) #answer is 2054 buildings
#or
colSums(is.na(data))
#Area YearBuilt   EUIsite EUIsource
#1361      1358      1195      2054

################################################################################
```

Assignment 3 Feedback

- Pay attention to the decimals

≥ 250,000 sf	Year Built	Largest Property Use Type - Gross Floor Area (sq ft)	Site EUI (kBtu/sq ft)	Source EUI (kBtu/sq ft)
Mean	1959.951449	5.498943e+05	9.912662e+03	1.196861e+04
Median	1962.000000	3.966800e+05	7.980000e+01	1.447000e+02
Maximum	2017.000000	1.507766e+07	2.405806e+07	2.894294e+07
Minimum	1841.000000	2.500000e+05	0.000000e+00	0.000000e+00
Standard Deviation	30.735296	5.820145e+05	4.803174e+05	5.778379e+05

Assignment 3 Feedback

- Figure captions

Figure 17: Histogram for Source EUI (kBTU/sf): **New York City** Buildings with Source EUI less than 300 kBTU/sf

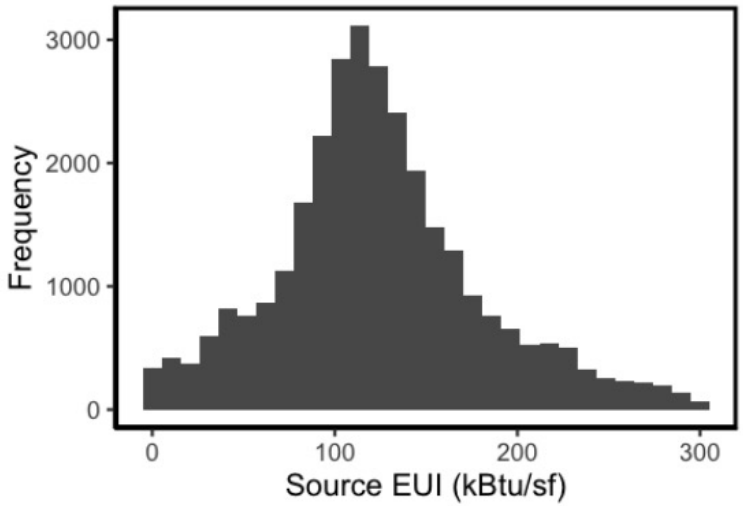
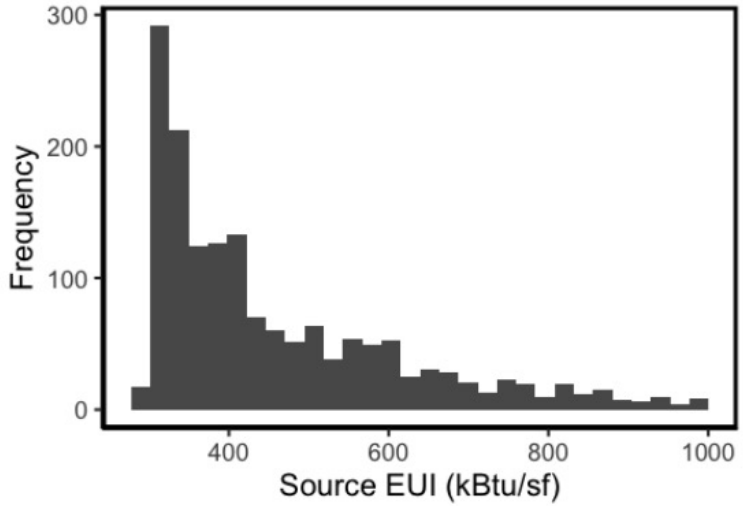


Figure 18: Histogram for Source EUI (kBTU/sf): **New York City** Buildings with Source EUI greater than 300 kBTU/sf and less than 1000 kBTU/sf



Assignment 3 Feedback

- If you are using Excel, make sure to pay attention to referencing to other files

ANNOUNCEMENTS

Announcements

ASHRAE Illinois Institute of Technology Student Branch

IES

Sustainable Building Design & Simulation

SPEAKER
Matthew Duffy
Business Development Manager

WHEN
October 6th, 2022
12:40pm – 1:40pm

WHERE
John T. Rettaliata Engineering Center, RE 034

TALK ABOUT
- ✔ Work experiences
- ✔ IESVE (Virtual Environment Software)

For more information, feel free to contact ASHRAE official email
ashrae_iit@iit.edu

Interested in Joining

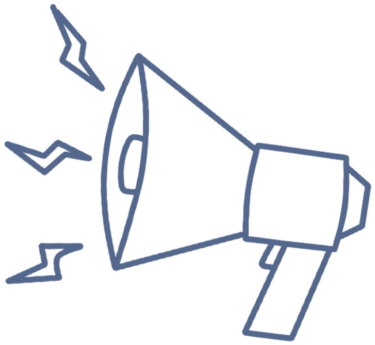
Lunch will be provided!

