

CAE 465/526 Building Energy Conservation Technologies

Fall 2023

September 14, 2023

Project feedback, intro to building energy
simulation, and OpenStudio training

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Illinois Institute of Technology

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ANNOUNCEMENTS

Announcements

- Assignment 2 is tomorrow (spent sufficient time on the assignment)
- Assignment 3 will be posted early next week
- Review the Q&A file regularly and please feel free to ask questions!

ASSIGNMENT 1 FEEDBACK

Assignment 1 Feedback

- Let's look at a few examples of what can be improved and a few good practices

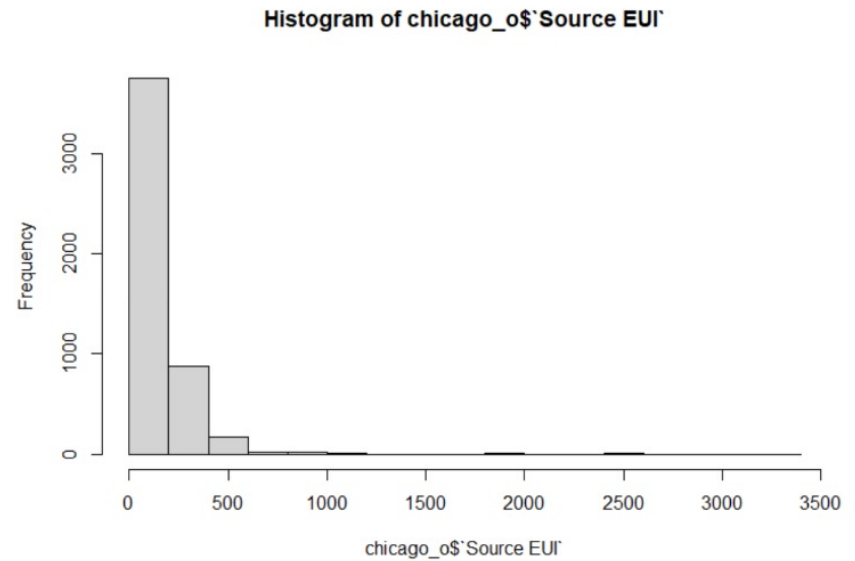
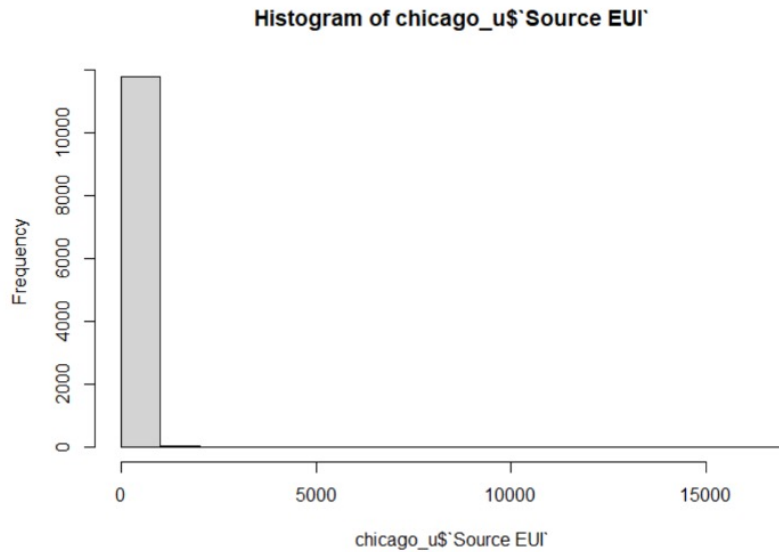
Assignment 1 Feedback

- Feedback: Common improvements

		Site EUI (kBtu/sq.ft.)	Source EUI (kBtu/sq.ft.)	Year Built	Floor Area (sq.ft.)
Chicago, IL	Areas Under 250,000 sq.ft.	Mean: 103.9 Median: 80 Max: 15634.5 Min: 0.1 SD: 294.9	Mean: 179.7 Median: 136.7 Max: 16485.4 Min: 0.2 SD: 335.9	Mean: 1960 Median: 1964 Max: 2020 Min: 1692 SD: 38.2	Mean: 110721 Median: 95310 Max: 249910 Min: 16333 SD: 52213.3
	Areas Over 250,000 sq.ft.	Mean: 90.88 Median: 78.20 Max: 3063.10 Min: 3.80 SD: 74.6	Mean: 175.2 Median: 148.1 Max: 3357.6 Min: 8.4 SD: 153.6	Mean: 1973 Median: 1976 Max: 2020 Min: 1845 SD: 32.5	Mean: 658460 Median: 445564 Max: 9245333 Min: 250000 SD: 656661.6
Washington, D.C.	Areas Under 250,000 sq.ft.	Mean: 96.33 Median: 61.50 Max: 124660.1 Min: 0 SD: 1567.1	Mean: 194.85 Median: 131.20 Max: 151010 Min: 0 SD: 2312.6	Mean: 1963 Median: 1964 Max: 2020 Min: 1727 SD: 33.47	Mean: 105670 Median: 89609 Max: 249965 Min: 714 SD: 60800.4
	Areas Over 250,000 sq.ft.	Mean: 81.37 Median: 57.20 Max: 100 Min: 0 SD: 26.82	Mean: 201 Median: 144 Max: 168490 Min: 0 SD: 65	Mean: 1982 Median: 1986 Max: 2022 Min: 1789 SD: 52.2	Mean: 481535 Median: 360200 Max: 5634890 Min: 250000 SD: 512116.9

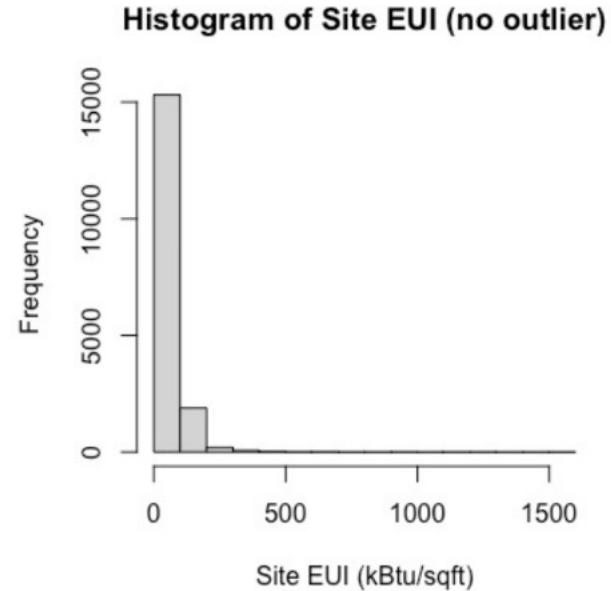
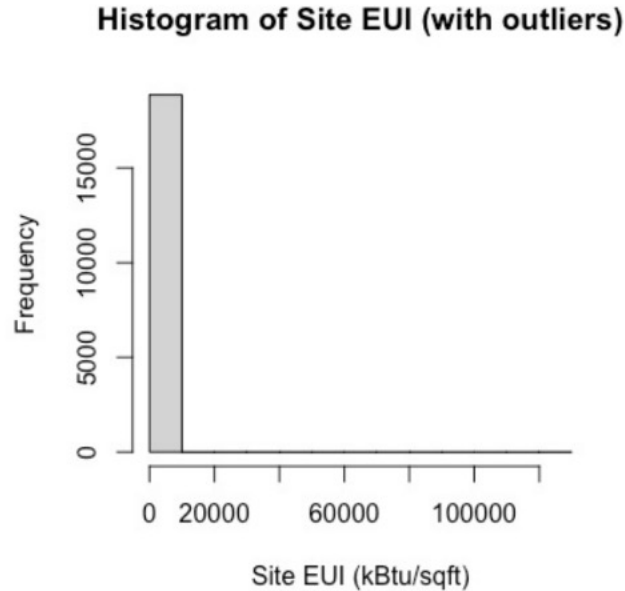
Assignment 1 Feedback

- Feedback: Common improvements



Assignment 1 Feedback

- Feedback: Common improvements



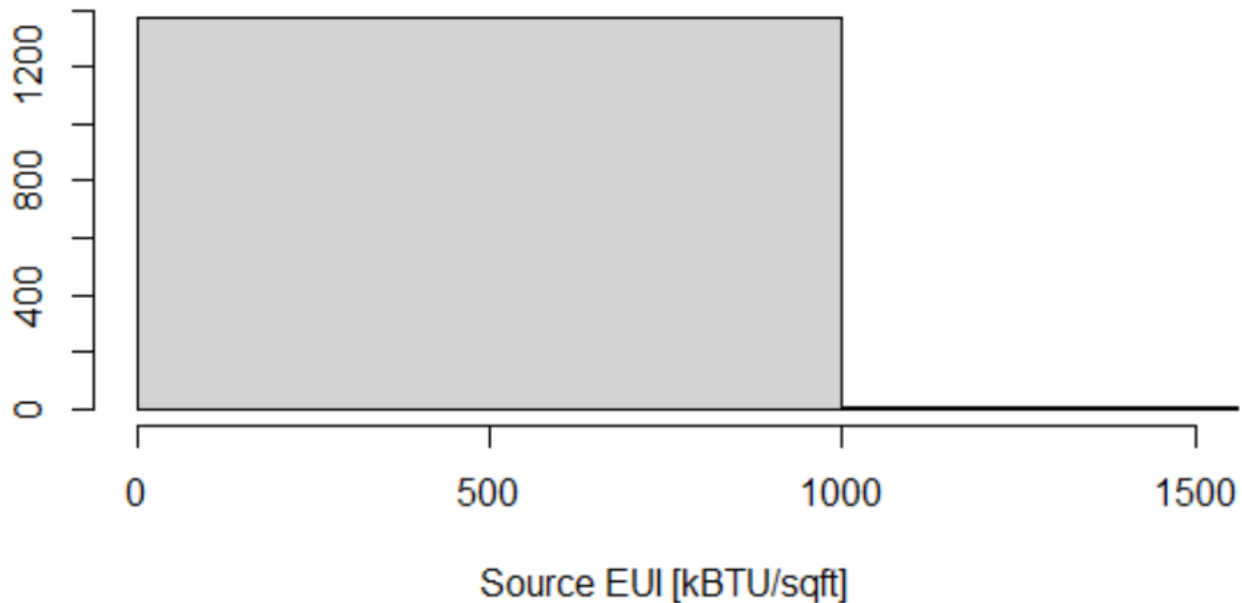
Summary without NA Data

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.0	42.40	59.60	92.18	79.30	124660.10

Assignment 1 Feedback

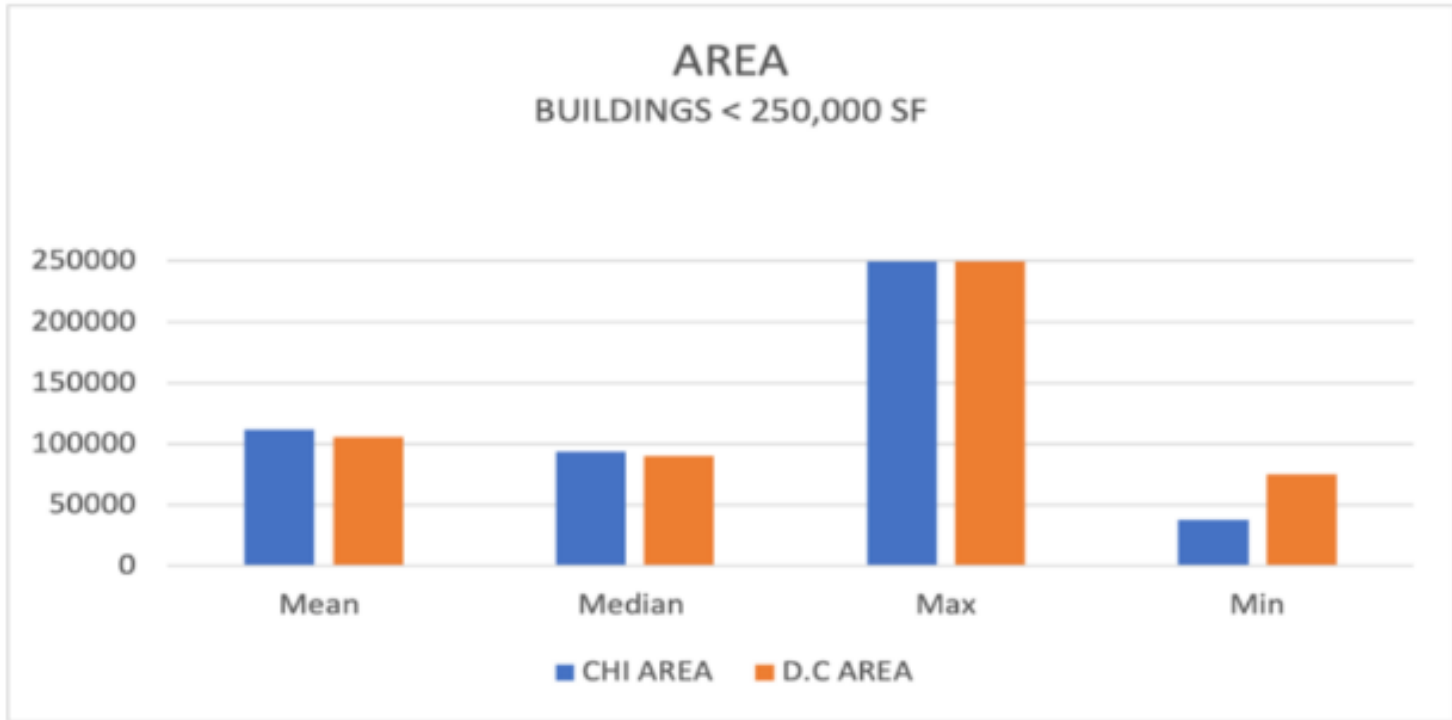
- Feedback: Common improvements

Histogram of source EUI of Chicago



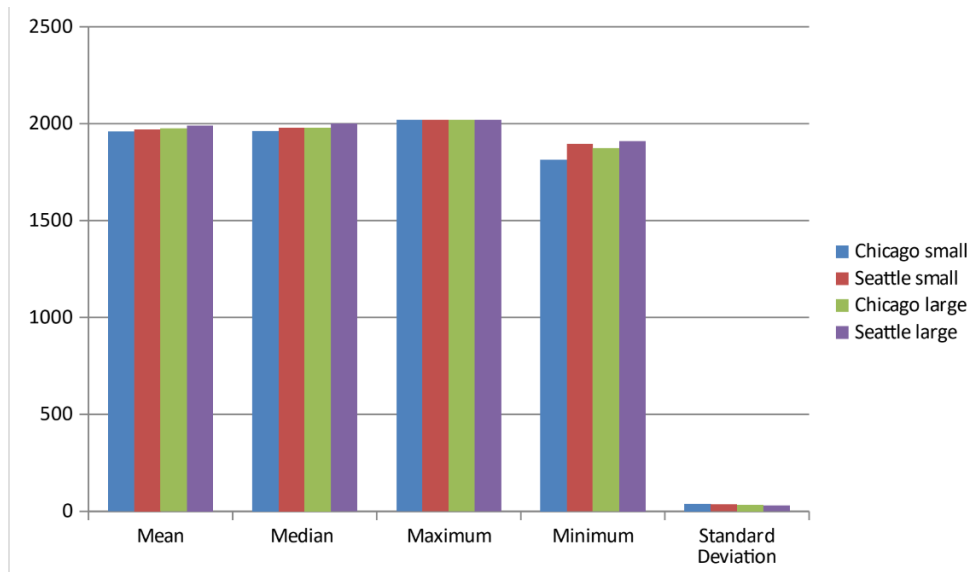
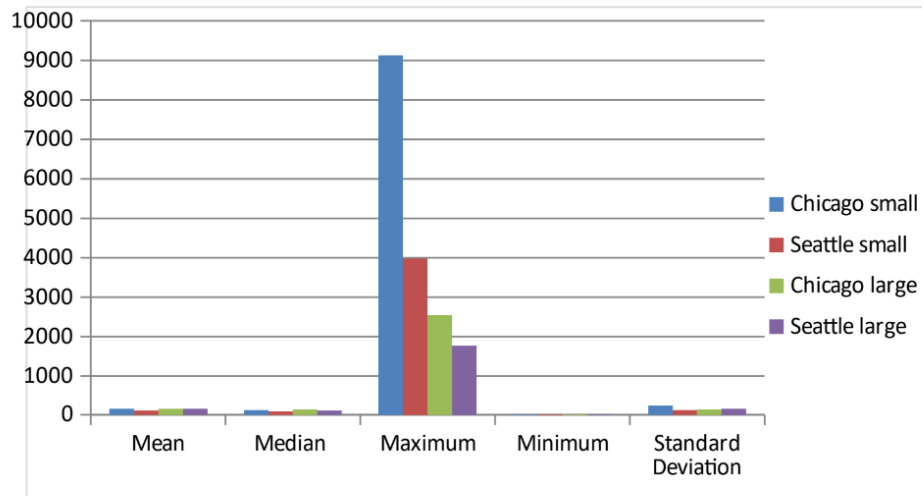
Assignment 1 Feedback

- Feedback: Common improvements



Assignment 1 Feedback

- Feedback: Common improvements



Assignment 1 Feedback

- Feedback: Common improvements

1.1 Buildings smaller than 250,000 ft2

sumtable {vtable} Summary Statistics

Summary Statistics of Small Buildings in Chicago

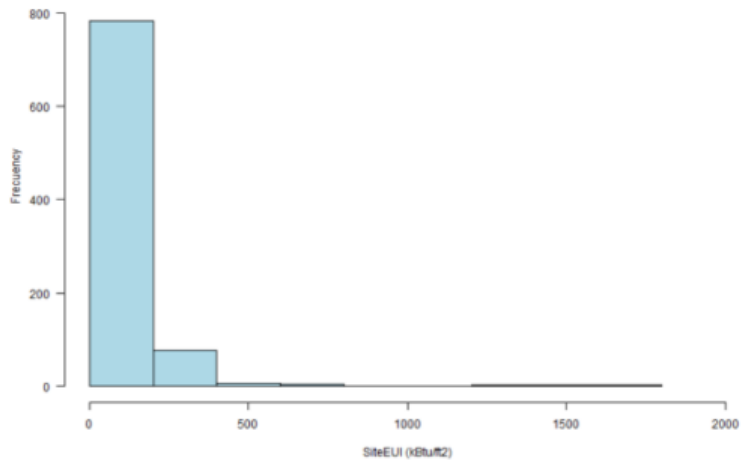
Variable	Mean	Median	Maximum	Minimum	Standard deviation
SiteEUI	113	88	1648	0.2	118
SourceEUI	192	144	1788	0.4	172
YearBuilt	1963	1968	2018	1692	38
Area	112058	94053	249600	38000	54247

sumtable {vtable} Summary Statistics

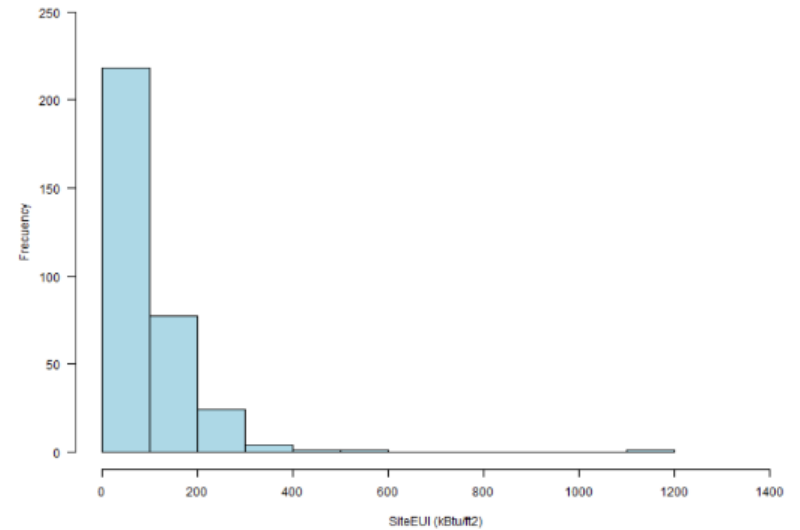
Assignment 1 Feedback

- Feedback: Common improvements

Site EUI histogram without Outliers Small Buildings Chicago



Site EUI histogram without Outliers Big Buildings Chicago



Assignment 1 Feedback

- Feedback: Good practice / Improvements

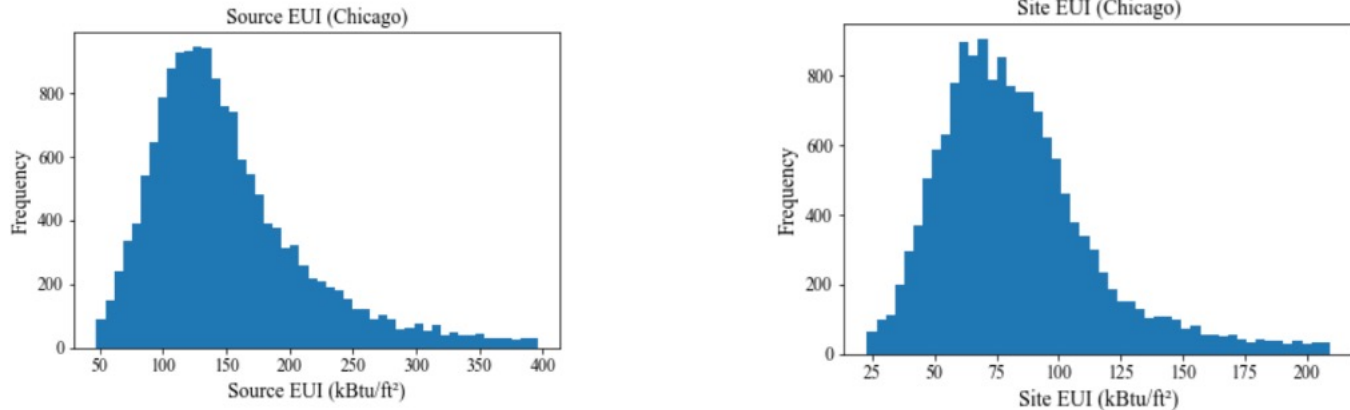


Fig.1: Histogram of site and source EUI for the city of Chicago

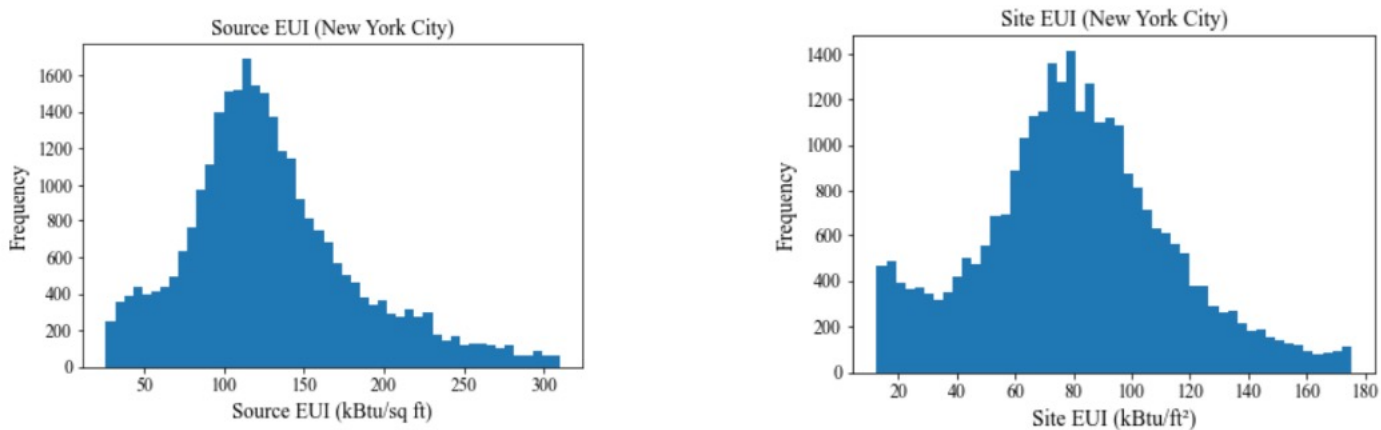


Fig.2: Histogram of site and source EUI for the city of New York

Assignment 1 Feedback

- Feedback: Good practice / Improvements

		Without Outliers				With Outliers			
		Area < 250000(ft ²)		Area > 250000(ft ²)		Area < 250000(ft ²)		Area > 250000(ft ²)	
		Chicago	NYC	Chicago	NYC	Chicago	NYC	Chicago	NYC
Area (ft ²)	Mean	104,898	69,346	554,102	475,315	110,795	75,870	664,125	560,765
	Median	92,454	59,989	435,118	394,913	95,500	61,750	449,107	404,293
	Maximum	218,875	180,166	1,687,710	1,357,968	249,910	249,978	9,245,333	8,942,176
	Minimum	50,060	12,960	252,504	253,376	16,333	1	250,200	250,044
	Stand. Dev.	44,629	37,420	313,717	234,446	52,114	48,400	670,022	523,843
Year Built	Mean	1956	1941	1971	1957	1959	1944	1973	1959
	Median	1962	1931	1974	1962	1964	1931	1977	1963
	Maximum	2012	2007	2013	2008	2020	2021	2020	2017
	Minimum	1889	1896	1893	1896	1692	1051	1,845	1,600
	Stand. Dev.	35.8	27.36	30.5	27.6	38.2	32.5	32.6	31.6
Source EUI (kBtu/ft ²)	Mean	148.7	124.48	148.7	152.18	179.7	354.6	175.4	11,565
	Median	78.3	118.6	76.7	142.8	79.8	120.9	78.3	146.3
	Maximum	406.6	306.7	377.1	385.6	16,485	2,219,625	3,357	28,942,940
	Minimum	32.3	6.6	50.4	0.6	0.2	0.0	8.4	0.0
	Stand. Dev.	65.54	54.67	65.5	68.2	335.8	14,795	335.8	567,744
Site EUI (kBtu/ft ²)	Mean	83.7	78	80.9	81.75	104.2	234.9	91.4	9,568
	Median	78.3	78.5	76.7	79.45	79.8	80.0	78.3	80.3
	Maximum	212.9	173.7	201.7	211.3	15,634	1,340,295	3,063	24,058,060
	Minimum	14.6	2.8	24.6	1.3	0.1	0.0	3.8	0.0
	Stand. Dev.	33.7	34.87	29.3	35.7	301.5	8,897	76.4	471,927