Announcements

ASCE, ASHRAE, CMAA, EWB,
ITRC, SEAOI, & SEES PRESENT

ASCE
ILLINOIS TECH

8TH ANNUAL CAEE CAREER FAIR



MAKE CONNECTIONS!

SCAN HERE TO REGISTER

TUESDAY
18TH
OCTOBER 2022

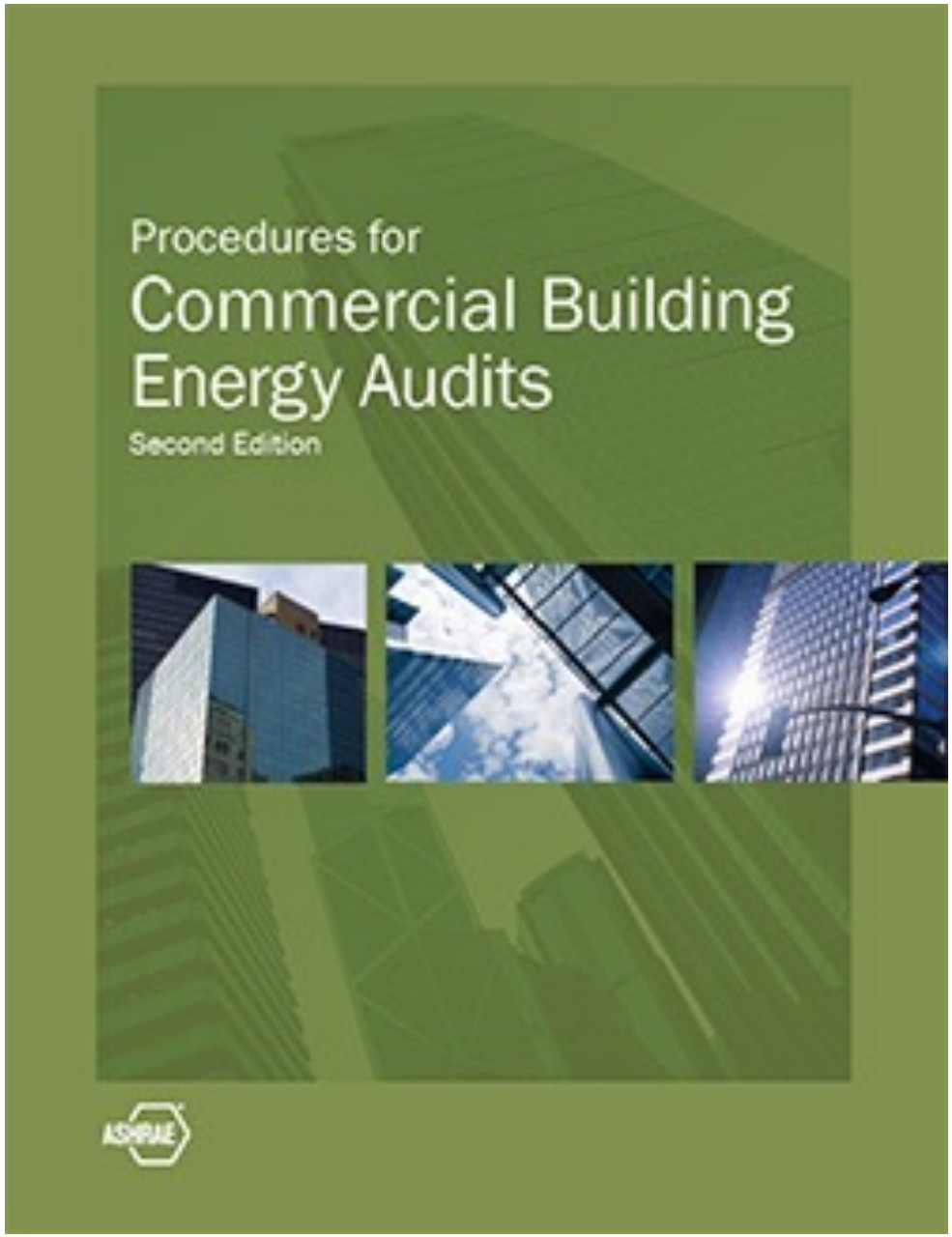
Herman Hall Expo
2pm - 5pm

ASSIGNMENT

COMMERCIAL BUILDING ENERGY AUDITS

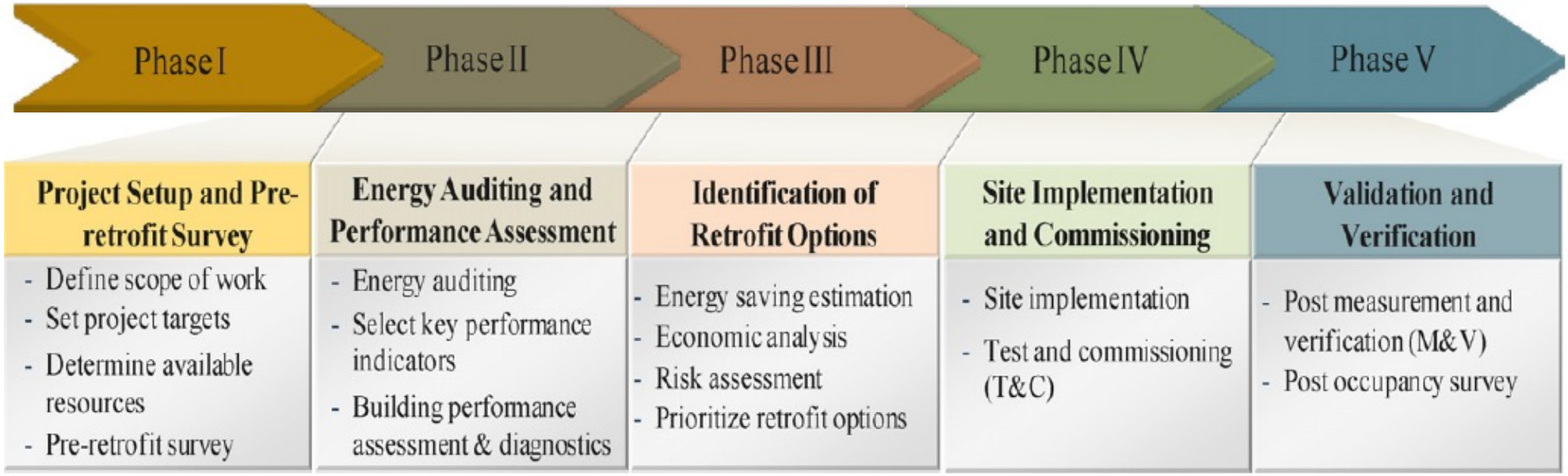
Reference: Procedures for commercial building energy audits, 2nd Edition, ASHRAE

Reference


Procedures for
Commercial Building
Energy Audits
Second Edition
ASHRAE

Retrofit Phases

- Suggested retrofit phases



Ma, Cooper, Daly, & Ledo, 2012

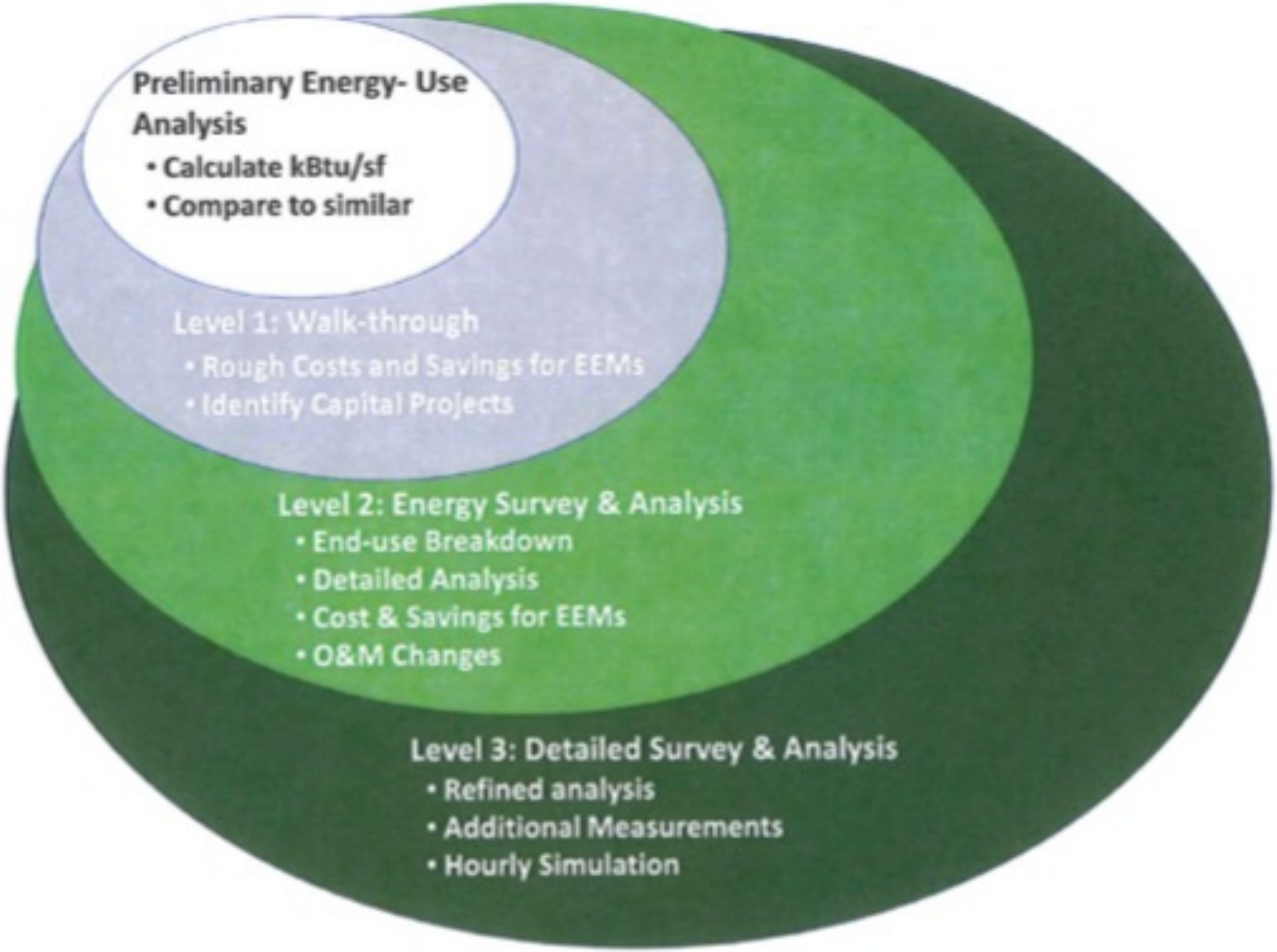
Level of Audits

- A commercial building energy analysis has three levels of:
  - Level 1: Walkthrough analysis
  - Level 2: Energy survey analysis
  - Level 3: Detailed analysis of capital-intensive modifications

- There is a prerequisite for any audit named “Preliminary Energy-Use Analysis (PEA)”

- There are another category named “Targeted audits”

Relationships between Audits



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PEA

- Requirements of PEA are to:
  - Analyze historic utility use, peak demand and cost
  - Develop Energy Cost Index (ECI) of the building in terms of $/ft^2-year
  - Develop EUI in kBtu/ft^2
  - Compare the EUI to the similar buildings
  - Analyze monthly data or interval data

Level 1 (Walkthrough/Survey)

- Level 1 requirements are:
  - Assess energy and cost using data compiled in PEA
  - Conduct brief survey of the building
  - Identify low-cost/no-cost energy efficiency measures
  - Provide a list of capital improvements
  - Prioritize items for improvements in Level 2 and 3
  - Remember energy and cost saving calculations in this level are approximate

Level 2 (Energy, Survey, Analysis)

- Level 2 audit includes:
  - Involve a more detailed building survey and breakdown of the end-uses
  - Identify more savings for all practical EEMs to meet the building owner and operator's constraints
  - Provide additional capital improvements that may require additional data collection

Level 3 (Detailed Analysis of Capital-Intensive)

- Level 3 audits include:
  - Focus on potential capital-intensive projects identified during Level 2 analysis
  - Require more field data gathering as well as more rigorous engineering and economic analyses
  - Often include modeling “simulation”
  - Go beyond Level 2 economic analysis and use Life-Cycle Cost Analysis (LCCA) for decision-making

Targeted Audits

- Targeted audits have different intensions. For example, it could consider:
  - Single energy-using system
  - Central plant
  - Area of the building (e.g., boiler control, lighting retrofit, chiller replacement)

Energy Audit Related Tasks

Table 1 — Energy Audit Required Tasks

Process	Level 1	2	3
Conduct PEA	•	•	•
Conduct walk-through survey	•	•	•
Identify low-cost/no-cost recommendations	•	•	•
Identify capital improvements	•	•	•
Review mechanical and electrical (M&E) design and condition and O&M practices		•	•
Measure key parameters		•	•
Analyze capital measures (savings and costs, including interactions)		•	•
Meet with owner/operators to review recommendations		•	•
Conduct additional testing/monitoring			•
Perform detailed system modeling			•
Provide schematic layouts for recommendations			•

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Energy Audit Related Tasks