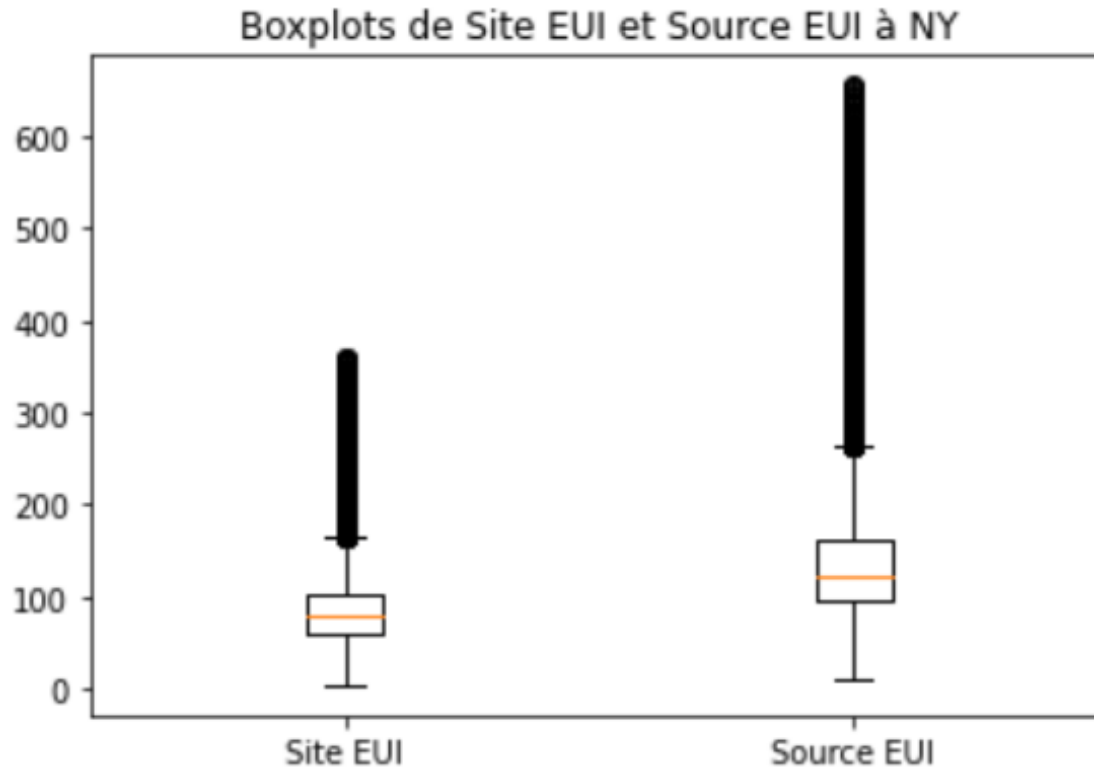
Assignment 1 Feedback

- Feedback: Good practice / Improvements

Table 2. Buildings in Chicago equal or bigger than 250000 sqft					
Variables	MEAN	MEDIAN	MAXIMUM	MINIMUM	STANDARD DEVIATION
SITE EUI	119,03	80,95	14680,60	0,20	552,46
SOURCE EUI	NA	NA	NA	NA	NA
YEAR BUILT	1976	1981	2019	1873	31,93
AREA	659007,40	455855	9245333	250000	647822

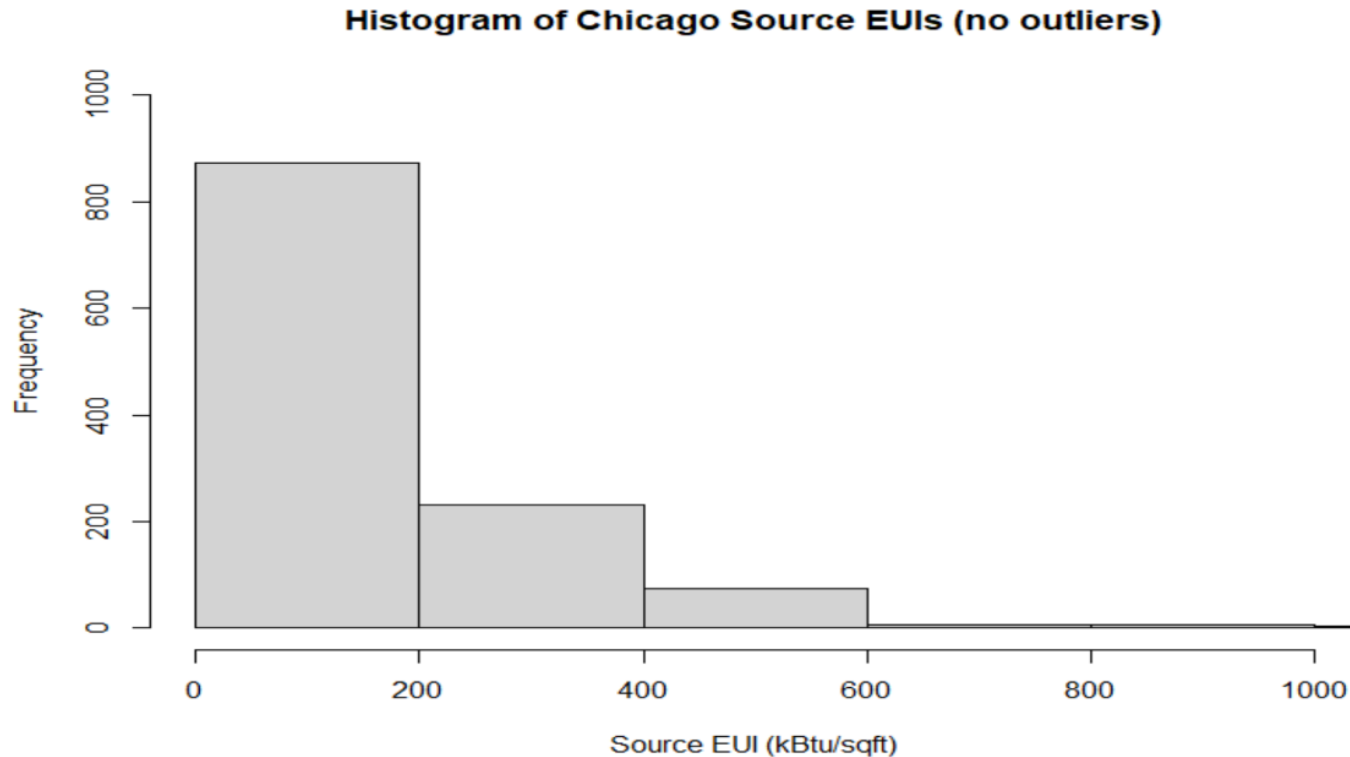
Assignment 1 Feedback

- Feedback: Good practice / Improvements



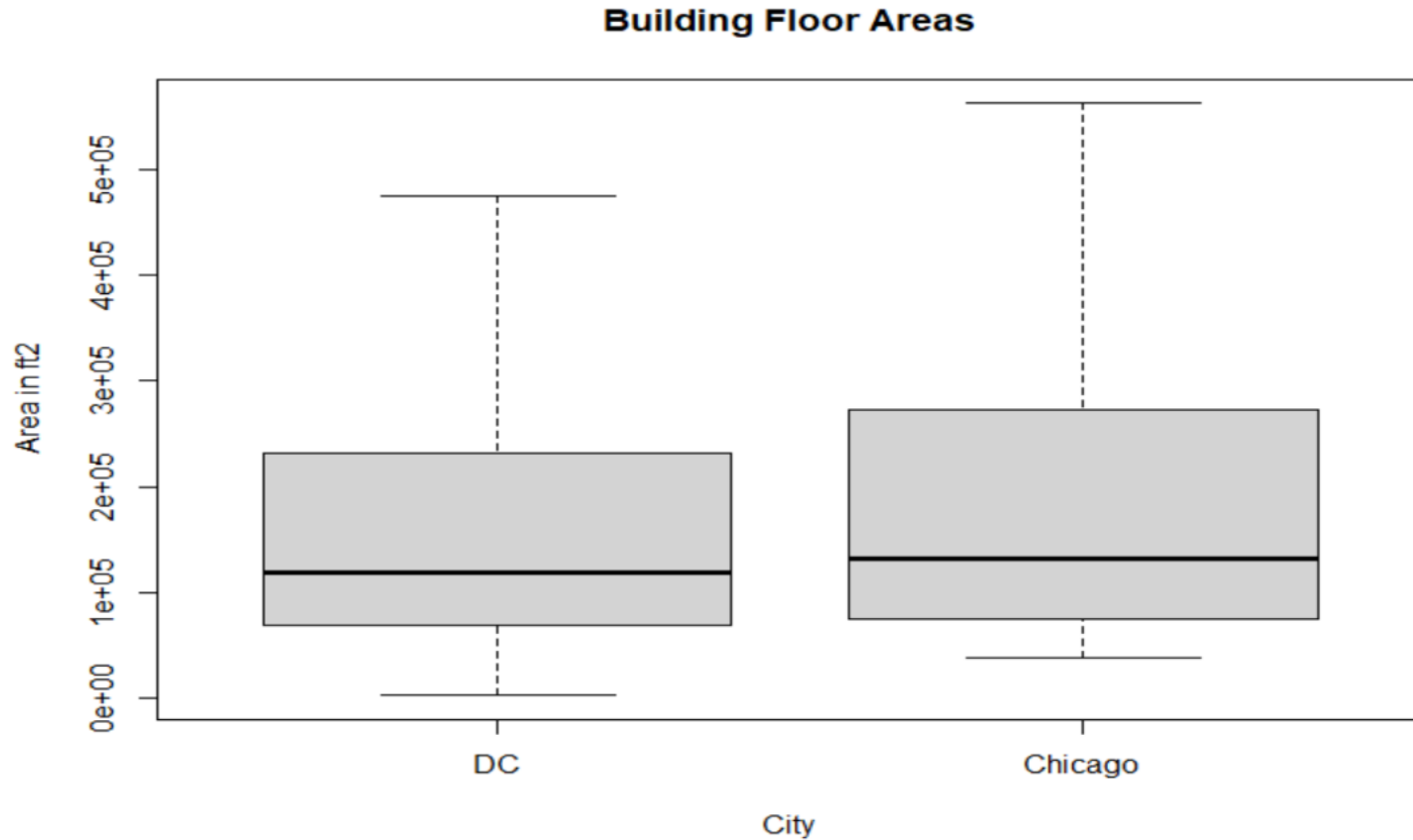
Assignment 1 Feedback

- Feedback: Good practice / Improvements



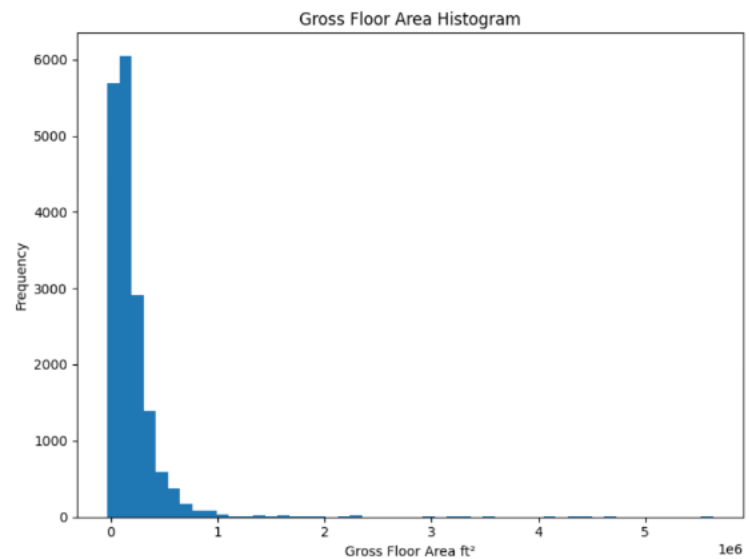
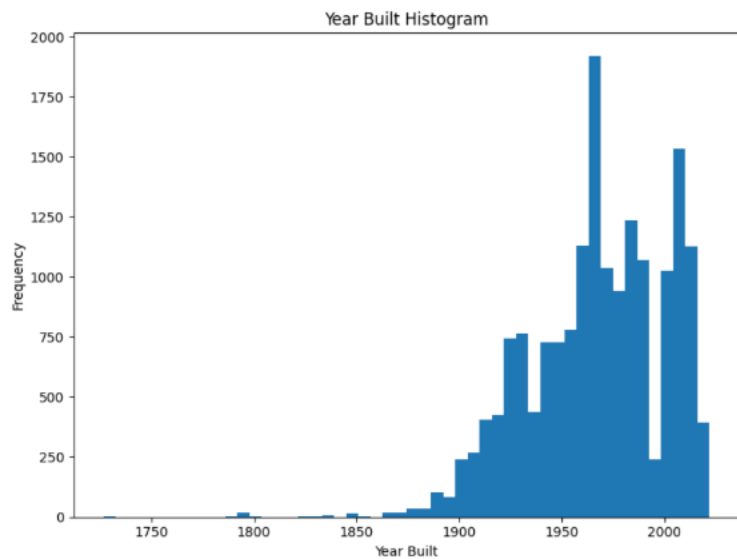
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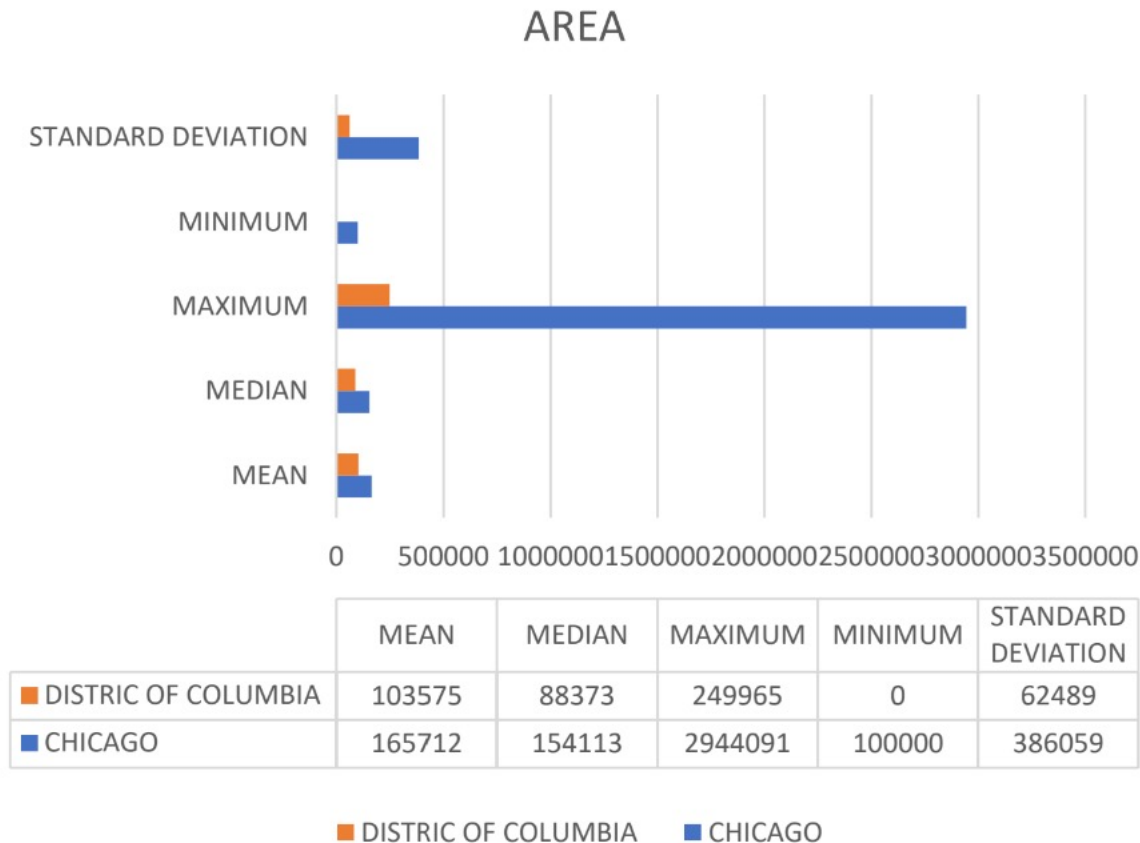
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- Feedback: Good practice / Improvements



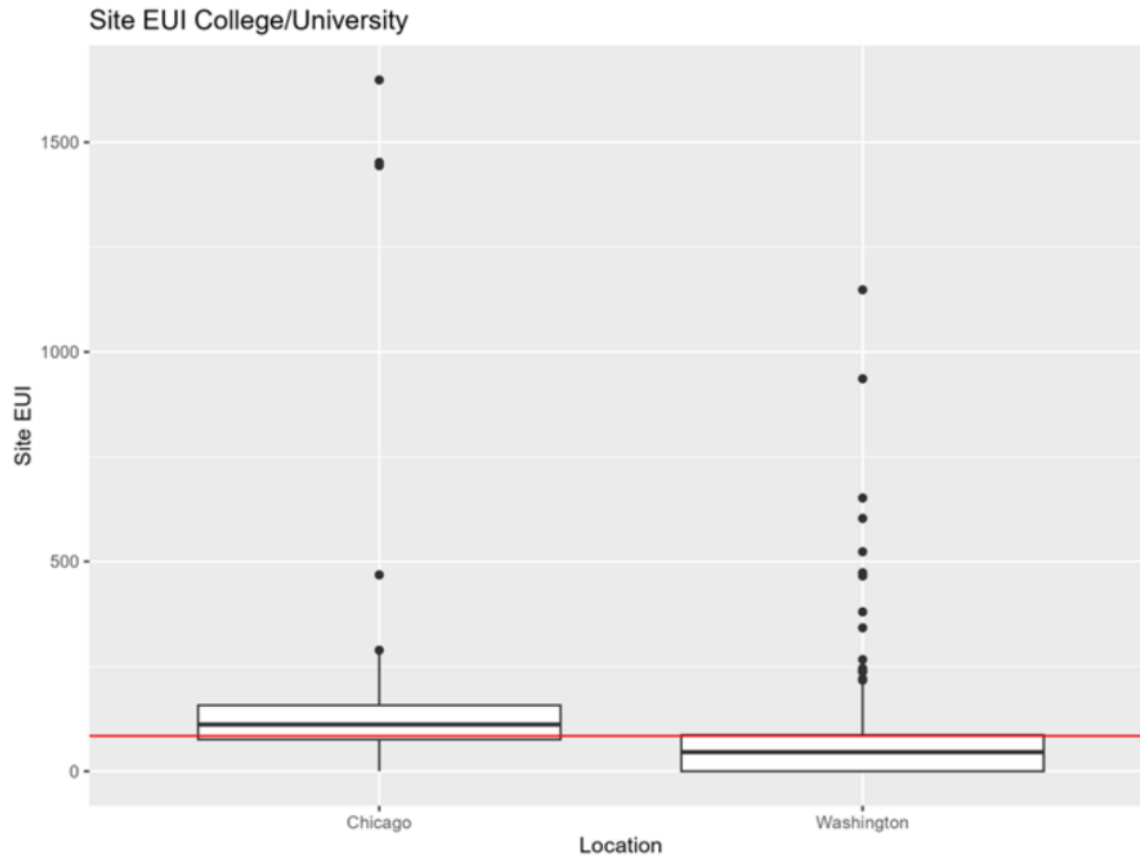
Assignment 1 Feedback

- Feedback: Good practice / Improvements



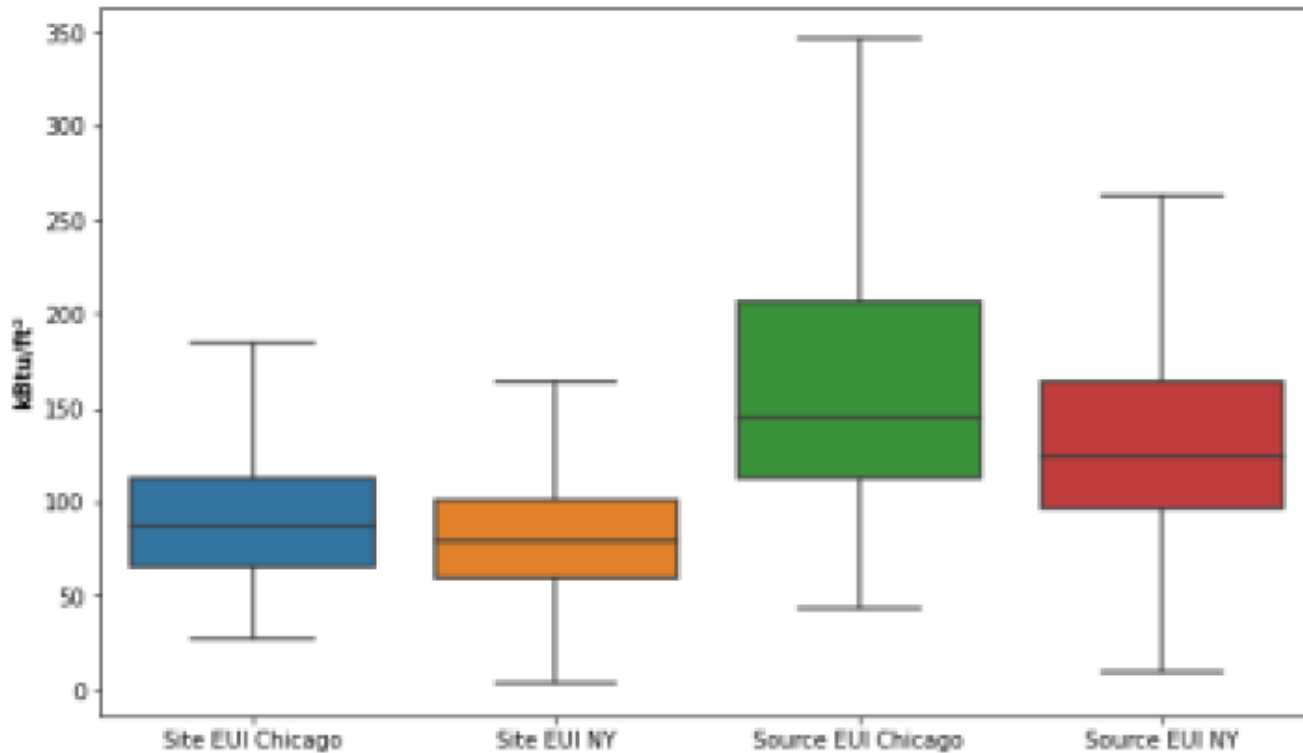
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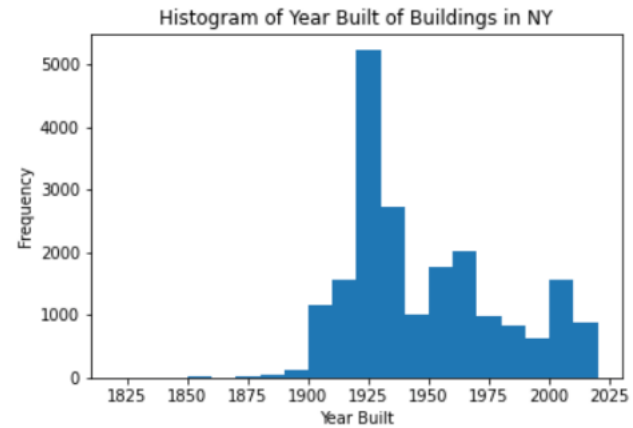
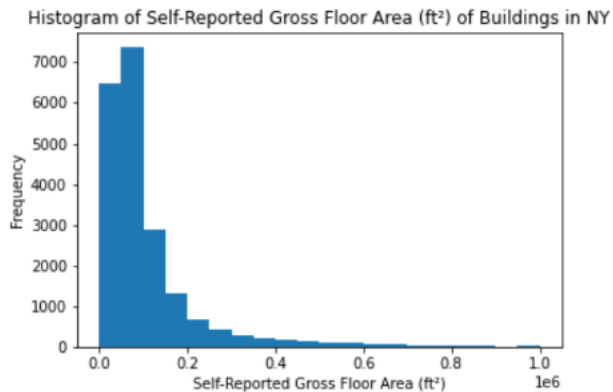
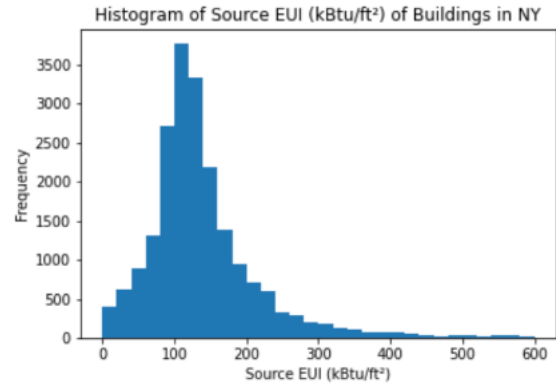
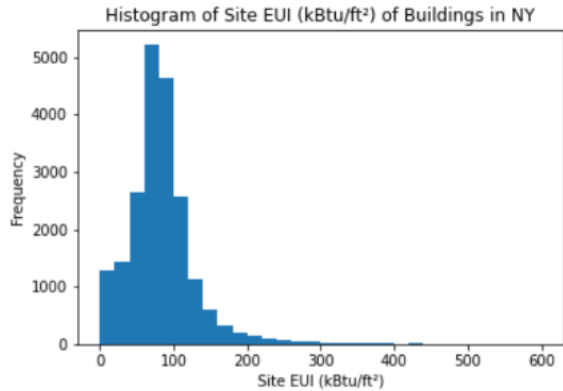
Assignment 1 Feedback

- Feedback: Good practice / Improvements



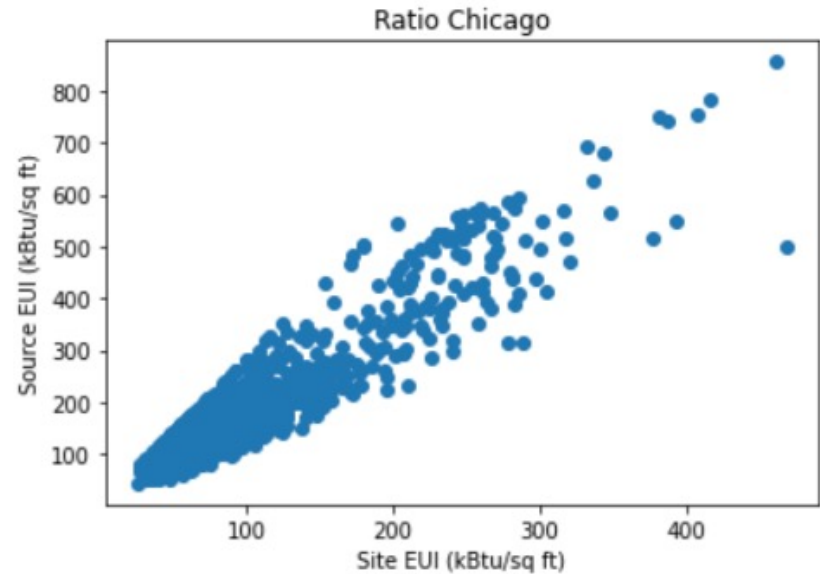
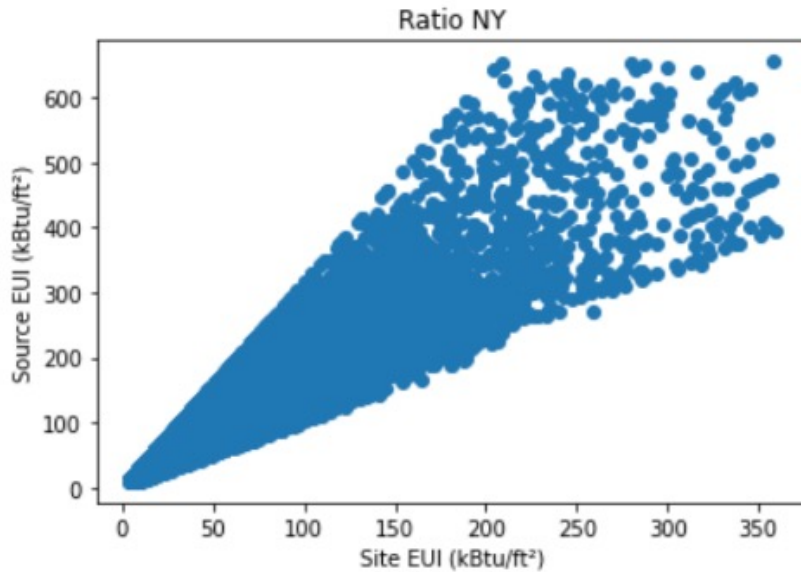
Assignment 1 Feedback