Preliminary Energy Use Analysis	• Analysis of two or more years of utility consumption
Site Visit Procedures	• Activities to prepare for the on-site audit
Measurement	• Site visit and audit of building to collect data to quantifying operating parameters and performance
Analysis	• Description and analysis of the energy-using systems of the building • Can include a whole building energy model
Energy Efficiency Measure Types	• Classify and recommended energy efficient measures and bundle together synergistic measures
Economic Evaluation	• Evaluate the capital costs and life cycle cost analysis of efficiency measures and bundles of efficiency measures
Developing an Audit Report	• Provide complete information needed by an owner/operator to decide whether to implement recommended measures
Presentation	• Meet with the owner/operator to review the report, explain results and plan the next step
Implementing Measures	• Implement the chosen efficiency measures • Includes Measures & Verification and continuous commissioning

https://thergroupllc.com/services/energy-consulting/energy-auditing-service/

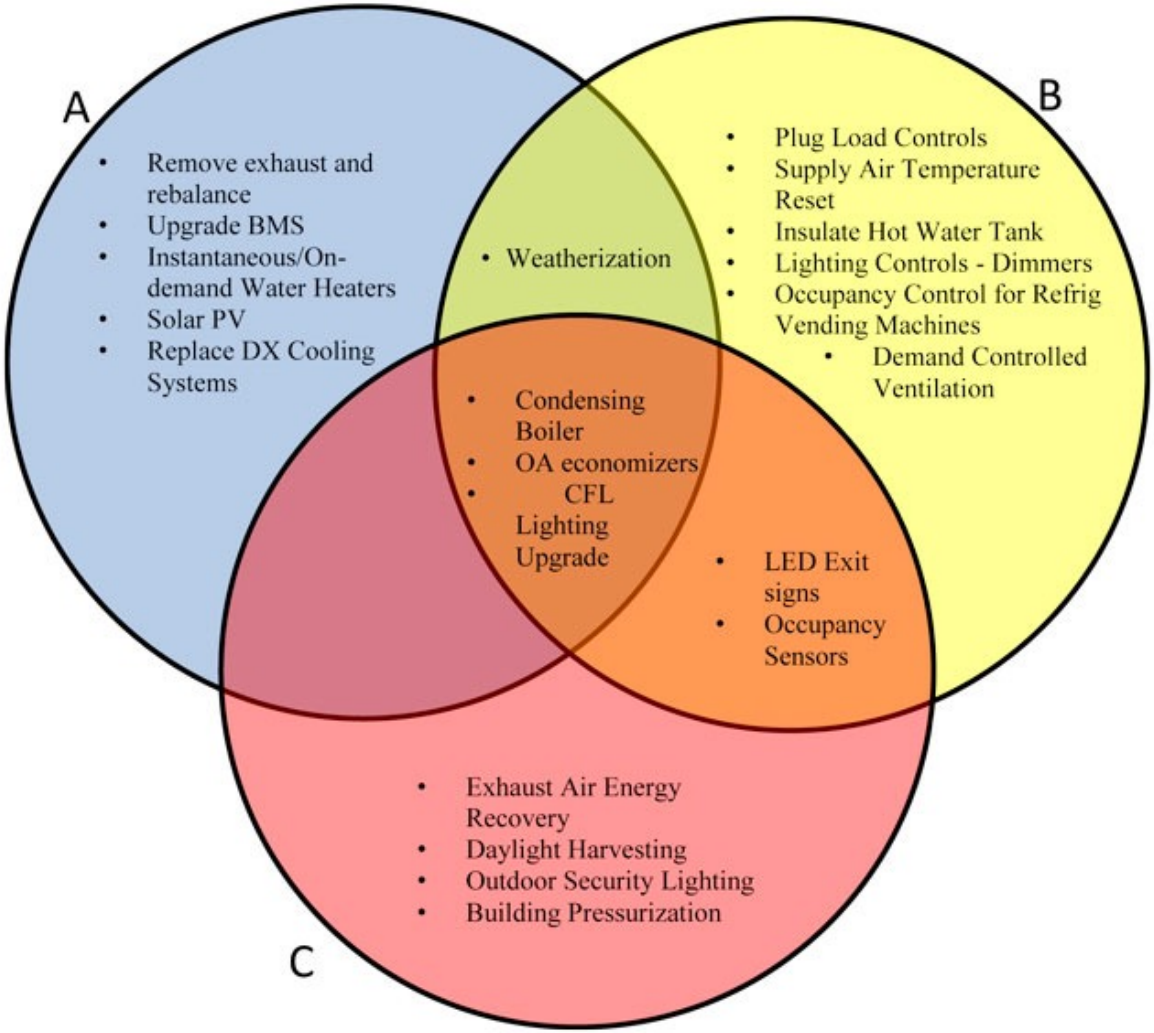
Report Format

Report	Level 1	2	3
Estimate savings from utility rate change	•	•	•
Compare EUI to EUIs of similar sites	•	•	•
Summarize utility data	•	•	•
Estimate savings if EUI were to meet target	•	•	•
Estimate low-cost/no-cost savings		•	•
Calculate detailed end-use breakdown		•	•
Estimate capital project costs and savings		•	•
Complete building description and equipment inventory		•	•
Document general description of considered measures		•	•
Recommend measurement and verification (M&V) method		•	•
Perform financial analysis of recommended EEMs		•	•
Write detailed description of recommended measures			•
Compile detailed EEM cost estimates			•

Reference: Procedures for commercial building energy audits, 2nd Edition, ASHRAE

Retrofit Suggestions

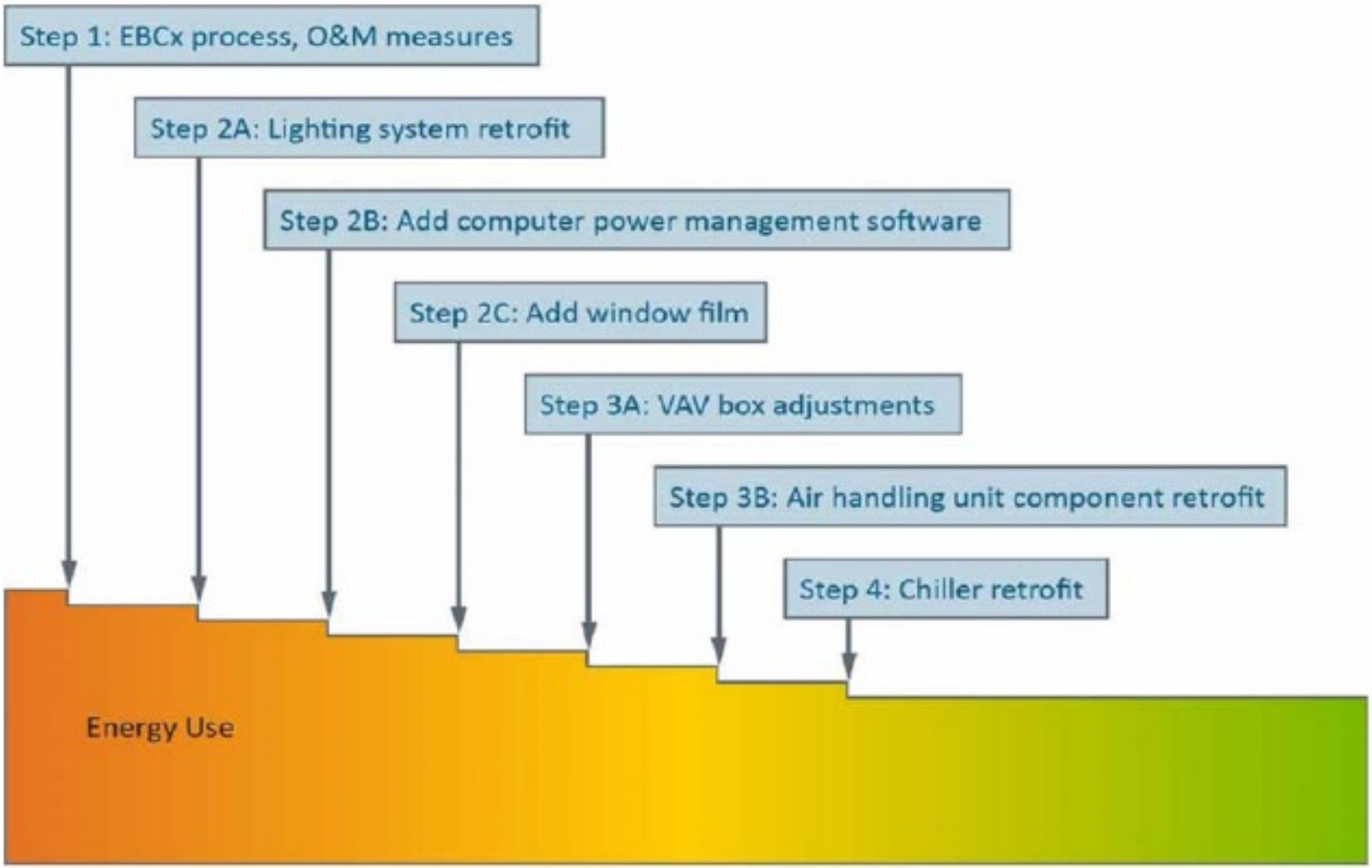
- Can we assume all auditors suggest the same retrofit packages?



http://cbei.psu.edu/variation-in-energy-audits/

Retrofit Path

- Why do we consider this path?



ADEG, PNNL 2011

ASHRAE Audit Forms

- It has different categories:

TABLE OF CONTENTS

PCBEA Sample Forms

ASHRAE Audit Forms