- Feedback: Good practice



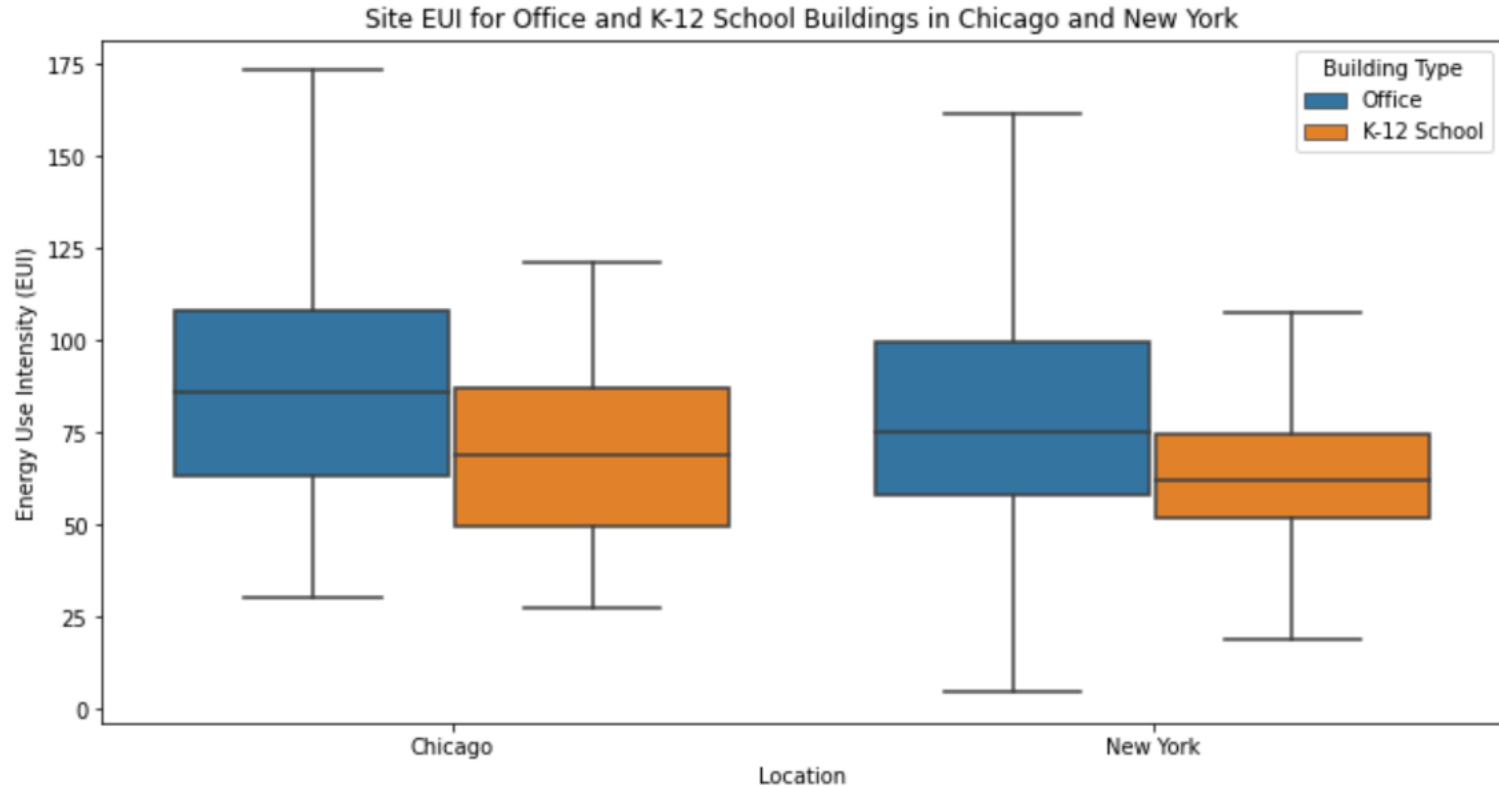
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Assignment 1 Feedback

- Feedback: Good practice



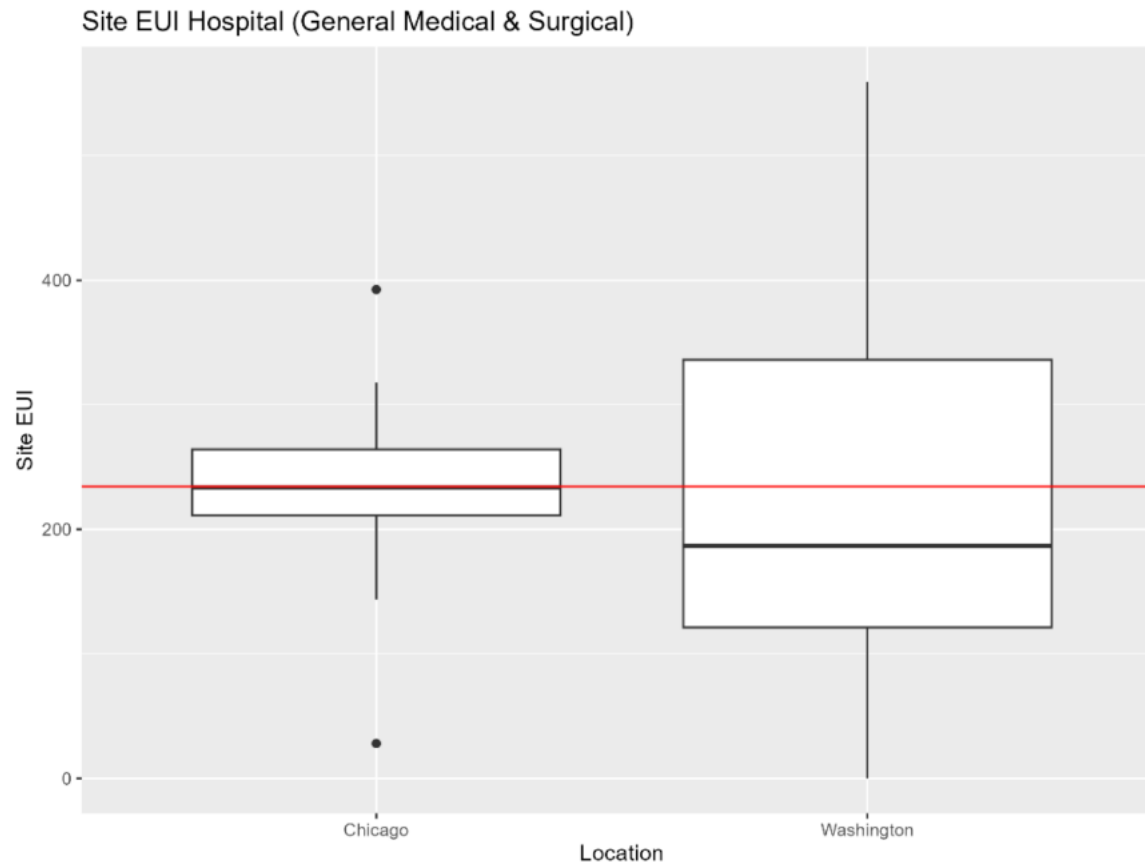
Assignment 1 Feedback

- Feedback: Good practice

Property Type	Mean Source EUI Chicago (kBtu/ft ²)	Mean Source EUI Washington (kBtu/ft ²)	CBECS Site EUI (kBtu/ft ²)
Adult Education	249.6	158.9	110.4
Bank Branch	130.7	162.8	209.9
College/University	562.4	120.8	180.6
Convention Center	221.0	164.8	109.6
Courthouse	165.6	249.7	211.4
Enclosed Mall	285.5	168.5	170.7
Financial Office	227.8	188.3	116.4
Fitness Center/Health Club/Gym	306.0	222.4	112.0
Hospital (General Medical & Surgical)	393.6	396.7	426.9
Hotel	403.2	489.4	146.7
Indoor Arena	316.0	197.9	
K-12 School	113.4	360.4	104.4
Laboratory	553.5	368.4	318.2
Library	228.8	247.8	143.6
Medical Office	263.3	219.6	121.7
Mixed Use Property	206.5	265.7	89.3
Movie Theater	347.5	262.4	112.0
Multifamily Housing	126.8	127.9	118.1
Museum	520.6	268.1	112.0
Office	189.5	187.6	116.4
Other	141.0	245.4	
Other - Education	375.0	105.0	110.4
Other - Entertainment/Public Assembly	173.7	249.2	
Other - Lodging/Residential	170.0	135.9	143.6
Other - Mall	316.8	42.5	225.3
Other - Public Services	393.8	184.6	89.3
Other - Recreation	185.6	215.4	112.0
Other - Specialty Hospital	370.7	292.9	433.9

Assignment 1 Feedback

- Feedback: Good practice



Assignment 1 Feedback

- Feedback: Good practice

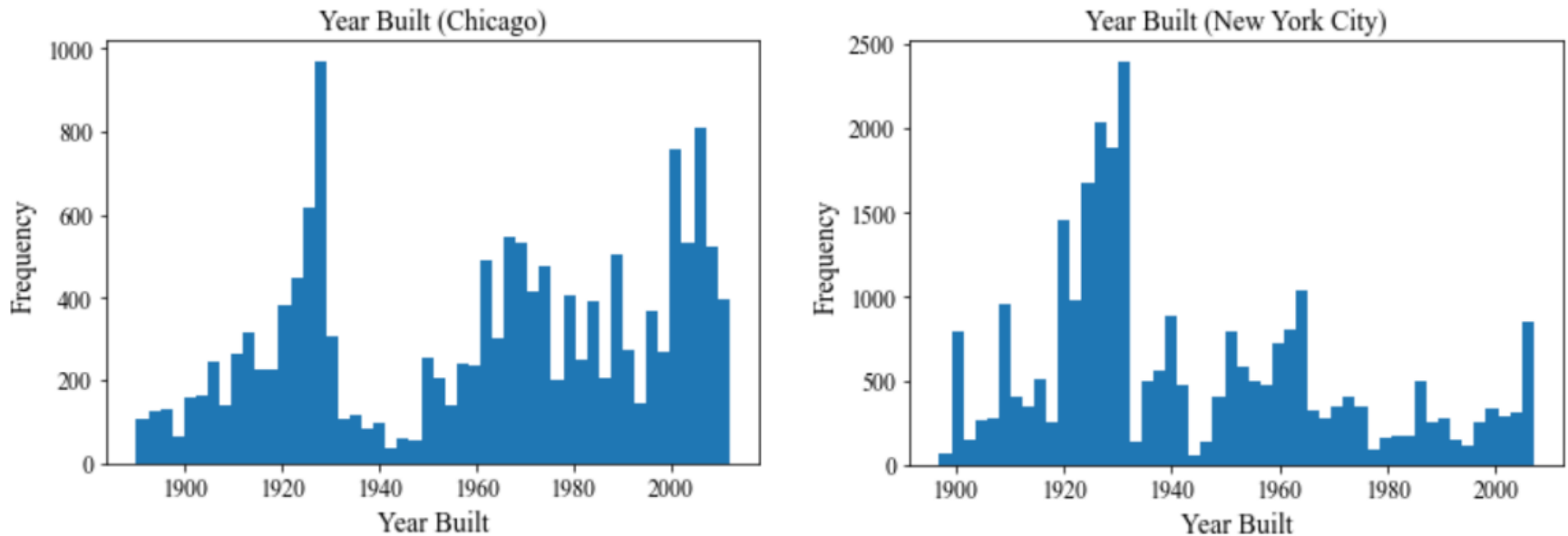


Fig.4: Histogram of year built for the city of Chicago and New York

Assignment 1 Feedback

- Feedback: Good practice

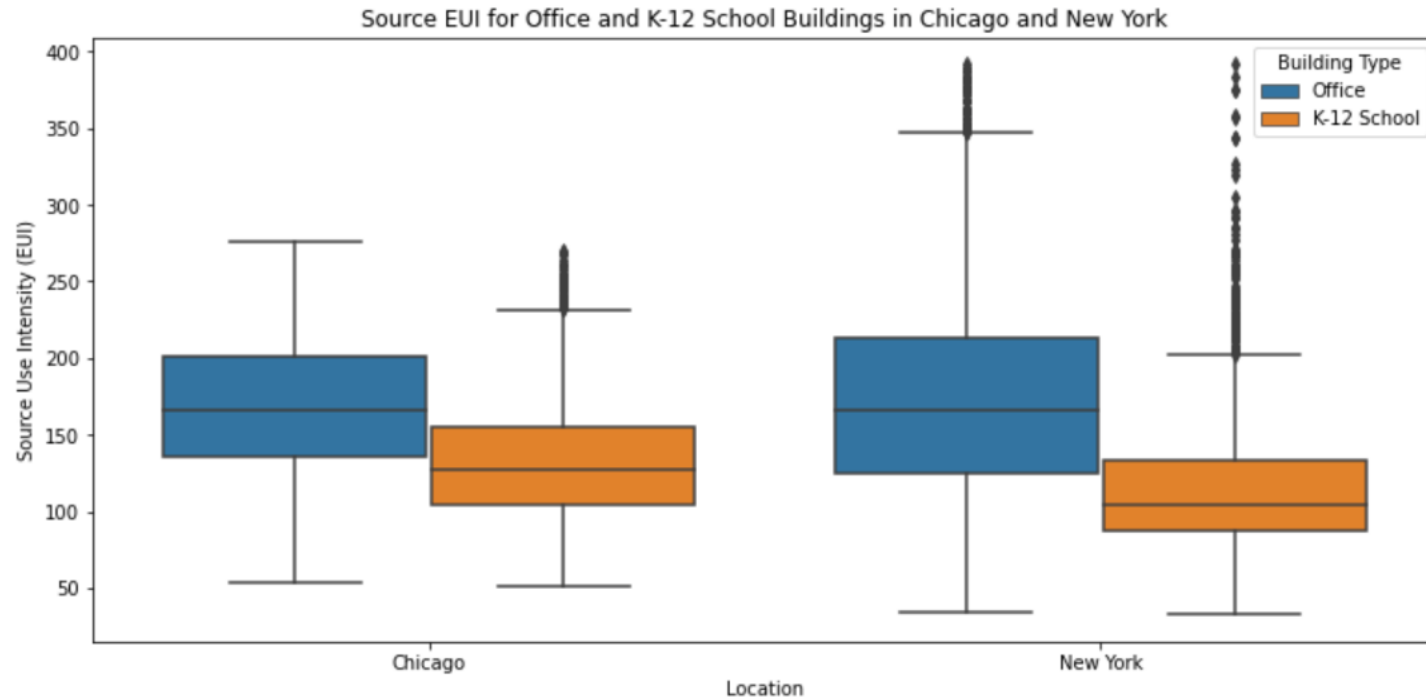
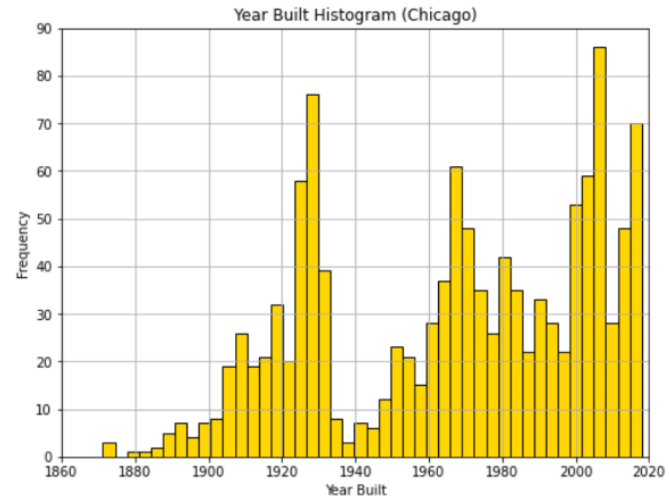
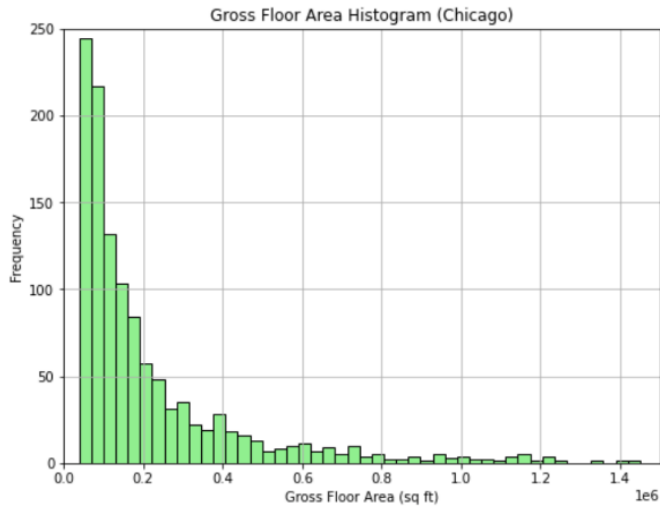
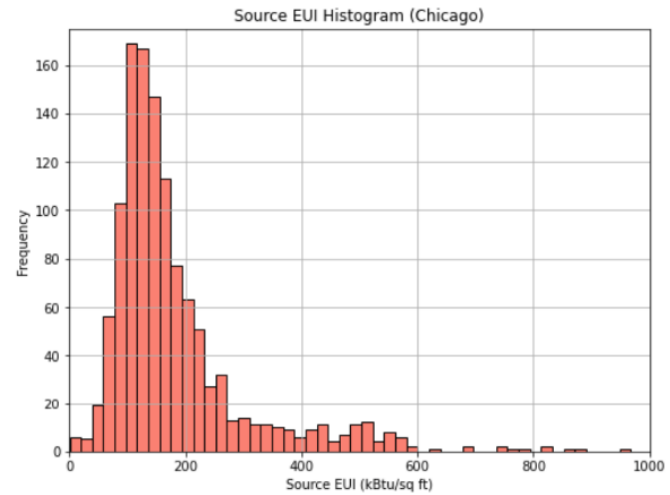
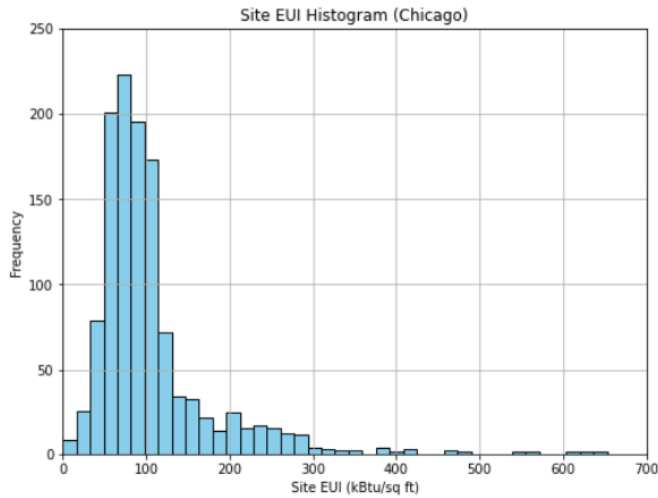


Fig.9: Box plot of Year built for buildings in New York and Chicago

Assignment 1 Feedback

- Feedback: Good practice



Assignment 1 Feedback

- Feedback: Good practice

Table 2: Energy Efficiency (Buildings < 250,000 ft²)

	City of Chicago	City of Seattle
Site EUI in kBtu/sf (Mean / Median)	136.8 / 88.1	53.8 / 37.8
Source EUI in kBtu/sf (Mean / Median)	217.3 / 144.0	116.9 / 85.1

Table 3: Energy Efficiency (Buildings > 250,000 ft²)

	City of Chicago	City of Seattle
Site EUI in kBtu/sf (Mean / Median)	105.0 / 86.0	147.7 / 47.9
Source EUI in kBtu/sf (Mean / Median)	191.1 / 148.2	249.7 / 118.4

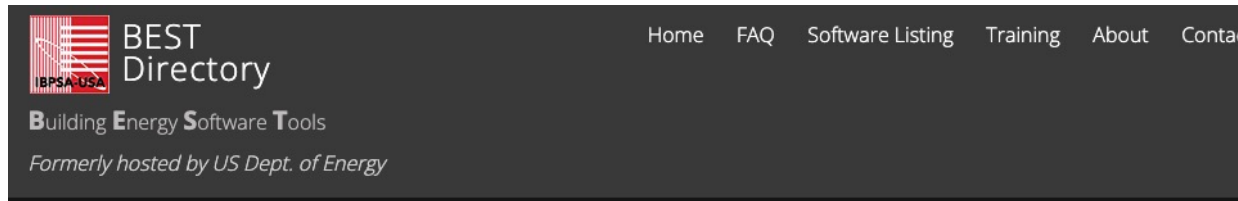
Assignment 1 Feedback

- Feedback: Common improvements
 - Do not forget about adding comments to your code!
 - Comment on your numbers

INTRO TO BUILDING ENERGY SIMULATIONS

Building Energy Simulation

- There are several graphical interface for EnergyPlus:



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EnergyPlus

Capabilities

- Whole Building Energy Simulation
- Load Calculations
- HVAC System Selection and Sizing
- Parametrics and Optimization
- Energy Conservation Measures
- Code Compliance
- Ratings and Certificates
- Utility Bill and Meter Data Analysis
- Weather Data and Climate Analysis
- Building Automation
- Building Energy Auditing
- Building Energy Benchmarking
- Building Energy Monitoring
- Lighting Simulation
- Air Flow Simulation
- Life Cycle Analysis
- Solar and Photovoltaic Analysis
- Support Services
- Training Services
- Weather
- Other

Building Type

- Subsystem Level
- Commercial



Sefaira Systems

Sefaira Systems produces high-quality HVAC sizing and energy results directly from architectural Revit and SketchUp models, enabling users to rapidly compare design options and respond to architectural changes quicker than ever before.

Whole Building Energy Simulation | Load Calculations | HVAC System Selection and Sizing
Commercial, Residential, Multi Family

Last Software Update: 28 August 2015 | **Last Entry Update:** 20 September 2018

Ratings ★★★★★ | **Reviews** 0 | **Add to compare**



BuildSimHub

BuildSimHub provides a cloud-based energy model management platform and a variety of modeling toolset to streamline and automate modeling cycles for businesses who focus on building sustainability, saving up to 70% modeling time and cost.

Whole Building Energy Simulation | Parametrics and Optimization | Code Compliance | Other
Commercial, Residential, Industrial

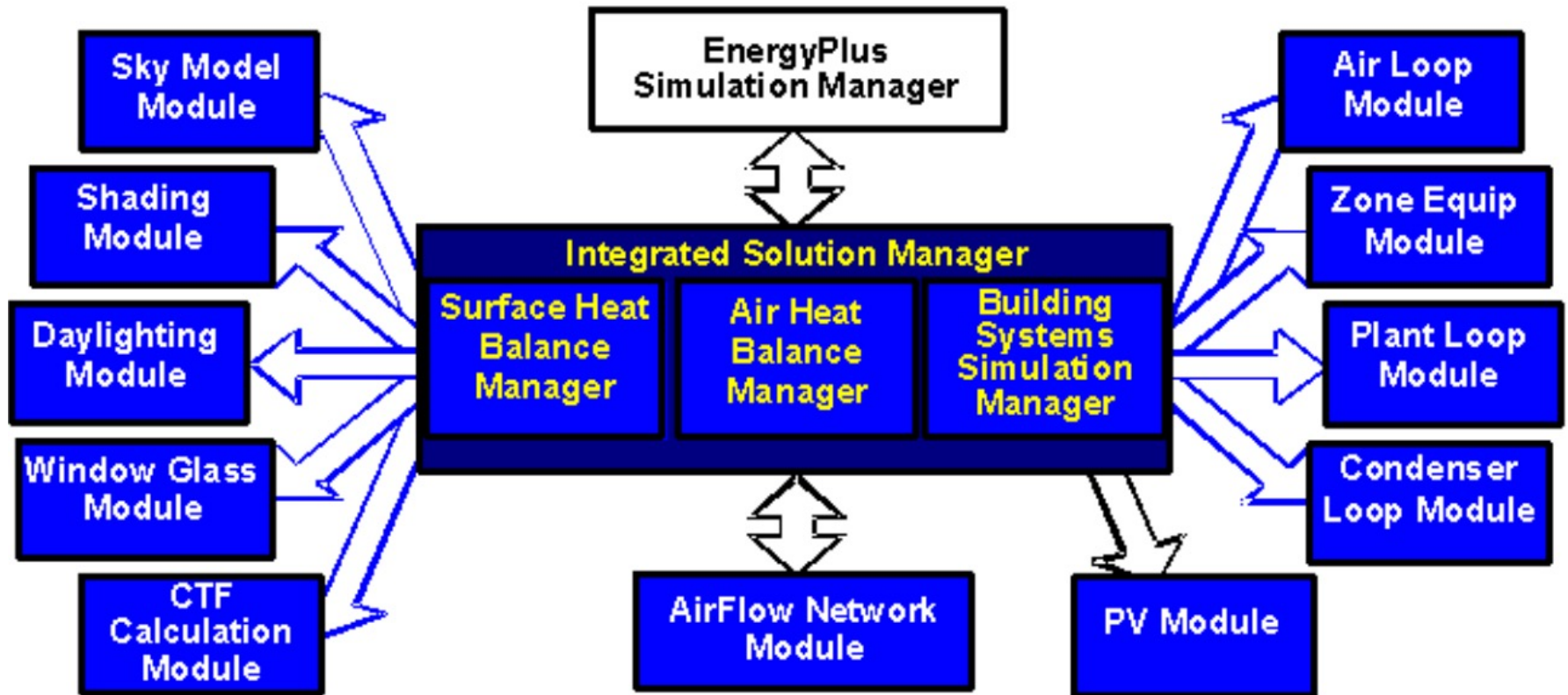
Last Software Update: 17 September 2018 |

Last Entry Update: 17 September 2018

Ratings ★★★★★ | **Reviews** 0 | **Add to compare**

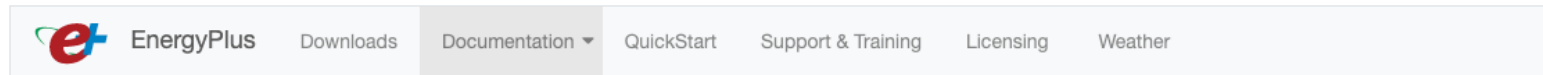
Building Energy Simulation

- EnergyPlus:



Building Energy Simulation

- EnergyPlus:



Documentation

PDF Documentation

PDF documentation can be downloaded from the following links.

[Download All PDFs](#)

[Acknowledgements](#)

[Auxiliary Programs](#)

[EMS Application Guide](#)

[EnergyPlus Essentials](#)

[Engineering Reference](#)

[External Interfaces Application Guide](#)

[Getting Started](#)

[Input Output Reference](#)

[Interface Developer](#)

[Module Developer](#)

[Output Details And Examples](#)

[Plant Application Guide](#)

[Tips and Tricks Using EnergyPlus](#)

[Using EnergyPlus for Compliance](#)

HTML Documentation

View [HTML documentation](#) for a HTML version of the EnergyPlus documentation.

Testing Documentation

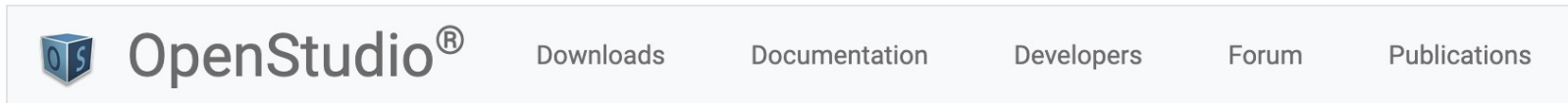
View [testing reports](#) for current and past versions of EnergyPlus.

<https://energyplus.net/documentation>

OPENSTUDIO

OpenStudio

- OpenStudio as a BEM operating system



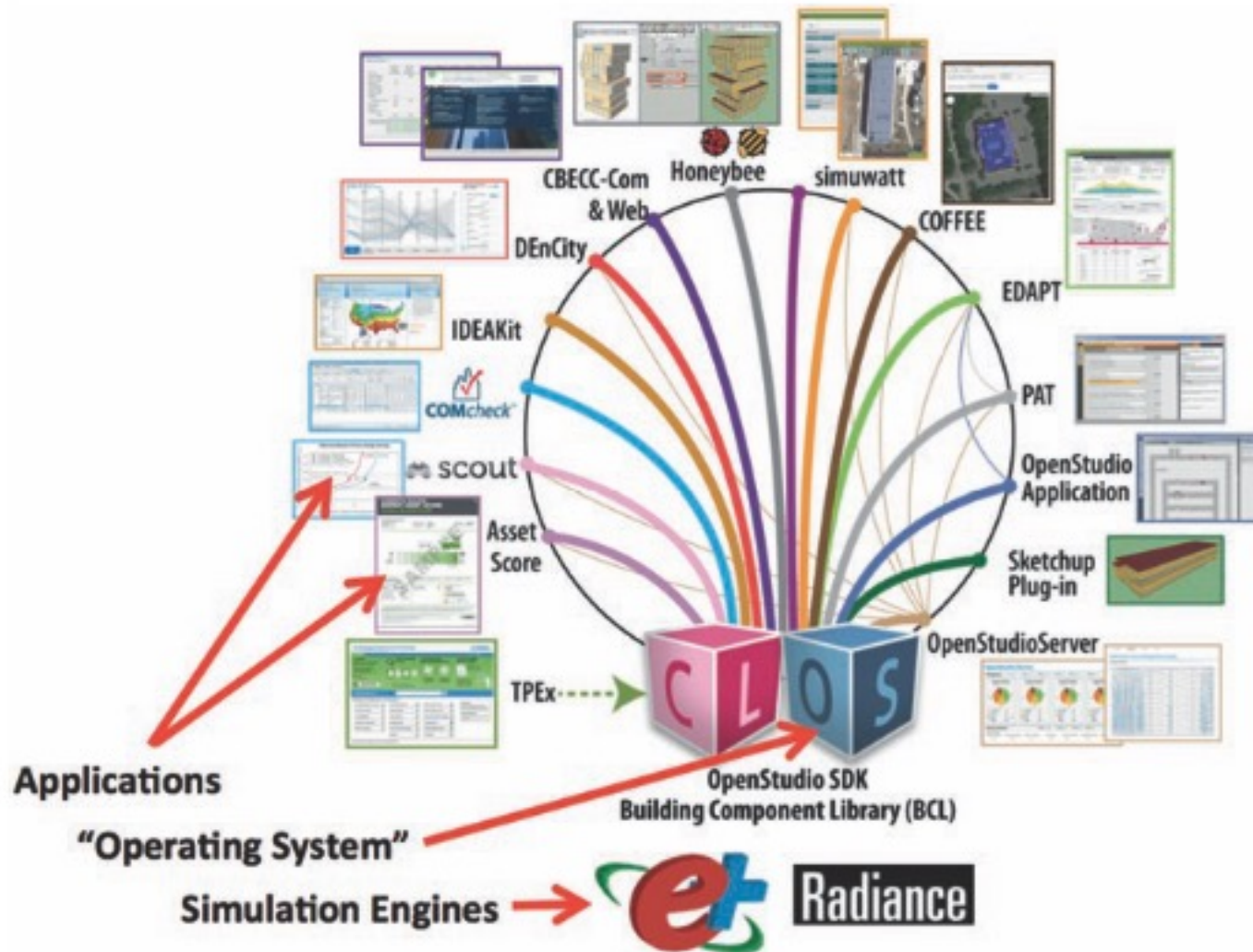
OpenStudio® is a cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance. OpenStudio is an open source project to facilitate community development, extension, and private sector adoption.

[OpenStudio SDK](#) is both a Software Development Kit (SDK) and a Command Line Interface (CLI). Conceptually, OpenStudio SDK provides an Application Programming Interface (API) to access the EnergyPlus modeling engine. This interface provides many benefits such as a stable, version-controlled interface, space typology abstractions that make it easier for end-users to model buildings, and language bindings in Ruby, Python and C-Sharp to make it more accessible to users familiar with these languages. The CLI is a powerful, cross-platform tool that allows users to run OpenStudio based workflows on supported architectures such as Linux, Windows and Mac.

The graphical applications include the [OpenStudio SketchUp Plug-in](#), [OpenStudio Application](#), and the [Parametric Analysis Tool](#). The SketchUp Plug-in and the Openstudio Application are maintained by the [OpenStudio Coalition](#), which was founded to maintain and develop these graphical applications for the building energy modeling community. The SketchUp Plug-in is an extension to Trimble's popular SketchUp 3D modeling tool that allows users to quickly create geometry needed for EnergyPlus. Additionally, OpenStudio supports import of gbXML and IFC for geometry creation. The OpenStudio Application is a fully featured graphical interface to OpenStudio models including envelope, loads, schedules, and HVAC. ResultsViewer enables browsing, plotting, and comparing simulation output data, especially time series. The Parametric Analysis Tool enables studying the impact of applying multiple combinations of OpenStudio Measures to a base model as well as export of the analysis results for EDAPT submission.

<https://openstudio.net/>

OpenStudio



OpenStudio

- We will create the model in a few different ways:
 - OpenStudio Application
 - Rhino + Grasshopper + LBT
 - SketchUp + OpenStudio
 - Application Programming Interface (API)

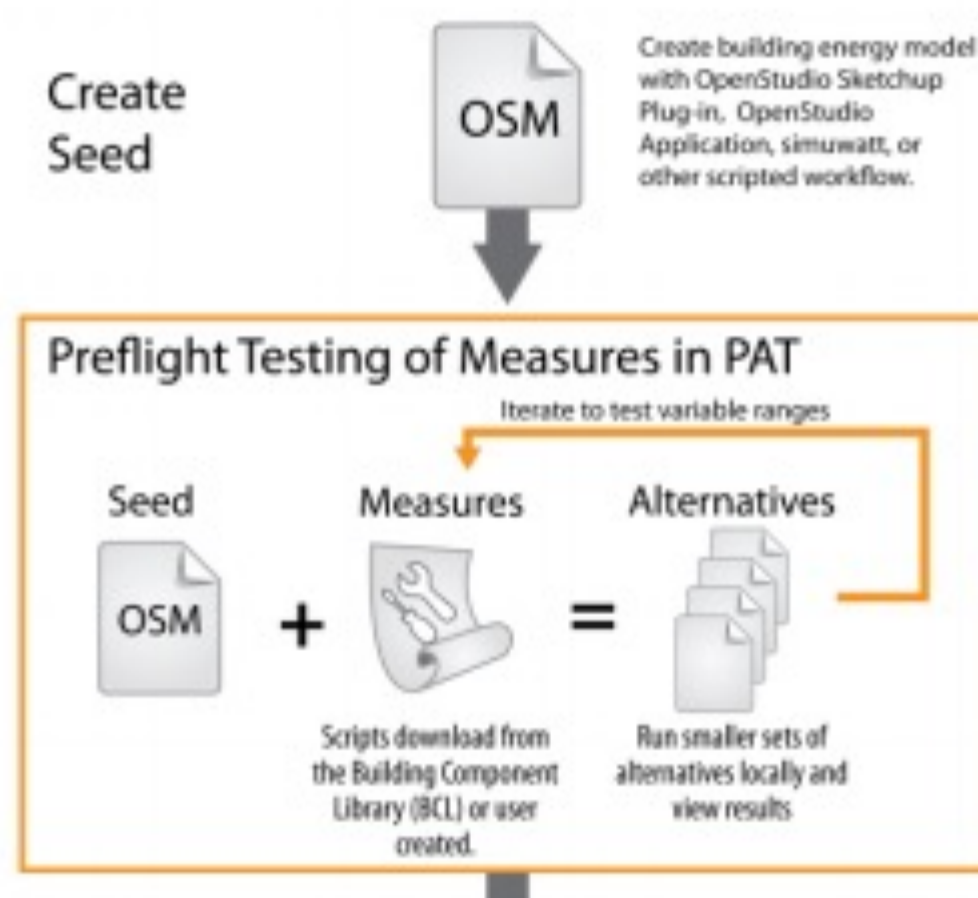
OPENSTUDIO INSTALLATION

OpenStudio Installation

- OpenStudio Page: <https://nrel.github.io/OpenStudio-user-documentation/>
- OpenStudio videos (The SketchUP part now is using FloorSpaceJS):
<https://www.youtube.com/user/NRELOpenStudio/videos?flow=grid&sort=dd&view=0>
- See existing questions or ask questions on unmethours:
<https://unmethours.com/questions/>

OpenStudio Installation

- Parametric Analysis Tool (PAT) allows installing different measures



OpenStudio Installation



OpenStudio Coalition User Docs

About ▾

Getting Started ▾

Tutorials ▾

Reference ▾

Organization

Organization Resources

For More Information:

- For releases of the OpenStudio Application and the OpenStudio SketchUp Plug-in:

OpenStudio Application

SketchUp Plug-in

- For information about OpenStudio Measures and the OpenStudio SDK:

OpenStudio Project

- For community support, to post a question, or to search for answers to your energy modeling questions:

Unmet Hours

Introducing the OpenStudio Coalition

The OpenStudio Coalition is a newly formed organization founded to support the OpenStudio Application and to expand the use of energy modeling generally using the free and open source OpenStudio Application. The goals of the OpenStudio Coalition (OSC) include:

- **Keeping the OpenStudio Application Free and Readily Available:** Free to individual user energy modeling tools have been around for a long time, most notably eQUEST. These tools have made it easier to learn energy modeling and for energy models to be used in various publicly funded activities such as energy efficiency programs. A free and open version of the OpenStudio Application will help the EnergyPlus engine be adopted in these contexts. Similar to the OpenStudio Application, many energy modeling tools, including eQUEST, got their start with public funding and then transitioned to other forms of support.
- **Keeping OpenStudio Application Current and Functional:** As the OpenStudio SDK evolves, OSC will coordinate investments in the OpenStudio application to maintain the ability to work interchangeably in both environments. The OpenStudio Application is an important debugging tool for application developers and for those that need to evaluate the results from tools that use the OpenStudio SDK, such as energy program evaluators and model reviewers.
- **Supporting OpenStudio Application Use:** The energy modeling community benefits from access to a free and functional tool for new users of energy modeling tools. The Coalition plans to actively promote the use of the OpenStudio Application to potential energy modelers with the goal of expanding understanding of building performance and increasing the use of energy modeling. It is the intent of this effort to expand both the supply of energy modelers and the demand for energy modeling tools in general, not just for the OpenStudio Application.

Organization

The OpenStudio Coalition is managed by volunteers from the founding organizations, The Energy Coalition (TEC), Vermont Energy Investment Corporation (VEIC) and Performance Systems Development (PSD). These organizations have worked together over the past several years, supporting development of and using the OpenStudio/EnergyPlus framework and have now formed this new organization to help support the OpenStudio Application and the expansion of the value and adoption of energy modeling. These organizations have been joined by expert developers who can help support the continued evolution of the OpenStudio Application.

It is the intent of the founding members to seek external funding to support the goals of the organization. The primary focus of initial funding will be to fund incremental development of the OpenStudio application.

https://openstudiocoalition.org/about/openstudio_coalition/

OpenStudio Installation

- Model creation using FloorSpaceJS:

Floorspace.js

Q Search

FloorspaceJS

Getting Started

Drawing Spaces

Assignments

Components



FloorspaceJS is a 2D geometry editor. Users can define an explicit floor plan for each story of a building. A story-by-story interface makes it easy to develop space geometry and assign properties. Referencing satellite imagery or floor plan images, when available, speeds up geometry entry. Conversion of 2D to 3D geometry is currently out of scope for FloorspaceJS, a reference implementation is available in the [OpenStudio SDK](#).

Explicit floor plans allow more building-specific information than parameterized shoe-boxes but less information than a full 3D BIM model. Sloped walls, complex roofs, detailed shading structures, and other complex 3D structures are out of FloorspaceJS's scope. In general, if users have a 3D BIM model in a tool that can export a useful BEM representation then it is better to use that export than to recreate a new model using FloorspaceJS.

Re-usability and minimal dependencies were key design considerations for software developers. Web technologies can be used in both online and desktop applications. The editor was written in pure JavaScript for maximum portability and re-usability. A custom JavaScript Object Notation (JSON) file format was developed to ease integration with other applications. Custom JSON schema design was a key part of FloorspaceJS development.

A [paper](#) with more information about FloorspaceJS will be published in the proceedings of [SimAUD 2018](#).









Getting Started

After loading FloorspaceJS, you will be prompted to create a new floorplan file, create a new floorplan file with a map background, or open an existing floorplan file. In this example we will choose to use the map background for reference.

<https://nrel.github.io/floorspace.js/docs/>

OpenStudio Installation

- Download Version 1.6.0 from this link (If you have the new version, that's fine, but you cannot use your model in the computer lab) :

 OpenStudioApplication-1.4.0+e0fb8f854d-macOS10.14-x86_64.dmg	460 MB	Jun 08, 2022
 OpenStudioApplication-1.4.0+e0fb8f854d-macOS12.1-arm64.dmg	444 MB	Jun 08, 2022
 OpenStudioApplication-1.4.0+e0fb8f854d-Ubuntu20.04.deb	429 MB	Jun 08, 2022
 OpenStudioApplication-1.4.0+e0fb8f854d-Ubuntu20.04.tar.gz	429 MB	Jun 08, 2022
 OpenStudioApplication-1.4.0+e0fb8f854d-Windows.exe	261 MB	Jun 08, 2022
 OpenStudioApplication-1.4.0+e0fb8f854d-Windows.zip	347 MB	Jun 08, 2022
 Source code (zip)		Jun 08, 2022
 Source code (tar.gz)		Jun 08, 2022

<https://github.com/openstudiocoalition/OpenStudioApplication/releases/tag/v1.6.0>

OpenStudio Installation

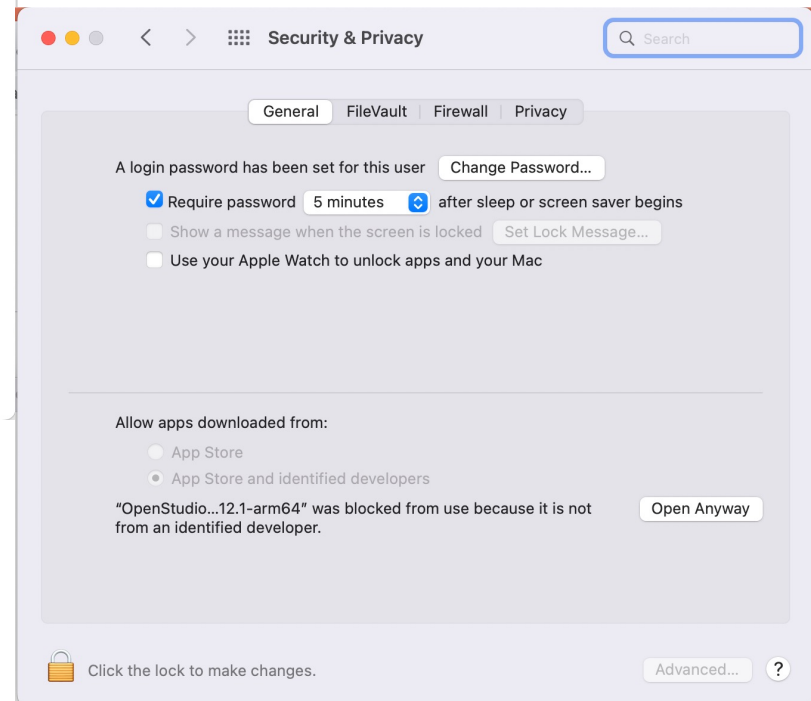
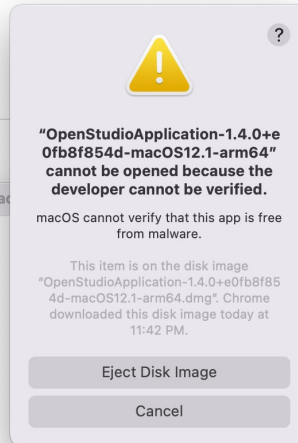
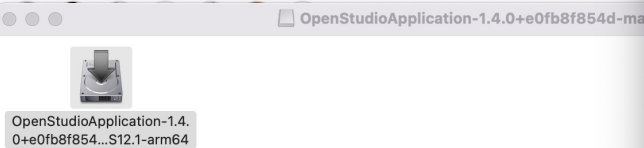
- In case you are using Mac, you might see this message when you click on the installer:

Total Open Issues: 131

Total Open Pull Requests: 3

▶ Click to see details

Contributors



OpenStudio Installation

- Download weather data files

- ❑ Download files from:

1. EnergyPlus: <https://energyplus.net/weather>

2. One Building:

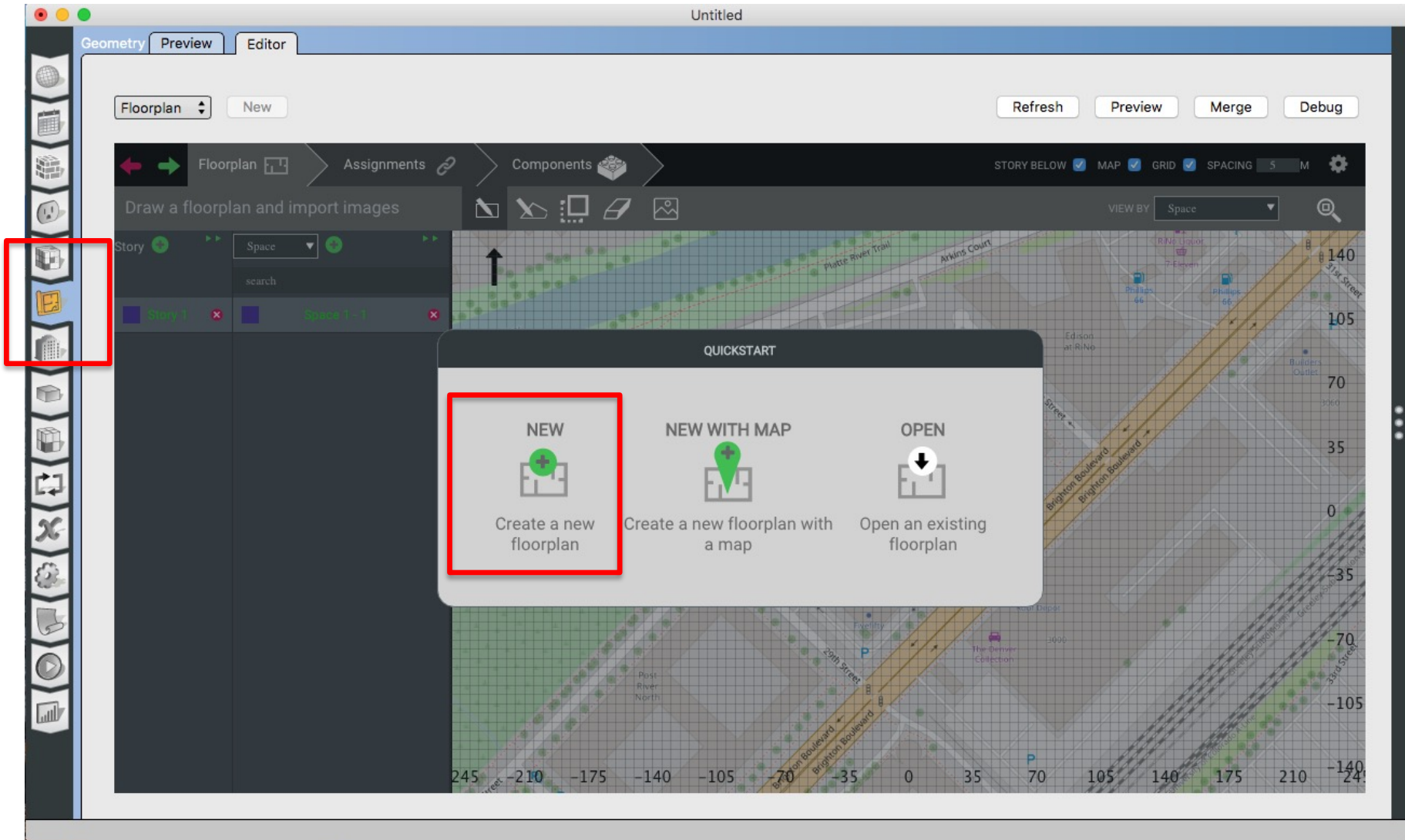
- http://climate.onebuilding.org/WMO_Region_4_North_and_Central_America/USA_United_States_of_America/index.html

3. Ladybug Tools: <https://www.ladybug.tools/epwmap/>

CREATE GEOMETRY

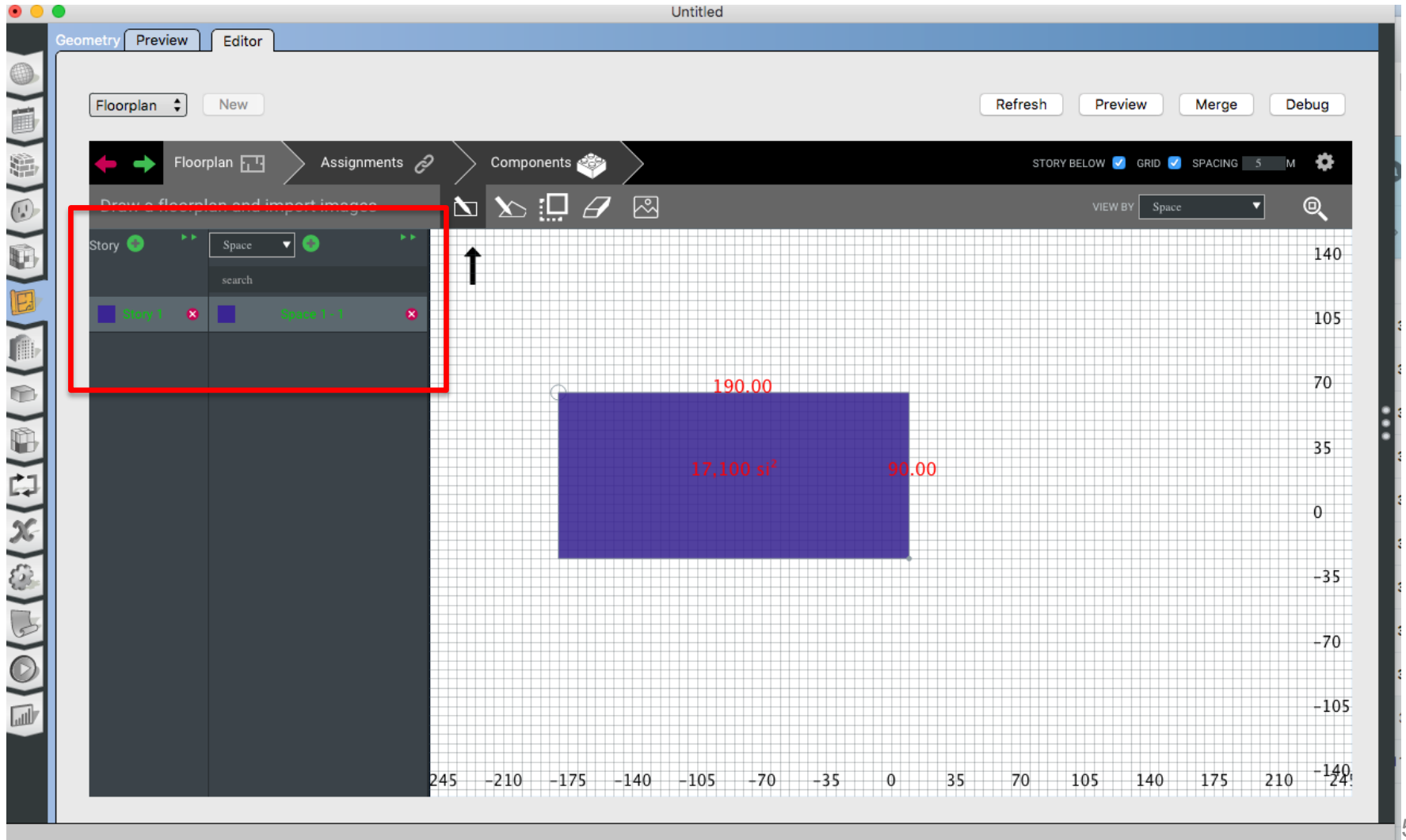
OpenStudio Training

- Step 1: Create or Import Floor Plan



OpenStudio Training

- Step 2: Add Spaces and Stories



OpenStudio Training

- Step 3: Add the height

The screenshot displays the OpenStudio interface. At the top, there are tabs for 'Geometry', 'Preview', and 'Editor'. Below these, a toolbar includes 'Floorplan', 'New', 'Refresh', 'Preview', 'Merge', and 'Debug'. The main workspace is divided into several sections: 'Draw a floorplan and import images', 'Assignments', and 'Components'. A red box highlights the 'Draw a floorplan and import images' section. Below this, a table lists the properties for 'Space 1 - 1' on 'Story 1'. A second red box highlights the 'Below Floor Plenum Height', 'Floor to Ceiling Height', and 'Above Ceiling Plenum Height' columns, which are currently set to 0. Below the table is a 2D floor plan view showing a blue rectangular space on a grid. The grid has x-axis labels from -285 to 135 and y-axis labels from -30 to 60. The space 'Space 1 - 1' is located between x = -180 and x = 30, and between y = 0 and y = 60.