- It has different categories:

HVAC AND CONTROLS OPTIONS

- ***2.0*** Boilers
- ***2.1*** Chillers
- ***2.2*** Cooling Towers and Fluid Coolers
- ***2.3*** Pumps and Piping Systems
- ***2.4*** Air-Handling System Equipment
- ***2.5*** Air-Handling System Controls
- ***2.6*** Air System Terminal Units
- ***2.7*** Zone Heating Equipment
- ***2.8*** Fan-Coil Units
- ***2.9*** Exhaust/Return Fans
- ***2.10*** Packaged Units: DX, Heat Pumps
- ***2.11*** Condensing Unit and Condensers

SPECIALTY LOADS

- ***3.0*** Swimming Pools
- ***3.1*** Kitchen Equipment
- ***3.2*** Lab Equipment
- ***3.3*** Refrigeration Equipment
- ***3.4*** Data Centers/IT Rooms
- ***3.5*** Process Equipment

CLASS ACTIVITY

Class Activity

Description		Your Building
Basic site information		
Owner/operator		
Expectation constraints		
Capital improvement ($, budget)		
Operational/energy cost ($)		
Building envelope (wall, window, roof)		
Exterior light (type/wattage)		
Interior light (type/wattage)		
Domestic hot water (fuel, flow rate, capacity)		
HVAC types (Boiler, chiller, …)		
Energy end-use breakdowns (%)		
Suggested EEM (list ten EEMs)		