Name	Story	Building Unit	Thermal Zone	Space Type	Construction Set	Below Floor Plenum Height	Floor to Ceiling Height	Above Ceiling Plenum Height	Floor Offset
Space 1 - 1	Story 1	(none)	(none)	(none)	(none)	0	0	0	0

OpenStudio Training

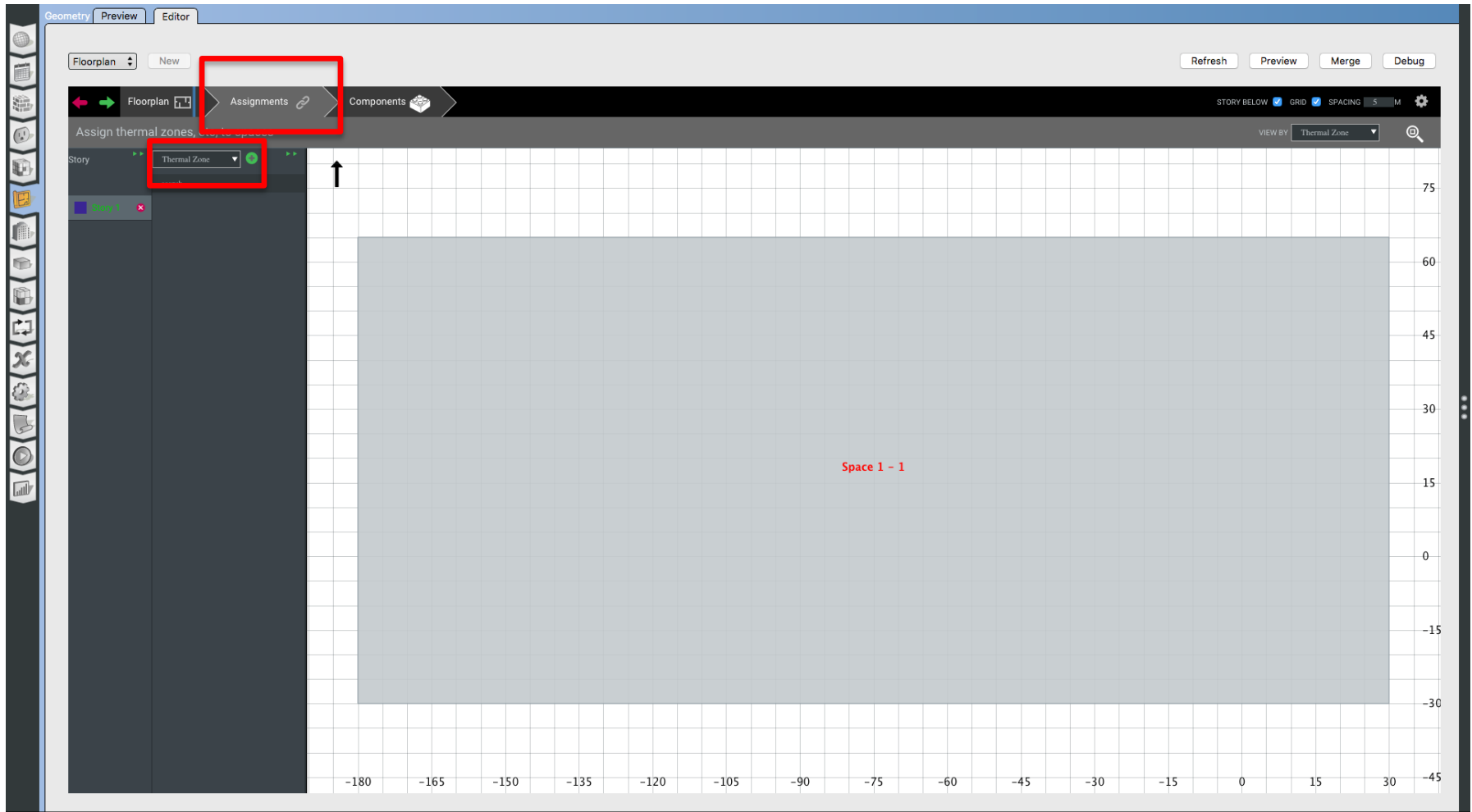
- Step 3: Add the height

The screenshot displays the OpenStudio software interface in the 'Floorplan' editor. The top toolbar includes a 'Space' dropdown menu, which is highlighted with a red box. Below the toolbar, the properties panel for the selected space is visible. The 'Height' property is highlighted with a red box and is set to 3. The bottom view shows a 2D grid with a blue rectangular area labeled 'Space 1 - 1'.

Property	Value
Building Unit	(none)
Thermal Zone	(none)
Space Type	(none)
Construction Set	(none)
Below Floor Plenum Height	0
Floor to Ceiling Height	3
Above Ceiling Plenum Height	0
Floor Offset	0
Open To Below	False
ID	#132288

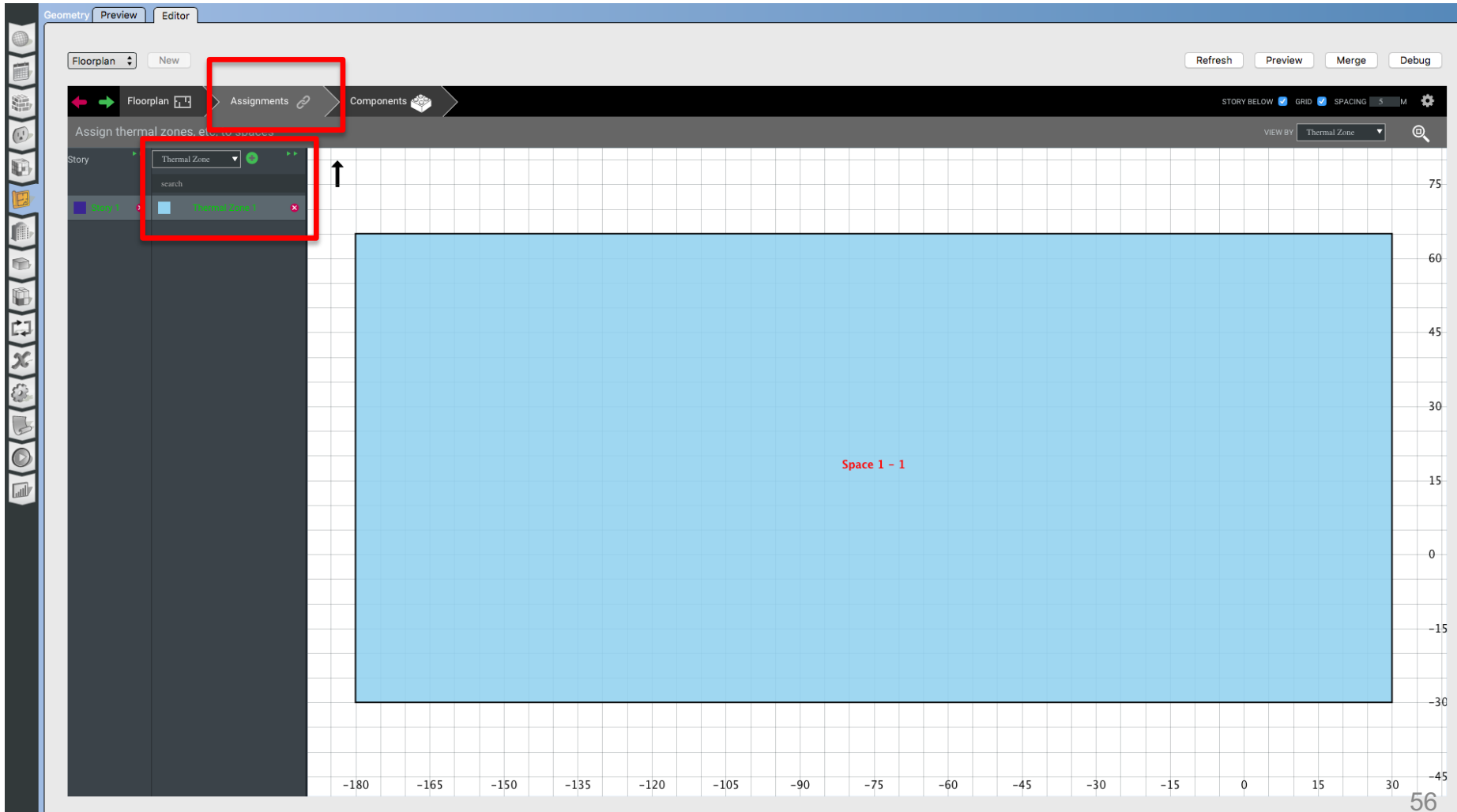
OpenStudio Training

- Step 4: Add Thermal Zone(s)



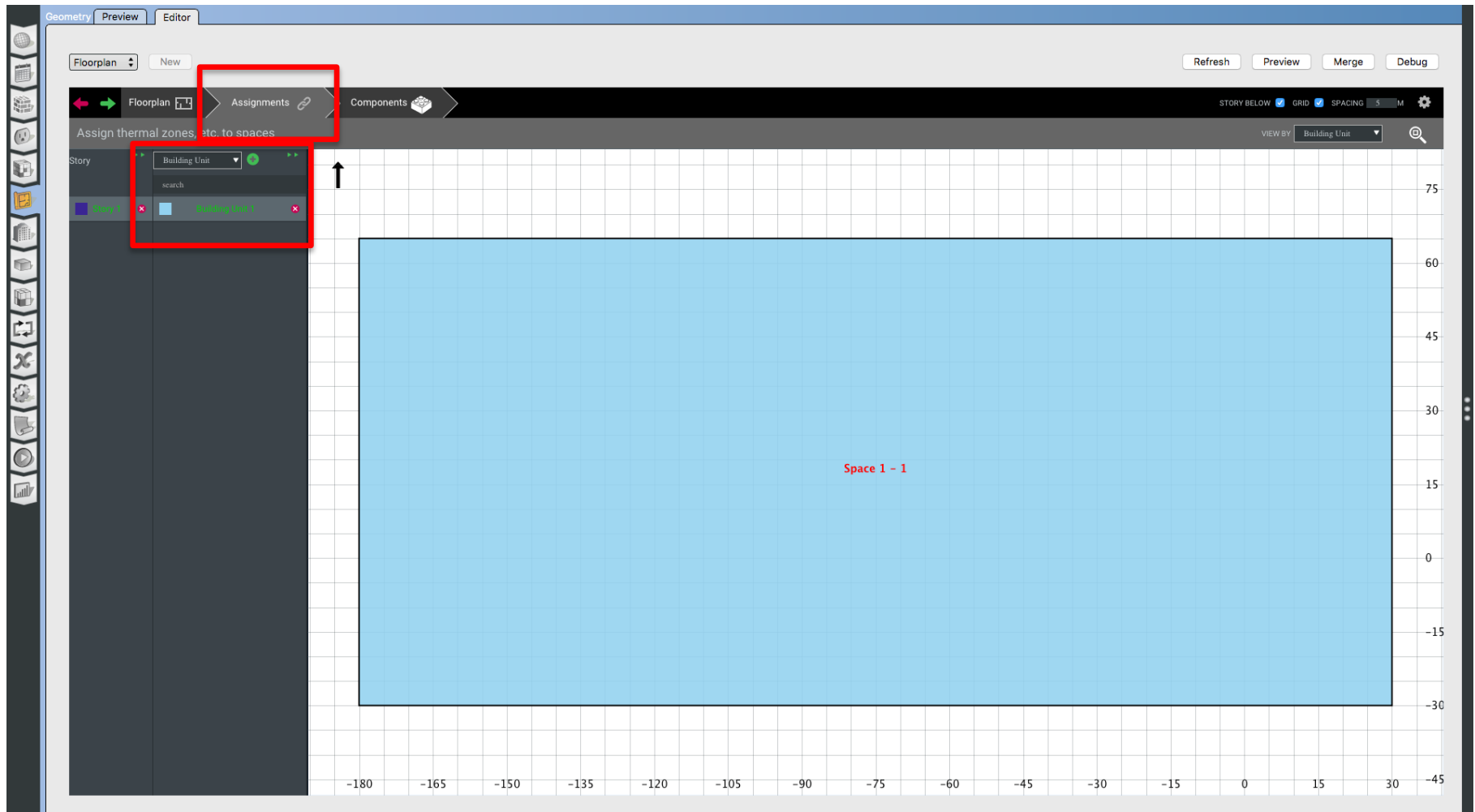
OpenStudio Training

- Step 4: Add Thermal Zone(s)



OpenStudio Training

- Step 5: Add Building Unit



OpenStudio Training

- Step 6: Add Windows (WWR or Individual)

The screenshot displays the OpenStudio software interface. At the top, there are tabs for 'Geometry', 'Preview', and 'Editor'. Below these, a 'Floorplan' dropdown menu is visible. The main workspace is divided into several sections. On the left, there is a vertical toolbar with various icons. The central area shows a 'Click to place a Window' prompt. Below this, a 'Story' dropdown menu is set to 'Window'. A red box highlights the 'Components' menu item in the top navigation bar. Another red box highlights the 'Window' dropdown menu. Below the 'Story' dropdown, a table lists window properties for 'Window 1'. A red box highlights the 'Window to Wall Ratio' dropdown menu and its corresponding value of '0.4'. The table has the following columns: Name, Mode, Window to Wall ratio, Height, Width, Sill Height, Spacing, Window Type, Overhang Projection Factor, and Fin Projection Factor. The 'Window to Wall ratio' column contains the value '0.4'. The 'Sill Height' column contains the value '0.9144000000000000'. The 'Window Type' column contains the value 'Fixed'. The 'Overhang Projection Factor' and 'Fin Projection Factor' columns contain the value '(none)'. At the bottom of the interface, there is a grid with a blue rectangular window placed on it. The grid has x-axis labels from -285 to 135 and y-axis labels from -30 to 60.

Name	Mode	Window to Wall ratio	Height	Width	Sill Height	Spacing	Window Type	Overhang Projection Factor	Fin Projection Factor
Window 1	Window to Wall Ratio	0.4	{none}	{none}	0.9144000000000000	{none}	Fixed	{none}	{none}

OpenStudio Training

- Step 7: Merge & Preview

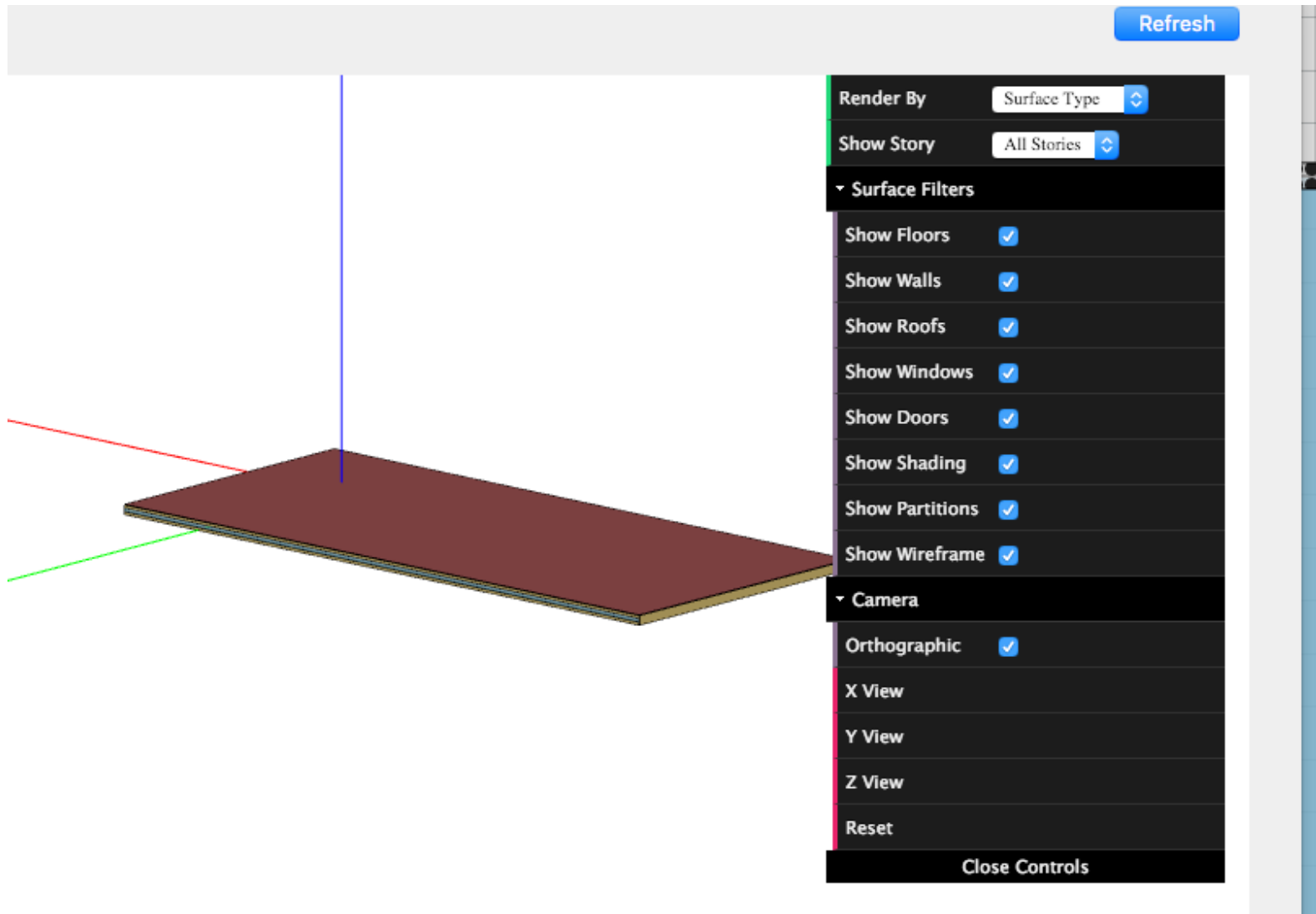
The screenshot displays the OpenStudio software interface. At the top, there are tabs for 'Geometry', 'Preview', and 'Editor'. Below these, a toolbar contains buttons for 'Floorplan', 'New', 'Refresh', 'Preview', 'Merge', and 'Debug'. The 'Merge' button is highlighted with a red rectangular box. The main workspace is divided into a top section for placing a window and a bottom section for a grid-based view. The top section includes a search bar and a table of window properties.

Name	Mode	Window to Wall ratio	Height	Width	Sill Height	Spacing	Window Type	Overhang Projection Factor	Fin Projection Factor
Window 1	Window to Wall Ratio	0.4	{none}	{none}	0.9144000000000000	{none}	Fixed	{none}	{none}

The bottom section shows a grid with a blue rectangular window placed on it. The grid axes are labeled with numerical values: the horizontal axis ranges from -285 to 135, and the vertical axis ranges from -30 to 60.

OpenStudio Training

- Step 7: Merge & Preview



**ADD DEFAULT VALUES TO TEST THE
MODEL**

OpenStudio Training

- Step 8: Add Default Values

The screenshot displays the OpenStudio software interface. The main window is titled 'Building' and contains several configuration sections:

- Name:** A text field containing 'Building 1'.
- Measure Tags (Optional):**
 - Standards Building Type:** A dropdown menu.
 - Relocatable:** A toggle switch set to 'false'.
 - Nominal Floor to Ceiling Height:** A text field with 'm' as a unit.
 - Nominal Floor to Floor Height:** A text field with 'm' as a unit.
 - Standards Number of Stories:** A text field.
 - Standards Number of Above Ground Stories:** A text field.
 - Standards Number of Living Units:** A text field.
- North Axis:** A text field containing '0.000000' with 'deg' as a unit.
- Space Type:** A dashed box containing the text 'Drag From Library'.
- Default Construction Set:** A dashed box containing the text 'Drag From Library'.
- Default Schedule Set:** A dashed box containing the text 'Drag From Library'.

The right sidebar is titled 'My Mode' and has a 'Library' tab selected. The sidebar contains several sections, with 'Construction Sets' highlighted by a red box. The 'Construction Sets' section lists several office space types:

- 189.1-2009 - C21 - Office
- 189.1-2009 - C22 - Office
- 189.1-2009 - C23 - Office
- 189.1-2009 - C24 - Office
- 189.1-2009 - C25 - Office
- 189.1-2009 - C26 - Office
- 189.1-2009 - C27-8 - Office

Other sections in the sidebar include 'Schedule Sets', 'Design Specification Outdoor Air', 'Space Infiltration Effective Leakage Areas', 'Space Infiltration Design Flow Rates', 'People Definitions', 'Lights Definitions', 'Luminaire Definitions', 'Electric Equipment Definitions', 'Gas Equipment Definitions', and 'Water Use Equipment Definitions'.

OpenStudio Training

- Step 8: Add Default Values

The screenshot displays the OpenStudio software interface. The main window is titled 'Facility' and has tabs for 'Building', 'Stories', 'Shading', and 'Exterior Equipment'. The 'Building' tab is active, showing a 'Name' field with 'Building 1'. Below this are sections for 'Measure Tags (Optional)', 'North Axis', 'Default Construction Set', and 'Default Schedule Set'. The 'North Axis' field is set to '0.000000 deg'. The 'Default Construction Set' and 'Default Schedule Set' sections each contain a 'Drag From Library' button. A red box highlights the 'Space Type' section, which also contains a 'Drag From Library' button. On the right side, there is a 'Space Types' panel with a list of space types, including '189.1-2009 - Office - BreakRoom - CZ1-3', '189.1-2009 - Office - BreakRoom - CZ4-8', '189.1-2009 - Office - ClosedOffice - CZ1-3', '189.1-2009 - Office - ClosedOffice - CZ4-8', '189.1-2009 - Office - Conference - CZ1-3', '189.1-2009 - Office - Conference - CZ4-8', '189.1-2009 - Office - Corridor - CZ1-3', '189.1-2009 - Office - Corridor - CZ4-8', '189.1-2009 - Office - Elec/MechRoom - CZ1-3', '189.1-2009 - Office - Elec/MechRoom - CZ4-8', '189.1-2009 - Office - IT_Room - CZ1-3', '189.1-2009 - Office - IT_Room - CZ4-8', '189.1-2009 - Office - Lobby - CZ1-3', '189.1-2009 - Office - Lobby - CZ4-8', '189.1-2009 - Office - OpenOffice - CZ1-3', and '189.1-2009 - Office - OpenOffice - CZ4-8'. A red box highlights the top of this panel, specifically the 'Space Types' header and the first two items.

OpenStudio Training

- Step 8: Add Default Values

The screenshot displays the OpenStudio software interface, specifically the 'Building' tab. The main workspace shows configuration options for a building named 'Building 1'. The 'Name' field is set to 'Building 1'. Under 'Measure Tags (Optional)', the 'Standards Building Type' is set to a dropdown menu, and the 'Relocatable' checkbox is checked. The 'Nominal Floor to Ceiling Height' and 'Nominal Floor to Floor Height' are both set to 0 m. The 'Standards Number of Stories' and 'Standards Number of Above Ground Stories' are both set to 0. The 'Standards Number of Living Units' is set to 0. The 'North Axis' is set to 0.000000 deg. The 'Space Type' is set to 'Office - ClosedOffi'. The 'Default Construction Set' is set to '189.1-200 - CZ2 - Office'. The 'Default Schedule Set' is set to '189.1-2009 - Office - BreakRoom - CZ1-3 Schedule Set'. A red box highlights the 'Space Type' and 'Default Construction Set' fields. Another red box highlights the 'Default Schedule Set' field. A third red box highlights the 'Schedule Sets' library on the right side of the interface, which contains a list of schedule sets, including '189.1-2009 - Office - BreakRoom - CZ1-3 Schedule Set' and '189.1-2009 - Office - BreakRoom - CZ4-8 Schedule Set'.

TEST MODEL WITH IDEAL AIR LOOP

OpenStudio Training

- Step 9: Run Ideal Air Loop

The screenshot shows the OpenStudio interface for configuring Thermal Zones. The main window is titled 'Thermal Zones' and contains a table with the following columns: Name, All, Turn On Ideal Air Loads, Air Loop Name, Zone Equipment, Cooling Thermostat Schedule, Heating Thermostat Schedule, Humidifying Setpoint Schedule, Dehumidifying Setpoint Schedule, and Multiplier. The 'All' column has a checked checkbox for 'Thermal Zone 1'. The 'Turn On Ideal Air Loads' column has an unchecked checkbox. The 'Air Loop Name' column has a dropdown menu set to 'None'. The 'Multiplier' column has a text input field set to '1'. A red box highlights the 'All' column checkboxes. Another red box highlights the 'Run Ideal Air Loop' icon in the left sidebar.

Name	All	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule	Dehumidifying Setpoint Schedule	Multiplier
Thermal Zone 1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	None	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	1

Right sidebar menu items:

- Schedule Rulesets
- Compact Schedules
- Zone Ventilation Design Flow Rate
- Unit Ventilator
- Unit Heater
- High Temp Radiant
- Low Temp Radiant Electric
- Low Temp Radiant Variable Flow
- Low Temp Radiant Constant Flow
- PTAC
- Water To Air HP
- PTHP
- Water Heater - Heat Pump - Wrapped Condenser
- Water Heater - Heat Pump
- Fan Zone Exhaust
- Four Pipe Fan Coil
- ERV
- Dehumidifier - DX
- Baseboard Radiant Convective Water
- Baseboard Radiant Convective Electric
- Baseboard Convective Water

ADD WEATHER DATA

OpenStudio Training

- Step 10: Add Weather Data Files

Weather File

Name: Chicago O'hare Intl Ap
 Latitude: 41.98
 Longitude: -87.92
 Elevation: 201
 Time Zone: -6
 Download weather files at www.energyplus.net/weather

Measure Tags (Optional):

ASHRAE Climate Zone
 CEC Climate Zone

Design Days

Design Days

Date Temperature Humidity Pressure Wind Precipitation Solar Custom

Design Day Name	All	Day Of Month	Month	Day Type	Daylight Savings
Chicago O'hare Intl Ap Ann Clg .4% Condns DB=>MWB	<input type="checkbox"/>	21	7	SummerDesignDay	
Chicago O'hare Intl Ap Ann Clg .4% Condns DP=>MDB	<input type="checkbox"/>	21	7	SummerDesignDay	
Chicago O'hare Intl Ap Ann Clg .4% Condns Enth=>MDB	<input type="checkbox"/>	21	7	SummerDesignDay	
Chicago O'hare Intl Ap Ann Clg .4% Condns WB=>MDB	<input type="checkbox"/>	21	7	SummerDesignDay	
Chicago O'hare Intl Ap Ann Htg 99.6% Condns DB	<input type="checkbox"/>	21	1	WinterDesignDay	
Chicago O'hare Intl Ap Ann Htg Wind 99.6% Condns WS=>MCDB	<input type="checkbox"/>	21	1	WinterDesignDay	
Chicago O'hare Intl Ap Ann Hum_n 99.6% Condns DP=>MCDB	<input type="checkbox"/>	21	1	WinterDesignDay	

Select Year by:

Calendar Year 2000
 First Day of Year Sunday

Daylight Savings Time: off

Starts

Define by Day of The Week And Month First Sunday January
 Define by Date 4/1/09

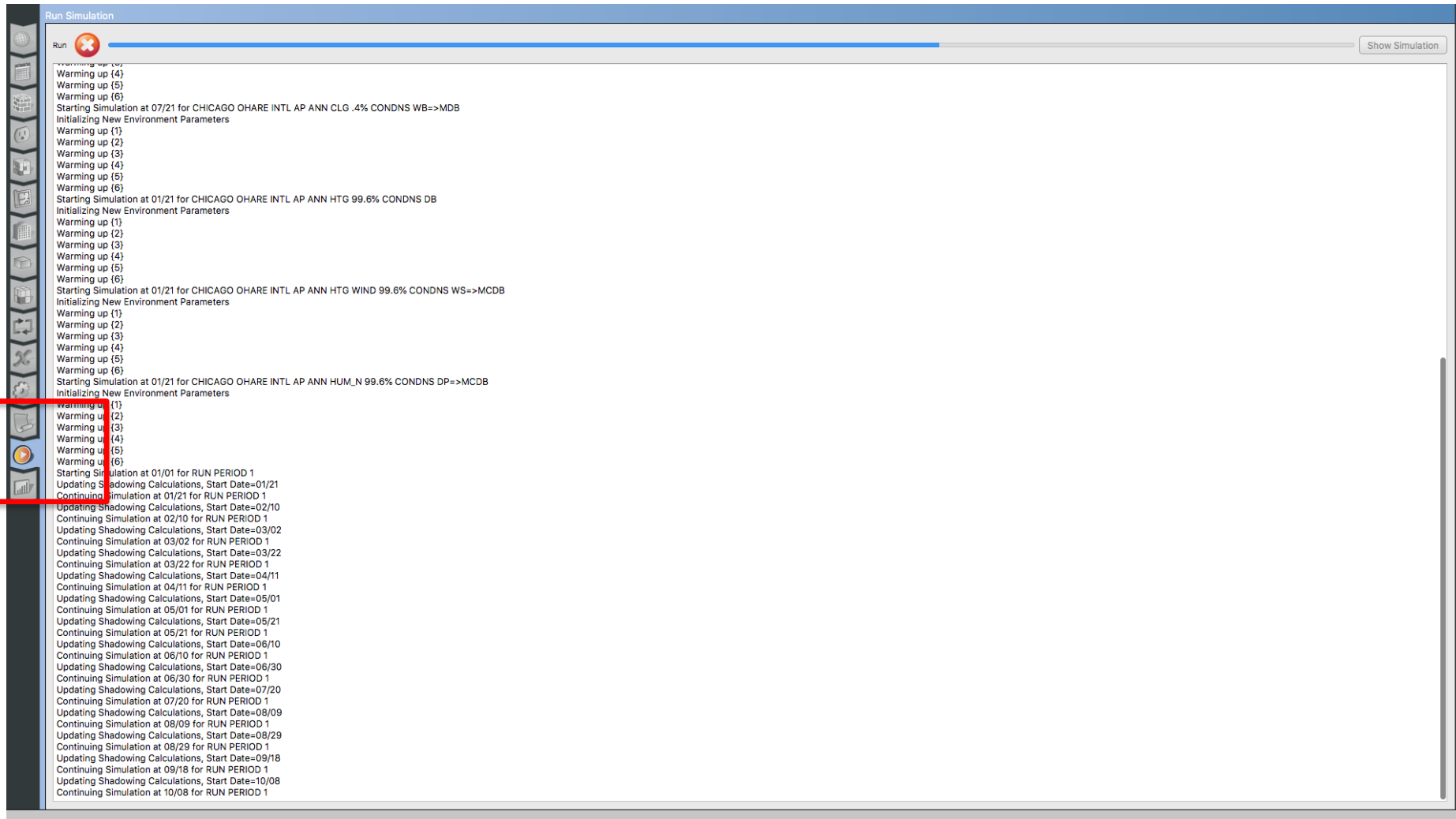
Ends

Define by Day of The Week And Month First Sunday January
 Define by Date 10/1/09

RUN MODEL

OpenStudio Training

- Step 11: Run the Model



VISIT RESULTS

OpenStudio Training

- Step 12: Visualize the Results

The screenshot displays the OpenStudio Results interface. On the left is a vertical navigation sidebar with various report categories. The main content area is titled "OpenStudio Results" and "Model Summary". It features three sub-sections: "Building Summary", "Weather Summary", and "Sizing Period Design Days".

Reports: OpenStudio Results Refresh Open DView for Detailed Reports

Model Summary

- Annual Overview
- Monthly Overview
- Utility Bills/Rates
- Envelope Summary
- Space Type Breakdown
- Space Type Summary
- Interior Lighting Summary
- Plug Loads Summary
- Exterior Lighting
- Water Use Equipment
- HVAC Load Profiles
- Zone Conditions
- Zone Overview
- Zone Equipment Detail
- Air Loops Detail
- Plant Loops Detail
- Outdoor Air
- Cash Flow
- Site and Source Summary
- Schedule Overview

Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	4,560,744 kBtu
Total Building Area	214,740 ft^2
Total Site EUI	21.24 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Weather Summary

	Value
Weather File	Chicago Ohare Intl Ap IL USA TMY3 WMO#=725300
Latitude	41.98
Longitude	-87.9
Elevation	659 (ft)
Time Zone	-6.0
North Axis Angle	0.00
ASHRAE Climate Zone	

Sizing Period Design Days

	Maximum Dry Bulb (F)	Daily Temperature Range (R)	Humidity Value	Humidity Type	Wind Speed (mph)	Wind Direction

TEST A ZONE LEVEL HVAC SYSTEM

OpenStudio Training

- Step 13: Add PTHP

The screenshot displays the 'Thermal Zones' interface in OpenStudio. The main window shows a table for 'Thermal Zone 1' with columns for Name, All, Turn On Ideal Air Loads, Air Loop Name, Zone Equipment, Cooling Thermostat Schedule, Heating Thermostat Schedule, Humidifying Setpoint Schedule, Dehumidifying Setpoint Schedule, and Multiplier. A red box highlights the 'Zone Equipment' column, which contains a dashed box and an 'Apply to Selected' button. On the right side, a vertical sidebar lists various HVAC equipment types. A red box highlights the 'PTHP' (Packaged Terminal Heat Pump) option in this list. Another red box highlights the 'Library' tab in the top right corner of the sidebar. The bottom left corner shows the standard Windows taskbar with icons for OpenStudio, a folder, and a terminal.

Name	All	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule	Dehumidifying Setpoint Schedule	Multiplier
Thermal Zone 1	<input type="checkbox"/>	<input type="checkbox"/>	None	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	1

OpenStudio Training

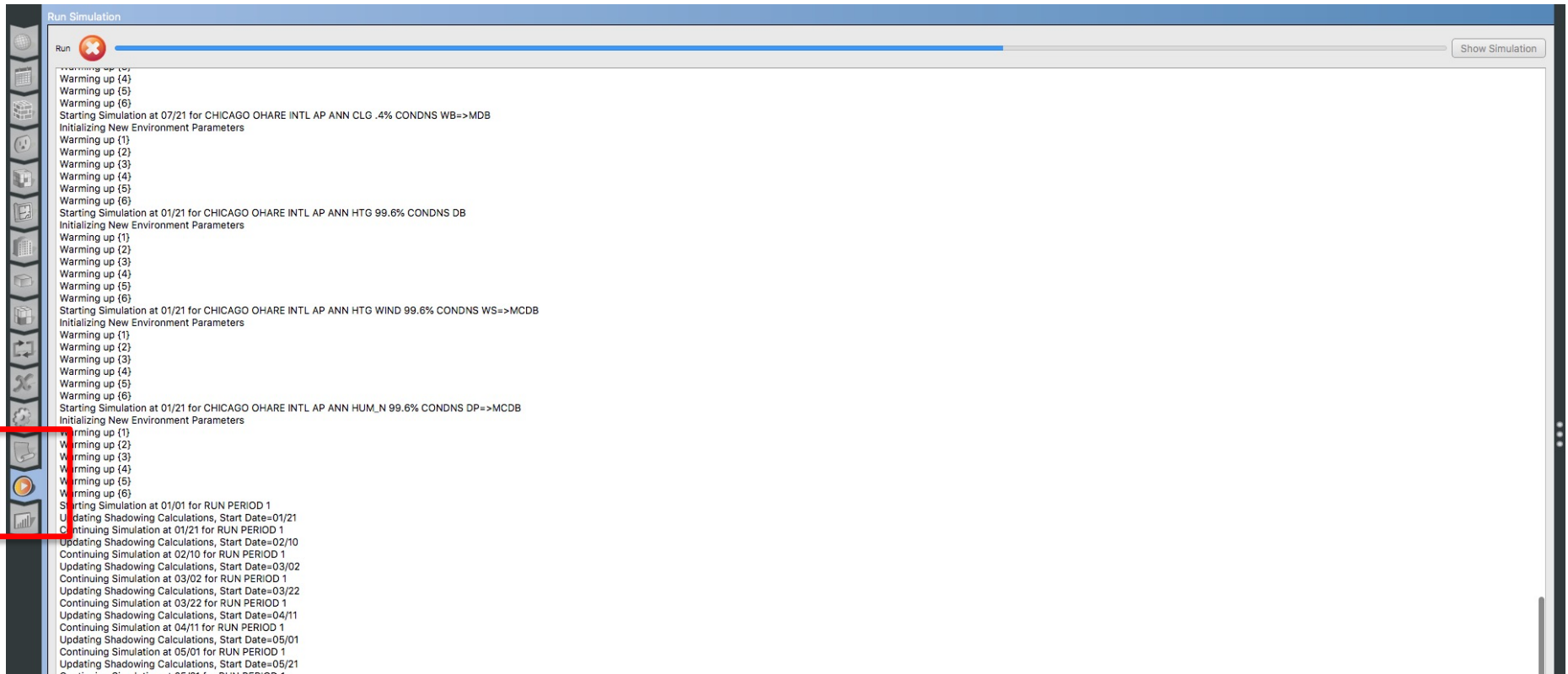
- Step 13: Add heating and cooling setpoints

The screenshot displays the 'Thermal Zones' configuration window in OpenStudio. The interface is divided into several sections:

- Top Bar:** 'Thermal Zones' title and tabs for 'My Model', 'Library', and 'Edit'.
- Configuration Tabs:** 'HVAC Systems', 'Cooling Sizing Parameters', 'Heating Sizing Parameters', and 'Custom'.
- Main Table:** A table with columns for Name, All, Turn On Ideal Air Loads, Air Loop Name, Zone Equipment, Cooling Thermostat Schedule, Heating Thermostat Schedule, Humidifying Setpoint Schedule, Dehumidifying Setpoint Schedule, and Multiplier. The row for 'Thermal Zone 1' shows 'None' for Air Loop Name, 'PTHP' for Zone Equipment, and 'Large Office ClgSetp' and 'Large Office HtgSetp' for the thermostat schedules. Red boxes highlight these two columns.
- Right Sidebar:** A list of components including 'HPWH Setpoint', 'HPWH Stratified - Wrapped Cond - Amb Temp', 'HPWH Stratified - Wrapped Cond - Heater 1 Setpoint', 'HPWH Stratified - Wrapped Cond - Heater 2 Setpoint', 'Inlet Air Humidity', 'Inlet Air Mixer Fraction', 'Inlet Air Temp', 'Large Office Activity', 'Large Office Bldg Equip', 'Large Office Bldg Light', 'Large Office Bldg Occ', 'Large Office ClgSetp', 'Large Office HtgSetp', 'Large Office Infil Quarter On', and 'Load Profile Schedule'. Red boxes highlight 'HPWH Setpoint' at the top and 'Large Office ClgSetp' and 'Large Office HtgSetp' at the bottom.

OpenStudio Training

- Step 14: Run the Model



TEST A LOOP HVAC SYSTEM

OpenStudio Training

- Step 15: Add System #5

The screenshot displays the OpenStudio interface during the process of adding a new HVAC system. The main workspace shows a schematic diagram of a service hot water system with a boiler and a cooling coil. A dialog box titled "Add HVAC System" is open, listing three options:

- Packaged Rooftop Unit
- Packaged Rooftop Heat Pump
- Packaged DX Rooftop VAV with Reheat

The "Packaged DX Rooftop VAV with Reheat" option is highlighted with a red box. The left sidebar contains a vertical toolbar with various icons, and the top right corner shows a "My Model" tab and a list of available HVAC components.

My Model	Library	Edit
Availability Manager Hybrid Ventilation		
Availability Manager Night Ventilation		
Availability Manager Night Cycle		
Availability Manager Optimum Start		
Availability Manager Differential Thermostat		
Availability Manager High Temperature Turn Off		
Availability Manager High Temperature Turn On		
Availability Manager Low Temperature Turn Off		
Availability Manager Low Temperature Turn On		
Availability Manager Scheduled Off		
Availability Manager Scheduled On		
Availability Manager Scheduled		
AirLoopHVAC Unitary VAV Changeover Bypass		
AirLoopHVAC Unitary System		
AirLoopHVAC Outdoor Air System		
Air Terminal Dual Duct VAV Outdoor Air		
Air Terminal Dual Duct VAV		
Air Terminal Dual Duct Constant Volume		
AirTerminal Single Duct Uncontrolled		
AirTerminal Single Duct VAV NoReheat		
AirTerminal Heat and Cool No		

OpenStudio Training

- Step 15: Add System #5

The screenshot displays the OpenStudio HVAC Systems interface. At the top, a search bar is highlighted with a red box, containing the following list of components:

- ✓ Packaged Rooftop VAV with Reheat
- Hot Water Loop
- Service Hot Water
- Refrigeration
- VRF

The main workspace shows a schematic diagram of an HVAC system. The diagram is divided into two sections by a horizontal dashed line: "Supply Equipment" (top) and "Demand Equipment" (bottom). The supply side includes a fan, a coil, and a control valve. The demand side includes a coil, a control valve, and a fan. A "Drag From Library" box is visible at the bottom of the diagram.

On the right side, a vertical list of components is shown, including:

- Availability Manager Hybrid Ventilation
- Availability Manager Night Ventilation
- Availability Manager Night Cycle
- Availability Manager Optimum Start
- Availability Manager Differential Thermostat
- Availability Manager High Temperature Turn Off
- Availability Manager High Temperature Turn On
- Availability Manager Low Temperature Turn Off
- Availability Manager Low Temperature Turn On
- Availability Manager Scheduled Off
- Availability Manager Scheduled On
- Availability Manager Scheduled
- AirLoopHVAC Unitary VAV Changeover Bypass
- AirLoopHVAC Unitary System
- AirLoopHVAC Outdoor Air System
- Air Terminal Dual Duct VAV Outdoor Air
- Air Terminal Dual Duct VAV
- Air Terminal Dual Duct Constant Volume
- Air Terminal Single Duct Uncontrolled
- Air Terminal Single Duct VAV NoReheat
- Air Terminal Heat and Cool No

OpenStudio Training

- Step 16: Add a thermal zone to the air loop

The screenshot displays the OpenStudio HVAC Systems interface. The main workspace shows a schematic of a packaged rooftop VAV air loop. The loop includes a supply air terminal, a VAV box, a reheat coil, and a return air terminal. A thermal zone is being added to the air loop, represented by a box labeled "zone" and a "Drag From Library" area. The interface includes a top toolbar with "Layout", "Control", and "Grid" buttons, and a right-hand sidebar with a "Library" tab. The sidebar lists various HVAC components, with "Thermal Zone" highlighted. The title bar indicates the current model is "Packaged Rooftop VAV with Reheat".

HVAC Systems

Layout Control Grid

Packaged Rooftop VAV with Reheat

My Model Library Edit

Year Schedules

Fixed Interval Schedules

Variable Interval Schedules

Chiller - Indirect Absorption

Chiller - Absorption

Chiller - Electric EIR

Central Heat Pump System

Coil Cooling Water

Coil Heating Water

Heat Exchanger Fluid To Fluid

Heat Pump - Water to Water - Cooling

Heat Pump - Water to Water - Heating

Refrigeration Condenser Water Cooled

Refrigeration System

Thermal Storage - Chilled Water

Thermal Zone

Thermal Zone 1

Water Heater Stratified

Water Heater Mixed

Water Use Connections

Supply Equipment

Demand Equipment

zone

Drag From Library

OpenStudio Training

- Step 17: Automatically added to the zone level

The screenshot displays the 'Thermal Zones' configuration window in OpenStudio. The interface includes a top navigation bar with 'My Model', 'Library', and 'Edit' tabs. Below this is a toolbar with various icons. The main area is a table with columns for different HVAC parameters. A red box highlights the 'Zone Equipment' column for 'Thermal Zone 1', which contains the text 'Single Duct VAV Reheat 1'. The 'Air Loop Name' column for this zone is 'Rooftop VAV with Reheat'. The 'Cooling Thermostat Schedule' column is 'Large Office ClgSetp', and the 'Heating Thermostat Schedule' column is 'Large Office HtgSetp'. The 'Multiplier' column is set to '1'. The right sidebar shows a list of HVAC equipment types, including 'PTHP', 'Water Heater - Heat Pump - Wrapped Condenser', 'Water Heater - Heat Pump', 'Fan Zone Exhaust', 'Four Pipe Fan Coil', 'ERV', 'Dehumidifier - DX', 'Baseboard Radiant Convective Water', and 'Baseboard Radiant Convective Electric'.

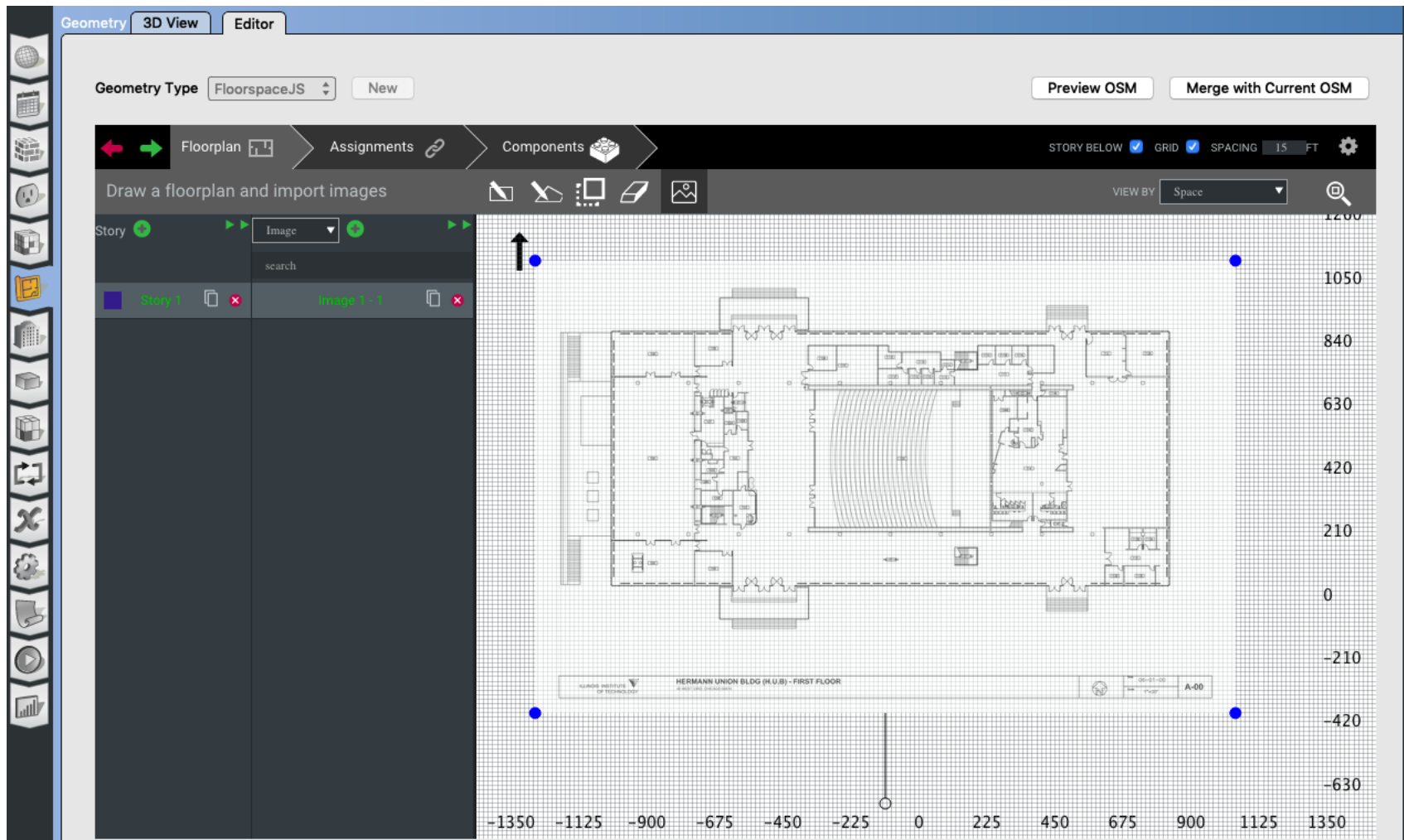
Name	All	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule	Dehumidifying Setpoint Schedule	Multiplier
Thermal Zone 1	<input type="checkbox"/>	<input type="checkbox"/>	Rooftop VAV with Reheat	Single Duct VAV Reheat 1	Large Office ClgSetp	Large Office HtgSetp			1

OPENSTUDIO TRAINING FROM EXISTING MODELS

GEOMETRY EDITOR

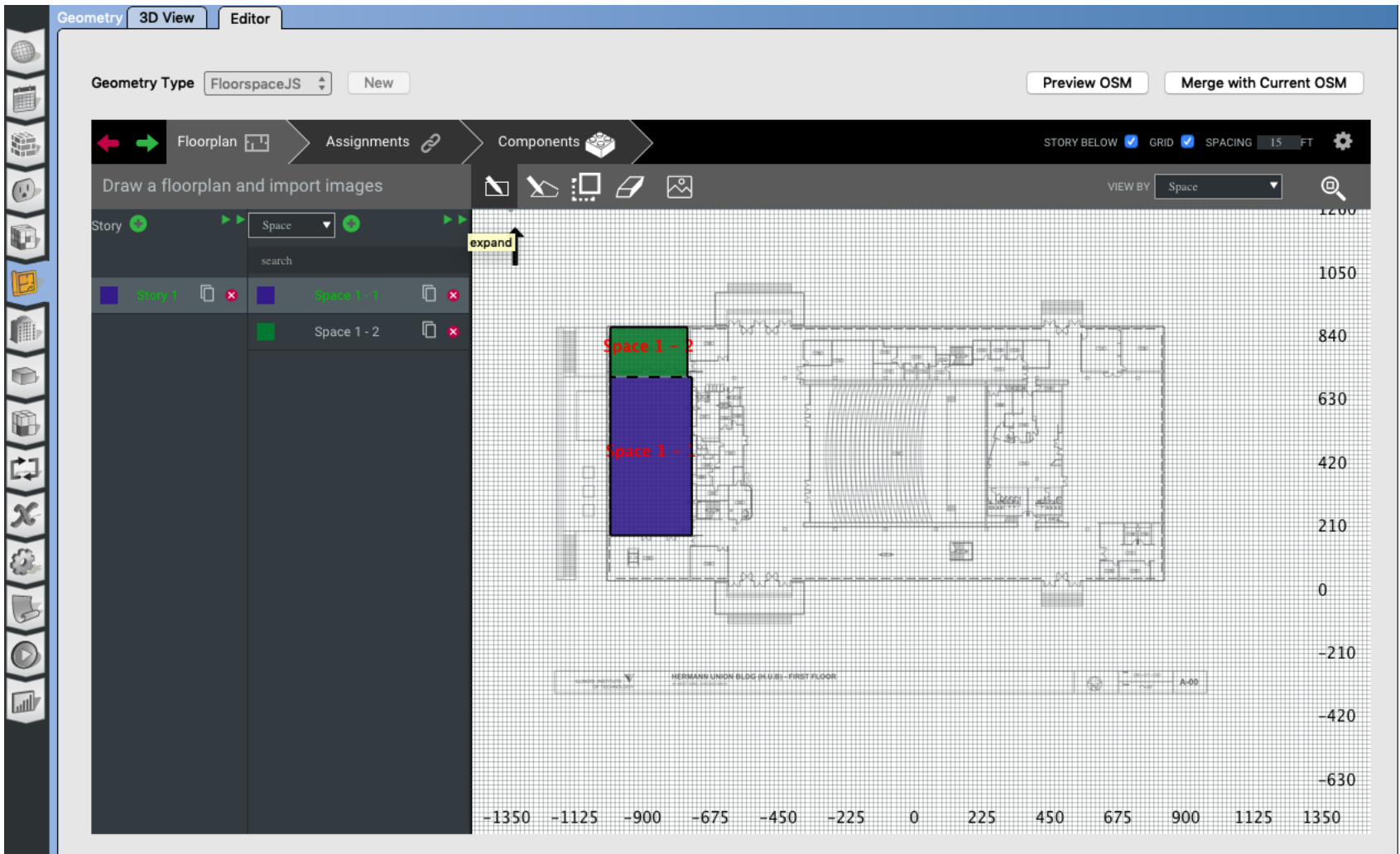
Draw From Floor Plan

- Import the floorplan using figure files



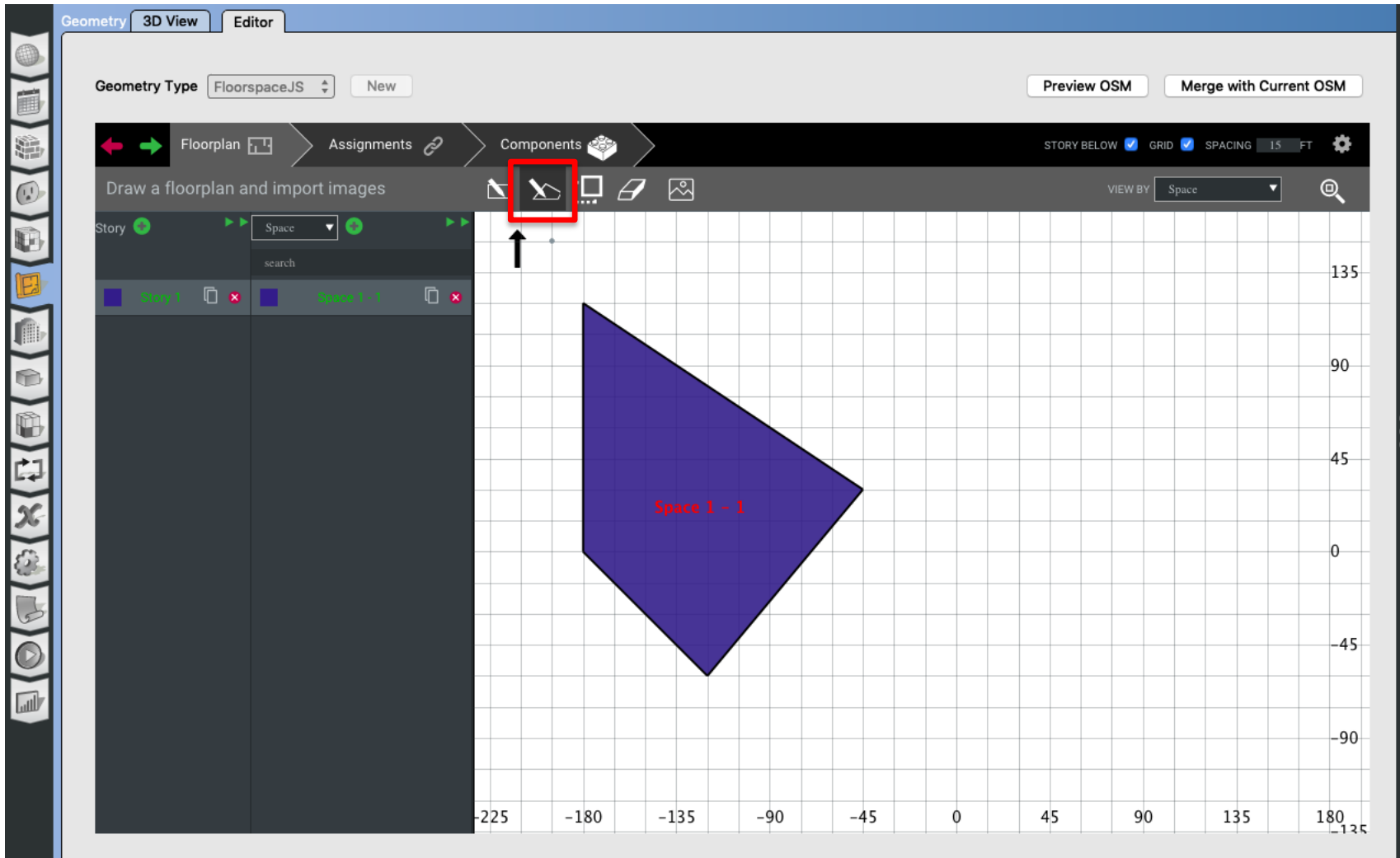
Draw From Floor Plan

- Build the spaces from the floorplan



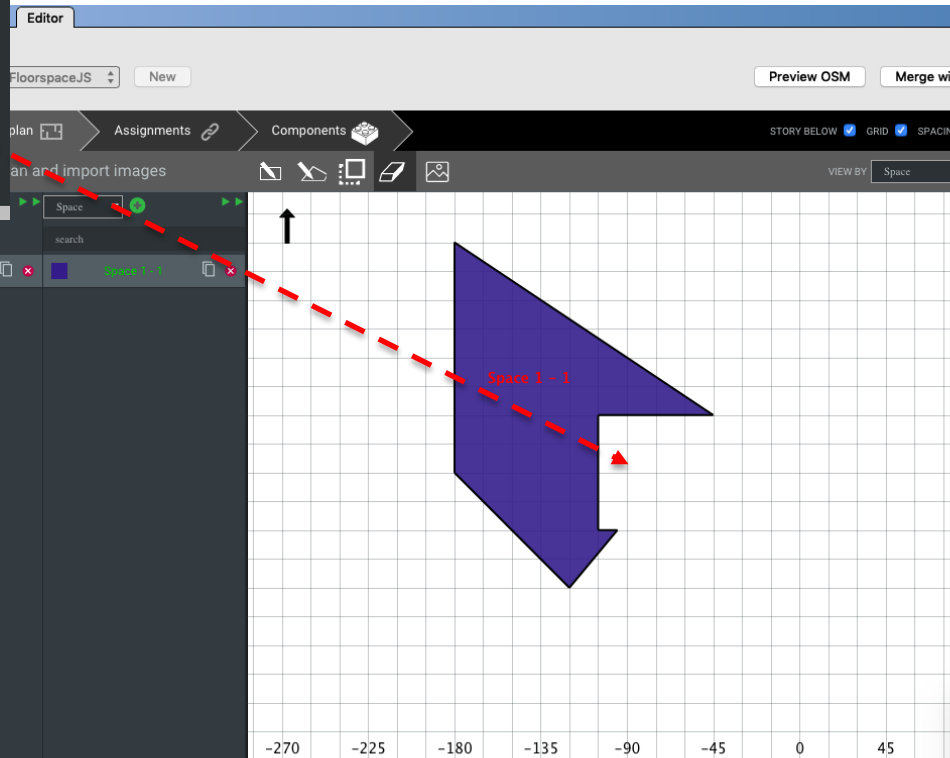
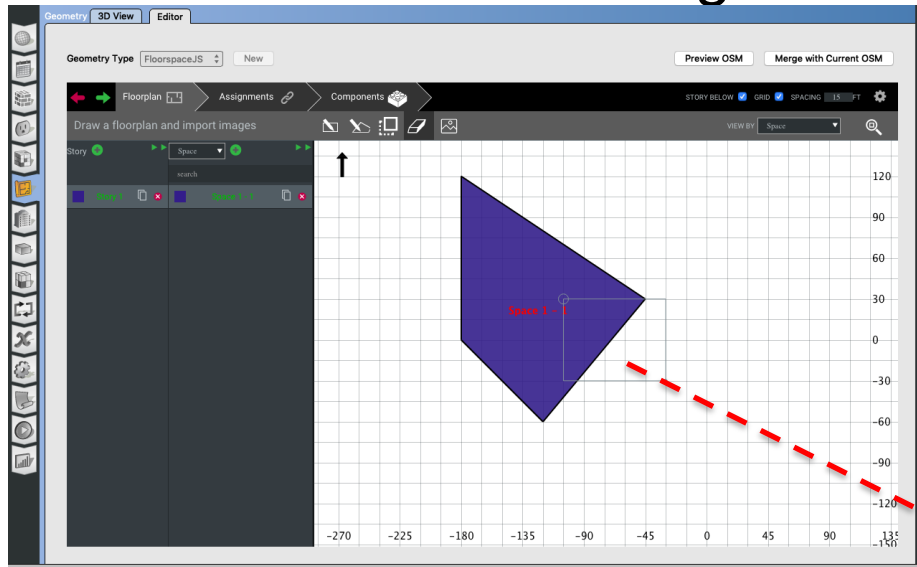
Draw Irregular Shapes

- Click on the irregular shape icon:



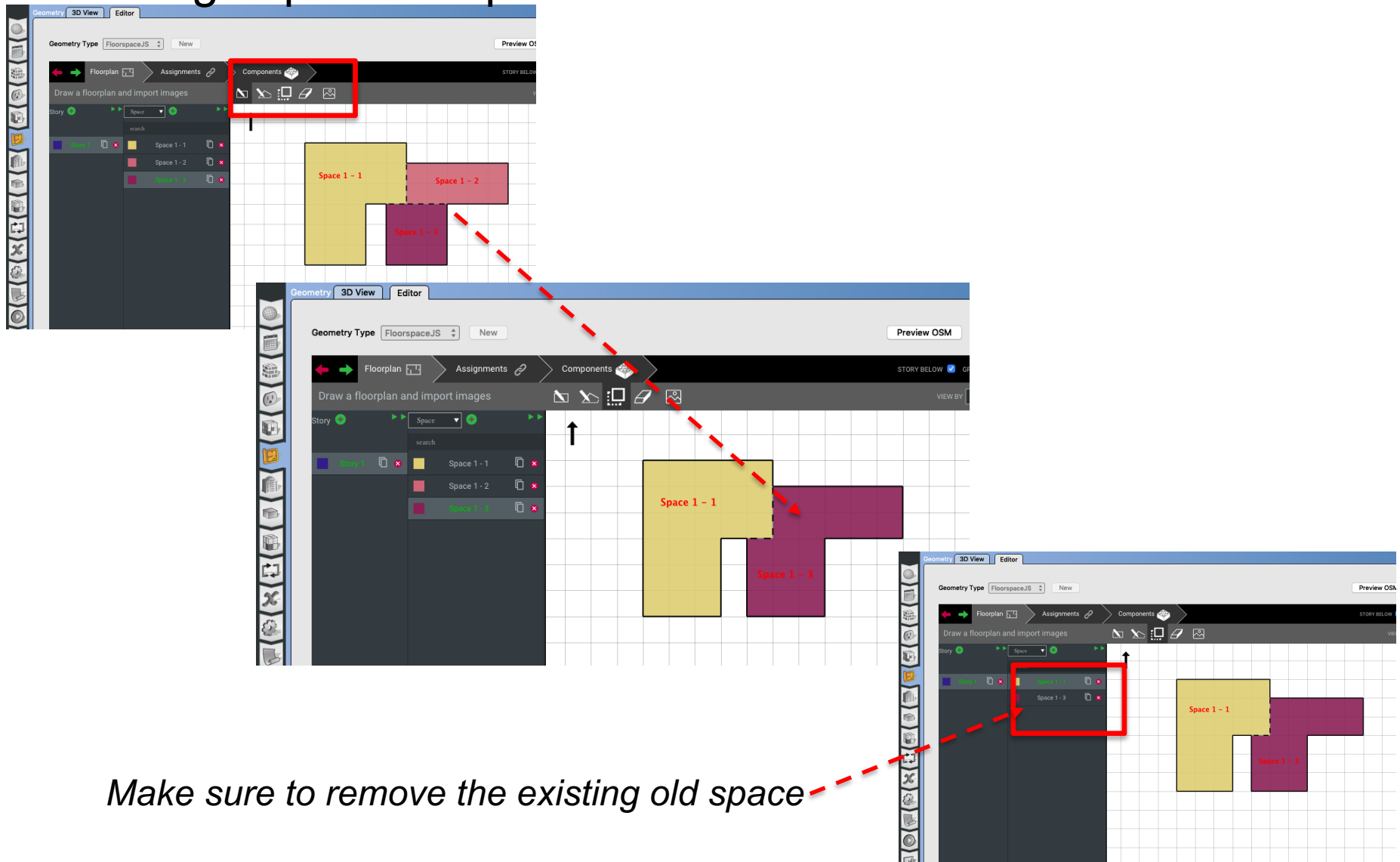
Cut Through the Space

- Select the cut through section:



Merge Spaces

- Merge spaces requires careful consideration:



TEMPLATES / LIBRARIES

Templates / Libraries

The screenshot shows a software application window with a menu bar (File, Preferences, Components & Measures, Help) and a toolbar. The 'File' menu is open, showing options like New, Open, Revert to Saved, Save, Save As, Import, Export, Load Library (highlighted in red), Examples, and Exit. Below the menu, there are tabs for 'Design Days', 'Life Cycle Costs', and 'Utility Bills'. The 'Design Days' tab is active, showing configuration options for 'Select Year by:' (Calendar Year: 2000, First Day of Year: UseWeatherFile), 'Daylight Savings Time:' (off), and 'Starts'/'Ends' (Define by Day of The Week And Month or Define by Date). Below these are 'ASHRAE Climate Zone' and 'CEC Climate Zone' dropdowns, and an 'Import From DDY' button. The main area is a table for 'Design Days' with columns for Date, Temperature, Humidity, Pressure Wind Precipitation, Solar, and Custom. Below the table, there are sections for 'Design Day Name', 'Day Of Month', 'Month', 'Day Type', and 'Daylight Saving Time Indicator', each with an 'Apply to Selected' button.

File Preferences Components & Measures Help

New %N Design Days Life Cycle Costs Utility Bills

Open %O Weather File

Revert to Saved %R

Save %S

Save As ⇧%S

Import

Export

Load Library files at www.energyplus.net/weather

Examples

Exit %Q

Measure Tags (Optional):

ASHRAE Climate Zone

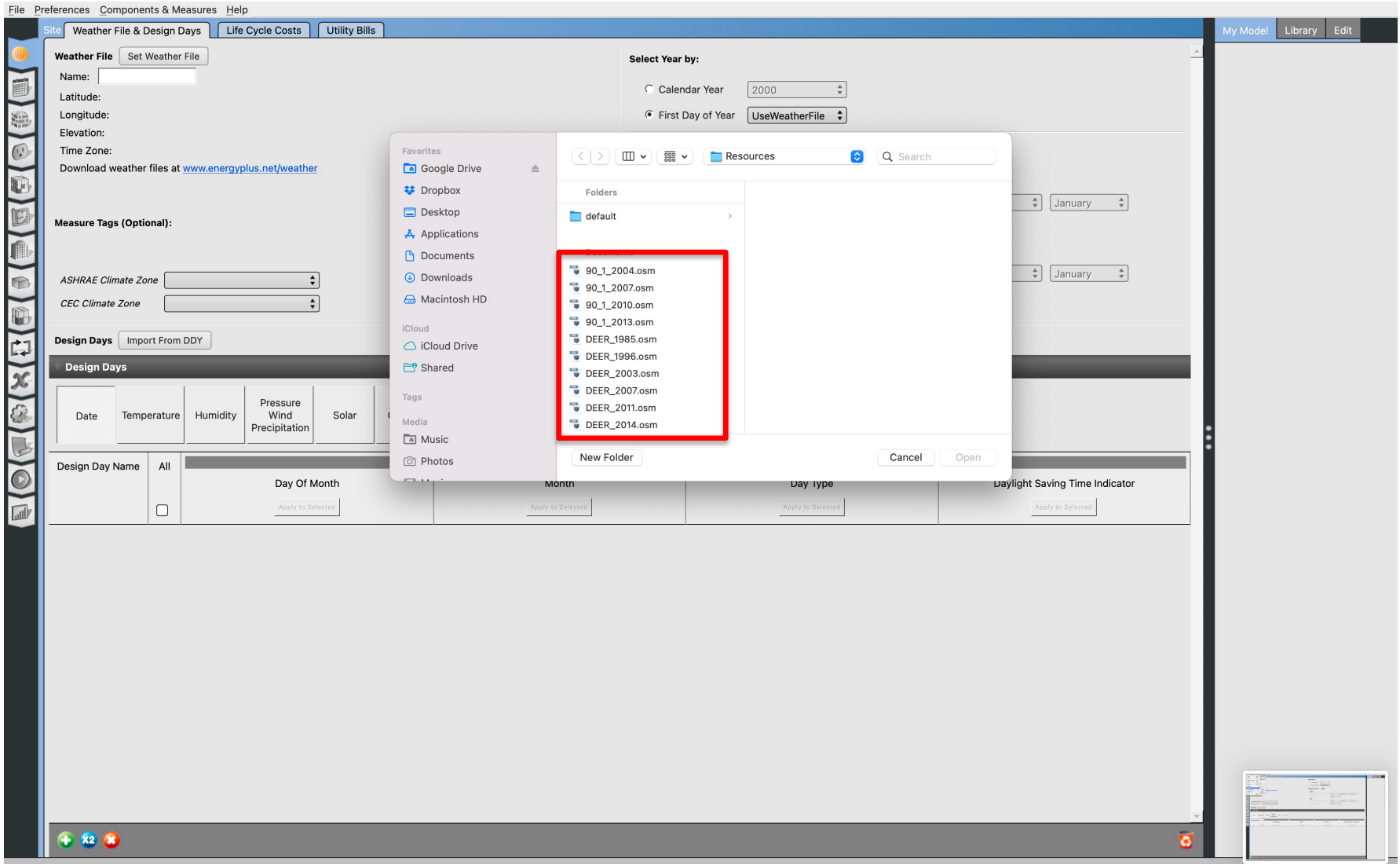
CEC Climate Zone

Design Days Import From DDY

Design Days

Date	Temperature	Humidity	Pressure Wind Precipitation	Solar	Custom
Design Day Name	All				
	<input type="checkbox"/>	Day Of Month	Month	Day Type	Daylight Saving Time Indicator
		<input type="button" value="Apply to Selected"/>	<input type="button" value="Apply to Selected"/>	<input type="button" value="Apply to Selected"/>	<input type="button" value="Apply to Selected"/>

Templates / Libraries



Templates / Libraries



U.S. Department of Energy Commercial Reference Building Models of the National Building Stock

Michael Deru, Kristin Field, Daniel Studer,
Kyle Benne, Brent Griffith, and Paul Torcellini
National Renewable Energy Laboratory

Bing Liu, Mark Halverson, Dave Winiarski,
and Michael Rosenberg
Pacific Northwest National Laboratory

Mehry Yazdanian
Lawrence Berkeley National Laboratory

Joe Huang
Formerly of Lawrence Berkeley National Laboratory

Drury Crawley
Formerly of the U.S. Department of Energy

OPENSTUDIO (SURFACE)

Construction Materials

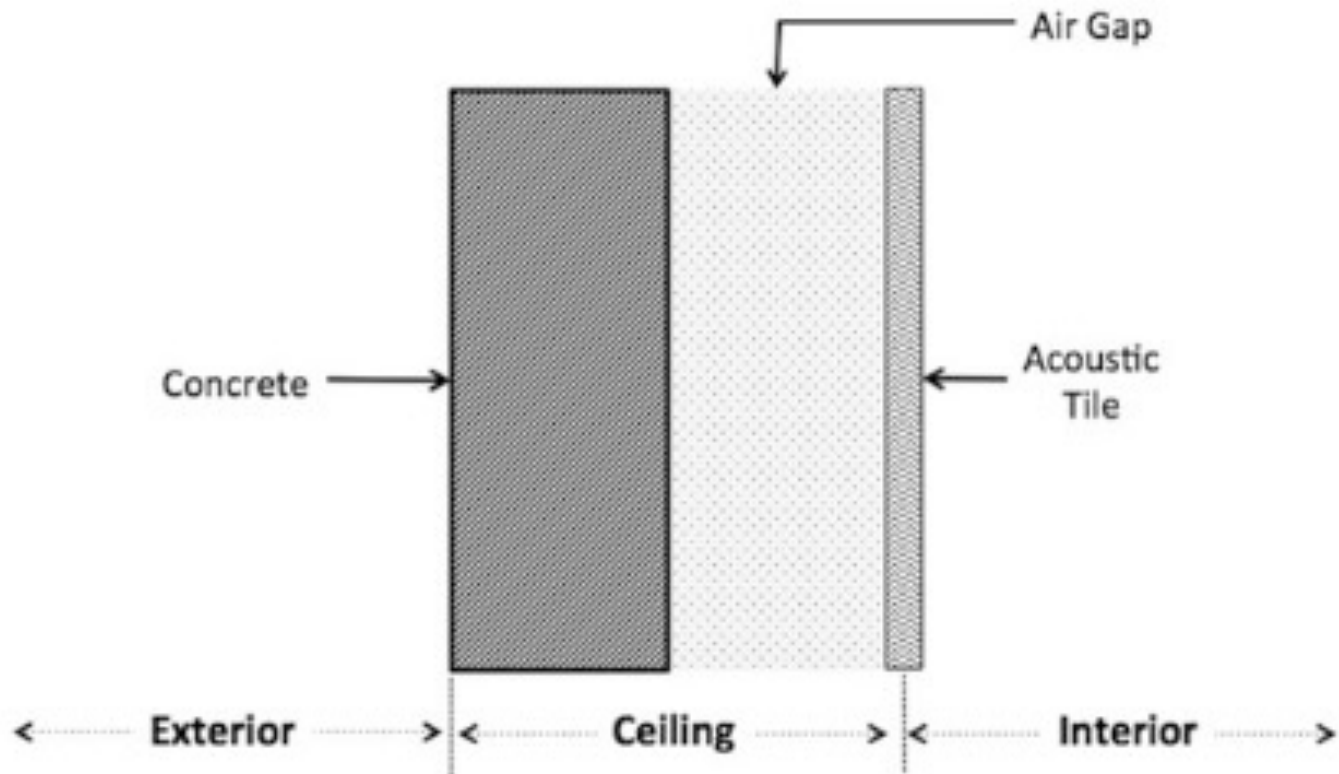
- Two types of surfaces:
 - ❑ Exterior
 - ❑ Interior surfaces
- Constructions are composed of layers of materials
- Surfaces with same orientation/properties are lumped into one surface for a thermal zone
 - e.g. combine windows facing same direction

Construction Materials

- Two types of surfaces:
 - Exterior
 - Interior surfaces

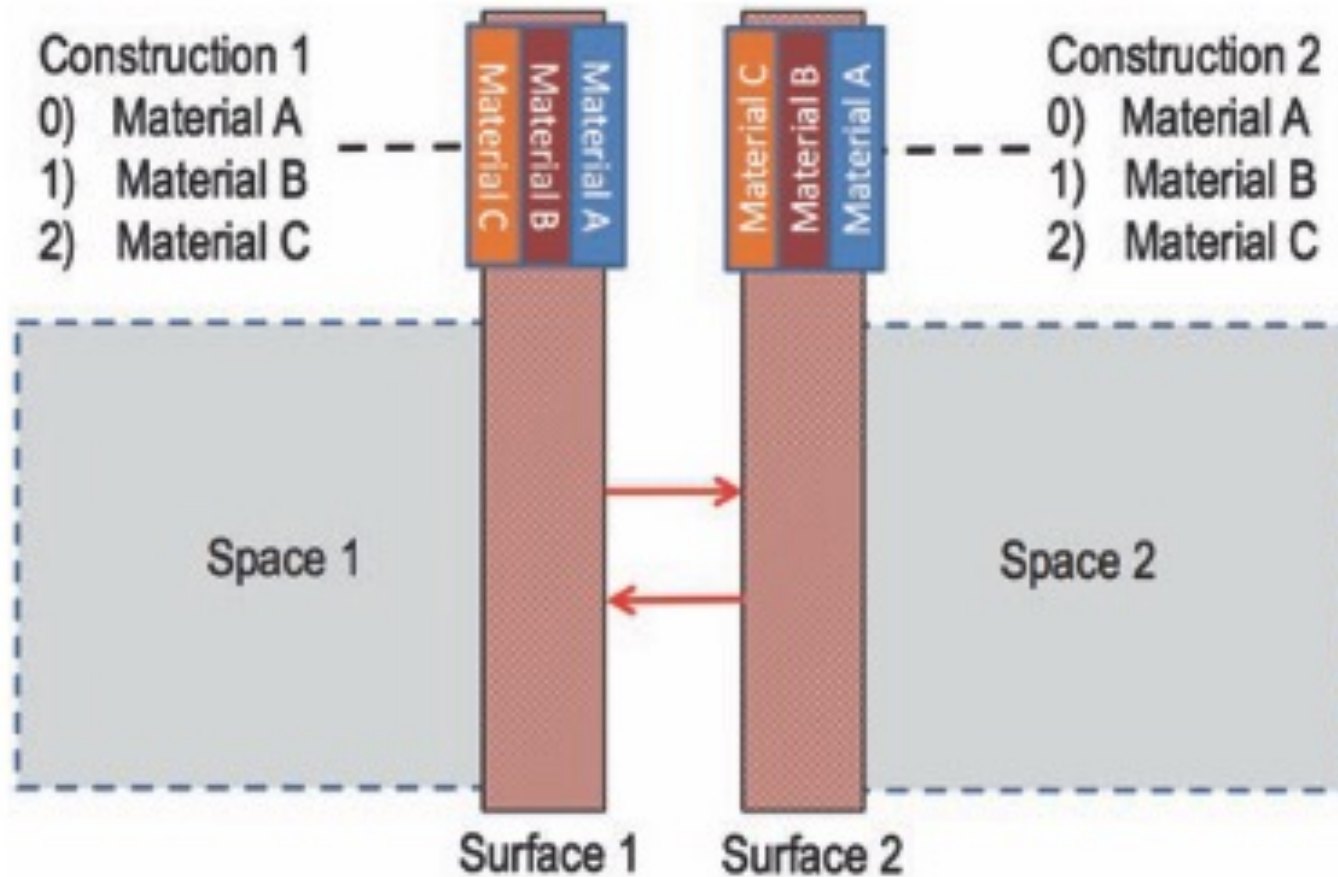
Constructions

- Constructions are composed of layers of materials



Constructions

- Constructions are composed of layers of materials



Add A New Material

- Add a new material

The screenshot displays the 'Materials' tab in a software application. The interface is divided into several sections:

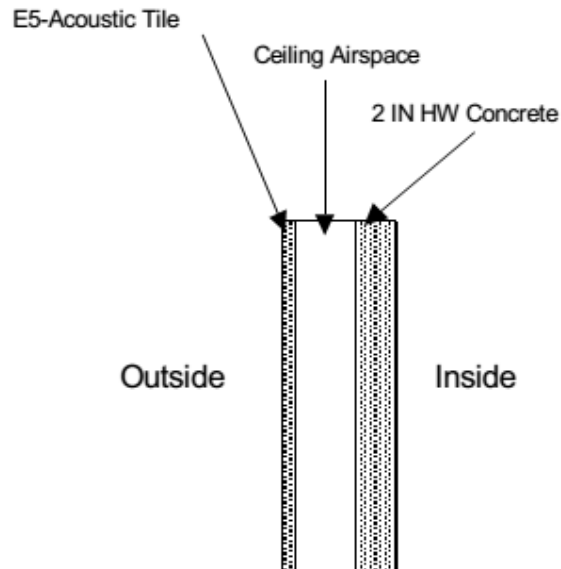
- Top Navigation:** 'Constructions', 'Construction Sets', 'Constructions', and 'Materials' tabs are visible.
- Left Panel:** A list of material types under the 'Constructions' category, including 'ext-slab-mass', 'Typical IEAD Roof', 'Typical Insulated Basement Mass Wall', 'Typical Insulated Exterior Mass Floor', 'Typical Insulated Exterior Mass Wall R-6.41 4', 'Typical Insulated Exterior Mass Wall R-6.41 5', 'Typical Insulated Metal Door', 'Typical Insulated Steel Framed Exterior Wall R-6.41 1', and a 'Drag From Library' button.
- Main Configuration Area:**
 - Name:** 'Typical Insulated Exterior Mass Wall R-6.41 Modified' (highlighted in a blue box).
 - Measure Tags (Optional):** A section with various dropdown menus for 'Standard', 'Standard Source', 'Intended Surface Type' (set to 'ExteriorWall'), 'Standards Construction Type' (set to 'Mass'), 'Fenestration Type', 'Fenestration Assembly Context', 'Fenestration Number of Panes', 'Fenestration Frame Type', 'Fenestration Divider Type', 'Fenestration Tint', 'Fenestration Gas Fill', and 'Fenestration Low Emissivity Coating' (set to 'off').
 - Layer:** A section labeled 'Outside' containing a list of materials: '1IN Stucco 1' and 'CONCRETI'.
- Right Panel:** A sidebar with a 'My Model' tab and a 'Library' tab. It lists various material categories: 'Materials', 'No Mass Materials', 'Air Gap Materials', 'Air Wall Materials', 'Infrared Transparent Materials', 'Roof Vegetation Materials', 'Simple Glazing System Window Materials', 'Glazing Window Materials', 'Gas Window Materials', 'Gas Mixture Window Materials', 'Daylight Redirection Device Window Materials', 'Blind Window Materials', 'Screen Window Materials', and 'Shade Window Materials'.
- Bottom Left:** A set of icons (plus, x2, x, trash) is highlighted with a red dashed box.

Construction Materials

- Constructions are composed of layers of materials (EnergyPlus)

An IDF example:

```
Material,A2 - 4 IN DENSE FACE BRICK, ! Material Name
Rough, ! Roughness
0.1014984 , ! Thickness (m)
1.245296 , ! Conductivity {W/M*K}
2082.400 , ! Density {Kg/M**3}
920.4800 , ! Specific Heat {J/Kg*K}
0.9000000 , ! Thermal Absorptance
0.9300000 , ! Solar Absorptance
0.9300000 ; ! Visible Absorptance
```



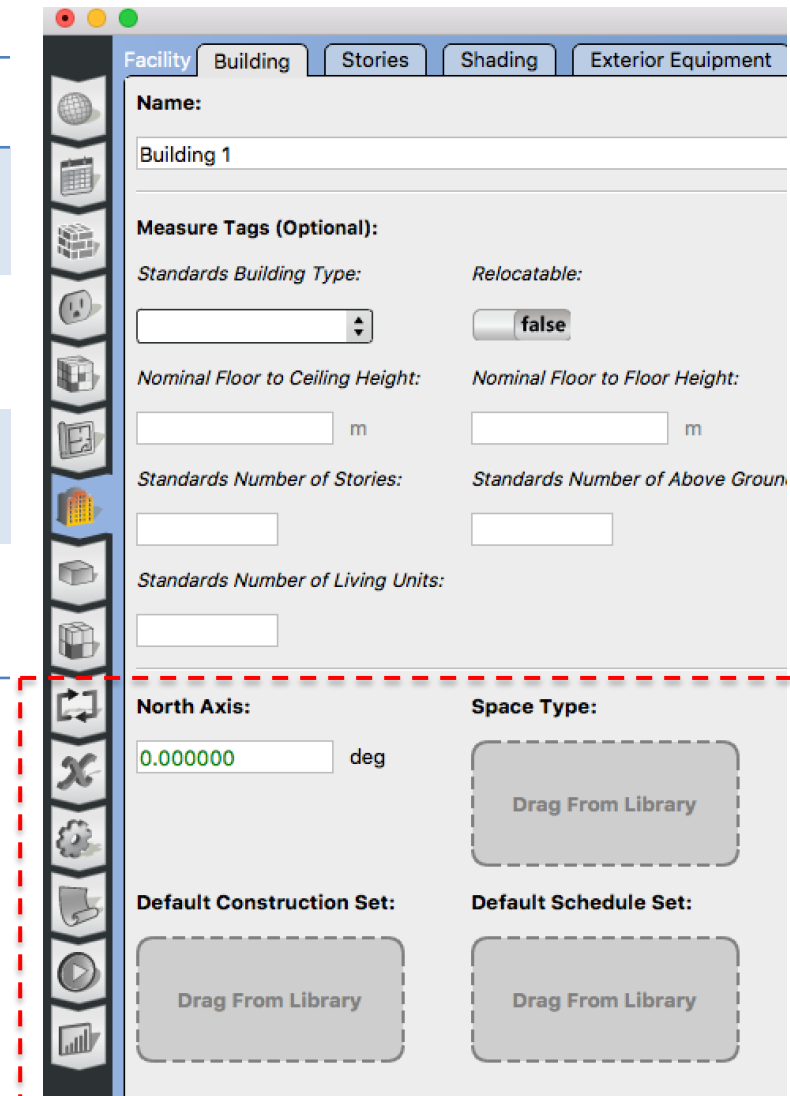
IDF Example (floor construction):

```
Construction, FLOOR38, ! Material layer names follow:
E5 - ACOUSTIC TILE,
E4 - CEILING AIRSPACE,
C12 - 2 IN HW CONCRETE;
```

Figure 22. Example Floor Construction illustration.

Inheritance

Priority	Level	Construction
1	Surface	Construction
2	Space	Default Construction Set
3	Story	Default Construction Set
4	Building	Default Construction Set



Inheritance

- Why do we see the “green color” text?

The screenshot shows the Revit Properties palette for a space named "Space 1 - 1". The "Surfaces" tab is active, and the "General" sub-tab is selected. The "Filters" section shows "Story" set to "All", "Thermal Zone" set to "All", "Space Type" set to "All", "Surface Type" set to "All", "Outside Boundary Condition" set to "All", and "Sun Exposure" set to "All".

Space Name	Surface Name	Surface Type	Construction	Outside Boundary Condition	Outside Boundary Condition
Space 1 - 1	Face 3	Wall	Typical Interior Wall	Surface	Face 10
	Face 2	Wall	Typical Insulated Baser	Ground	
	Surface 12	RoofCeiling	Typical Interior Ceiling	Surface	Face 26
	Surface 13	RoofCeiling	Typical Interior Ceiling	Surface	Surface
	Face 5	Wall	Typical Insulated Baser	Ground	
	Face 6	Wall	Typical Insulated Steel	Outdoors	
	Face 0	Floor	ext-slab-mass	Ground	
	Face 1	RoofCeiling	Typical Interior Ceiling	Surface	Surface
	Face 4	Wall	Typical Interior Wall	Surface	Face 19
	Surface 8	RoofCeiling	Typical Interior Ceiling	Surface	Face 34
	Surface 3	RoofCeiling	Typical Interior Ceiling	Surface	Face 86
	Surface 1	RoofCeiling	Typical Interior Ceiling	Surface	Face 70
	Face 18	Wall	Typical Insulated Baser	Ground	
	Face 19	Wall	Typical Interior Wall	Surface	Face 4

The "Construction" column contains green text labels: "Typical Interior Wall", "Typical Insulated Baser", "Typical Interior Ceiling", "Typical Insulated Steel", "ext-slab-mass", and "Typical Interior Wall".

The right sidebar shows the "My Model" tab with "Library" and "Edit" buttons. The "Fixed Interval Schedules" and "Variable Interval Schedules" sections are collapsed. The "Constructions" section is expanded, showing a list of construction types: "ext-slab-mass", "Typical IEAD Roof", "Typical Insulated Basement Mass Wall", "Typical Insulated Exterior Mass Floor", "Typical Insulated Exterior Mass Wall R-6.41 4", "Typical Insulated Exterior Mass Wall R-6.41 5", "Typical Insulated Metal Door", "Typical Insulated Steel Framed Exterior Wall R-6.41 1", and "Typical Interior Ceiling".

Inheritance

- Replace the construction from “My Model”

The screenshot shows a software interface with a table of surface properties and a list of construction types. The table has columns for Space Name, Surface Name, Surface Type, Construction, Outside Boundary Condition, and Outside Boundary Condition. The 'Construction' column contains various construction types, and the 'Outside Boundary Condition' column contains values like Surface, Ground, and Outdoors. A red dashed box highlights the 'ext-slab-mass' construction type in the list on the right.

Space Name	Surface Name	Surface Type	Construction	Outside Boundary Condition	Outside Boundary Condition
Space 1 - 1	Face 3	Wall	Typical Interior Wall	Surface	Face 10
	Face 2	Wall	Typical Insulated Baser	Ground	Face 26
	Surface 12	RoofCeiling	Typical Interior Ceiling	Surface	Surface
	Surface 13	RoofCeiling	Typical Interior Ceiling	Surface	Surface
	Face 5	Wall	Typical Insulated Exteri	Ground	Surface
	Face 6	Wall	Typical Insulated Exteri	Outdoors	Surface
	Face 0	Floor	ext-slab-mass	Ground	Surface
	Face 1	RoofCeiling	Typical Interior Ceiling	Surface	Surface
	Face 4	Wall	Typical Interior Wall	Surface	Face 19
	Surface 8	RoofCeiling	Typical Interior Ceiling	Surface	Face 34
	Surface 3	RoofCeiling	Typical Interior Ceiling	Surface	Face 86
	Surface 1	RoofCeiling	Typical Interior Ceiling	Surface	Face 70
	Face 18	Wall	Typical Insulated Baser	Ground	Face 4
	Face 19	Wall	Typical Interior Wall	Surface	Face 4

The list of construction types on the right includes:

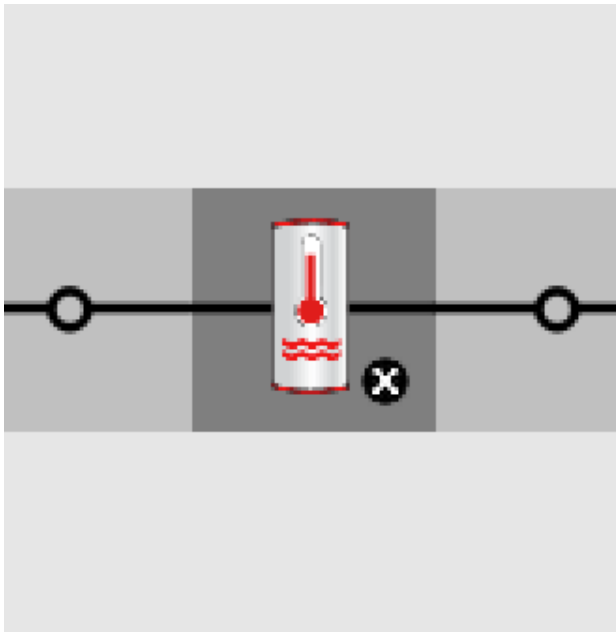
- ext-slab-mass
- Typical IEAD Roof
- Typical Insulated Basement Mass Wall
- Typical Insulated Exterior Mass Floor
- Typical Insulated Exterior Mass Wall R-6.41 4
- Typical Insulated Exterior Mass Wall R-6.41 5
- Typical Insulated Metal Door
- Typical Insulated Steel Framed Exterior Wall R-6.41 1
- Typical Interior Ceiling

Other Inputs

- Plug Load Density, Schedule
- Occupancy Density, Schedule, Metabolic Rate
- Domestic Hot Water Rate, Schedule
- Lighting Level
- Temperature/Humidity Control, Schedule
- Ventilation

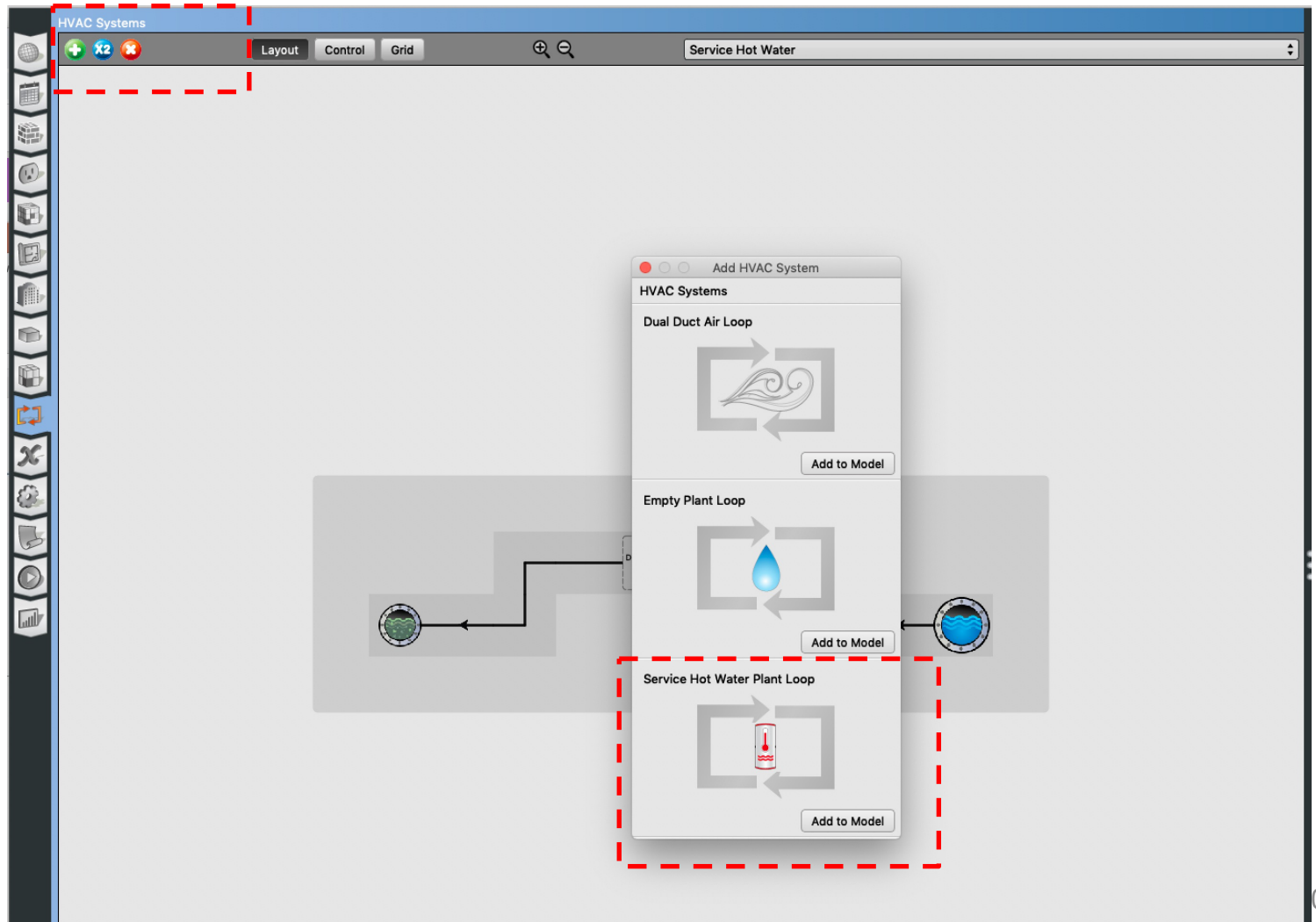
SERVICE HOT WATER

Service Hot Water



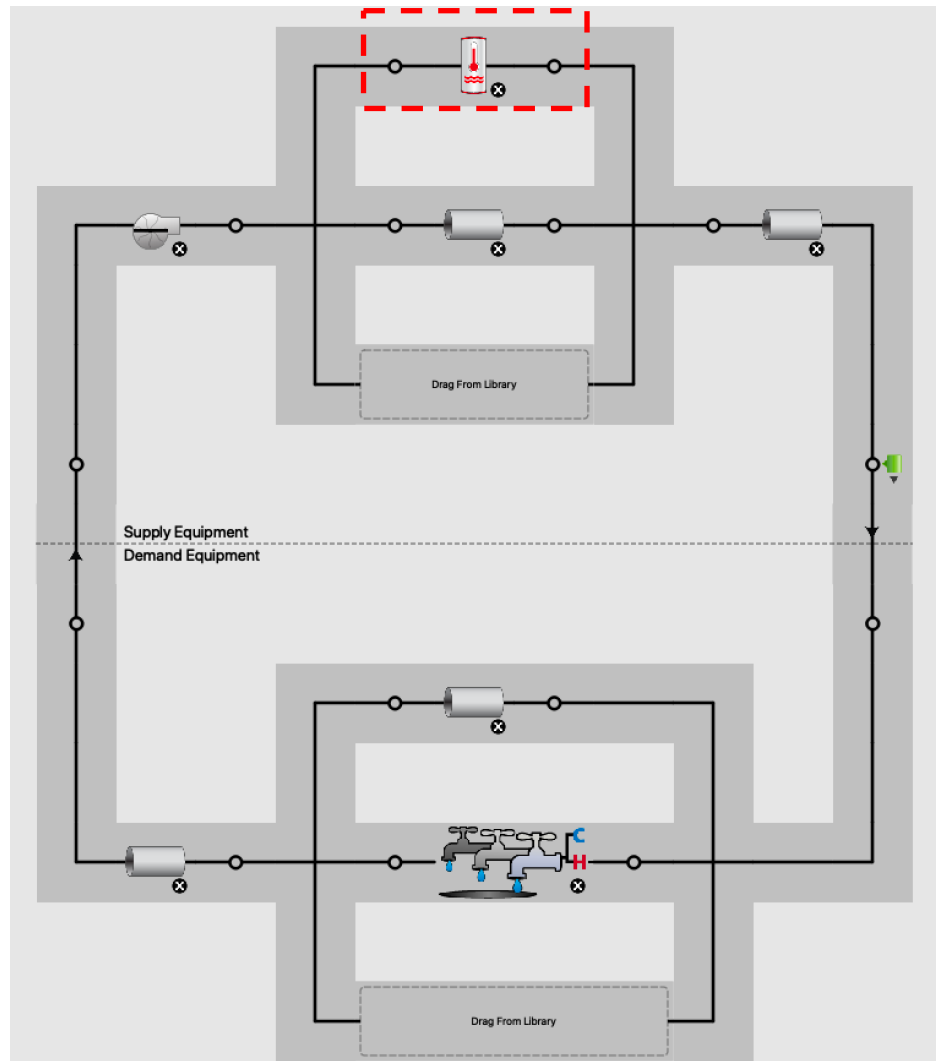
Service Hot Water

- Add a water heater tank to a plant loop:



Service Hot Water

- Add service hot water plant loop:



Service Hot Water

- Add a fixture:

HVAC Systems

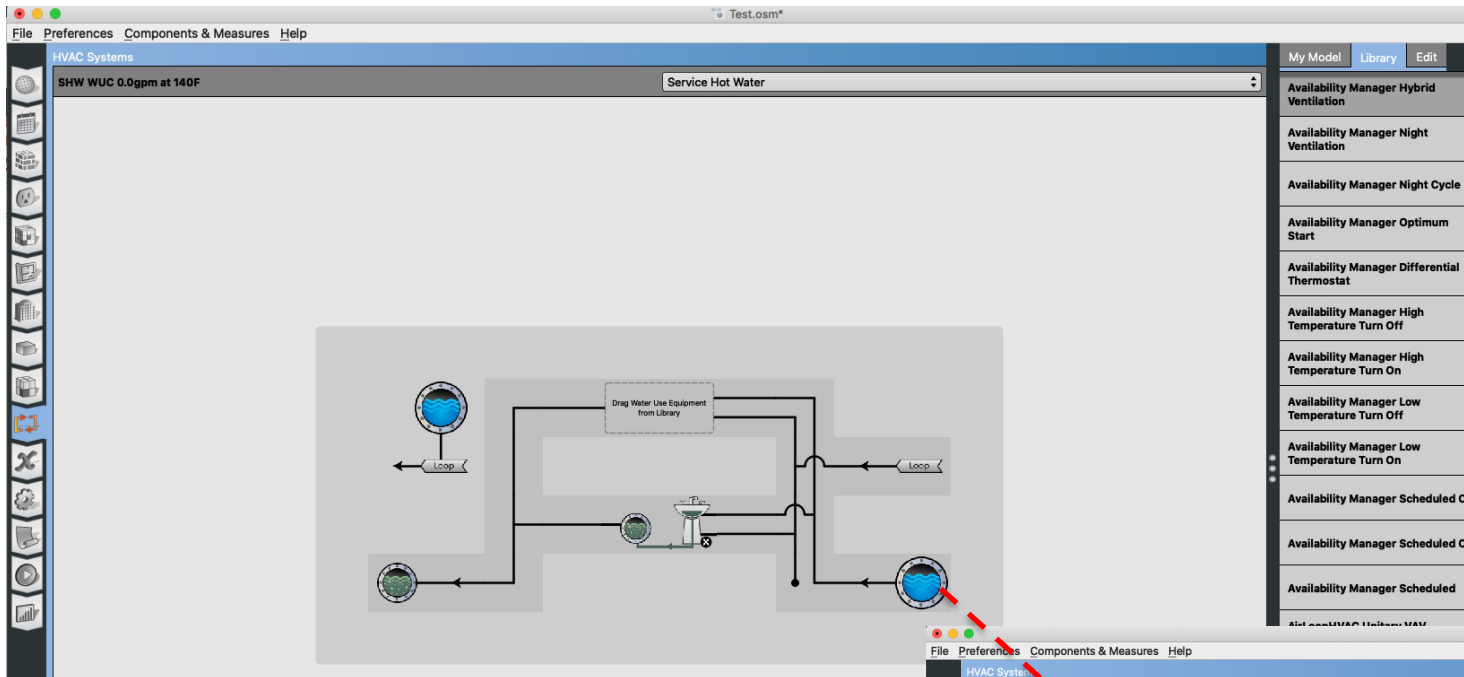
Water Use Connection Service Hot Water

The screenshot displays a software interface for configuring a Service Hot Water system. The main workspace shows a schematic diagram with a central box labeled "Drag Water Use Equipment from Library" and a sink fixture. The diagram includes pipes, valves, and loops, with arrows indicating flow direction. A right-hand sidebar lists available equipment options, including various Availability Manager settings and AirLoopHVAC units.

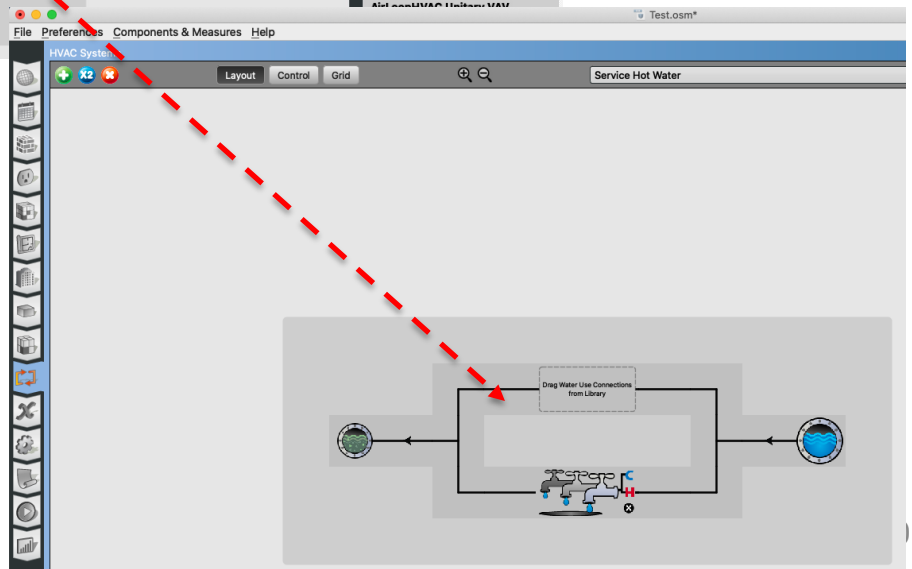
My Model Library Edit

- Availability Manager Hybrid Ventilation
- Availability Manager Night Ventilation
- Availability Manager Night Cycle
- Availability Manager Optimum Start
- Availability Manager Differential Thermostat
- Availability Manager High Temperature Turn Off
- Availability Manager High Temperature Turn On
- Availability Manager Low Temperature Turn Off
- Availability Manager Low Temperature Turn On
- Availability Manager Scheduled Off
- Availability Manager Scheduled On
- Availability Manager Scheduled
- AirLoopHVAC Unitary VAV Changeover Bypass
- AirLoopHVAC Unitary System

Service Hot Water



- My Model
- Library
- Edit
- Availability Manager Hybrid Ventilation
- Availability Manager Night Ventilation
- Availability Manager Night Cycle
- Availability Manager Optimum Start
- Availability Manager Differential Thermostat
- Availability Manager High Temperature Turn Off
- Availability Manager High Temperature Turn On
- Availability Manager Low Temperature Turn Off
- Availability Manager Low Temperature Turn On
- Availability Manager Scheduled Off
- Availability Manager Scheduled On
- Availability Manager Scheduled



Service Hot Water

- Add service hot water definition

The screenshot shows a software interface for defining service hot water loads. The main window is titled "Loads" and contains a list of definition categories on the left and a configuration panel on the right. The "Water Use Equipment Definitions" category is selected, and the "Water Fixture Definition" item is highlighted. The configuration panel shows the following fields:

- Name:** Water Fixture Definition
- End Use Subcategory:** General
- Peak Flow Rate:** 1.000155 gal/min
- Target Temperature Schedule:** Drag From Library
- Sensible Fraction Schedule:** Drag From Library
- Latent Fraction Schedule:** Drag From Library

The "Water Fixture Definition" item in the list is highlighted with a red dashed border, and the "Peak Flow Rate" and "Target Temperature Schedule" fields are also highlighted with a red dashed border. The right sidebar shows a list of construction and schedule categories, including "Ruleset Schedules", "Compact Schedules", "Constant Schedules", "Year Schedules", "Fixed Interval Schedules", "Variable Interval Schedules", "Constructions", "Internal Source Constructions", "C-factor Underground Wall Constructions", "F-factor Ground Floor Constructions", and "Window Data File Constructions".

Service Hot Water

- DOE Reference Buildings
 - Section 5.1.6 Service Water Heater Demand

Table 11 Peak Service Hot Water Demand and Data Sources

Space Type	Use Rate		Temp. at Fixture		Data Sources
	gal/h	L/h	°F	°C	
Guest room (small hotel)	1.75	6.6	110	43	Jiang et al. 2008, ASHRAE 2007
Guest room (large hotel)	1.25	4.7	110	43	Jiang et al. 2008, ASHRAE 2007
Laundry (small hotel)	67.5	255.5	140	60	Jiang et al. 2008, ASHRAE 2007
Laundry (large hotel)	156.6	592.8	140	60	Jiang et al. 2008, ASHRAE 2007
Restrooms (primary school)	56.5	214.0	110	43	ASHRAE 2007
Restrooms (secondary school)	104.4	395.0	110	43	ASHRAE 2007
Gym (secondary school)	189.5	717.2	110	43	ASHRAE 2007
Small office	3.0	11.4	110	43	Jarnagin et al. 2006, ASHRAE 2007
Medium office (per floor)	9.9	37.5	110	43	Jarnagin et al. 2006, ASHRAE 2007
Large office (per floor)	21.3	80.6	110	43	Jarnagin et al. 2006, ASHRAE 2007
Apartment	3.5	13.2	110	43	Gowri et al. 2007
Outpatient healthcare	30.0	113.5	110	43	Doebber et al. 2009
Hospital					
ER waiting room	1.0	3.8	120	49	Engineering judgment
Operating/surgical cystoscopic	2.0	7.6	120	49	Engineering judgment
Laboratory	2.0	7.6	120	49	Engineering judgment
Patient room	1.0	3.8	120	49	Engineering judgment

Service Hot Water

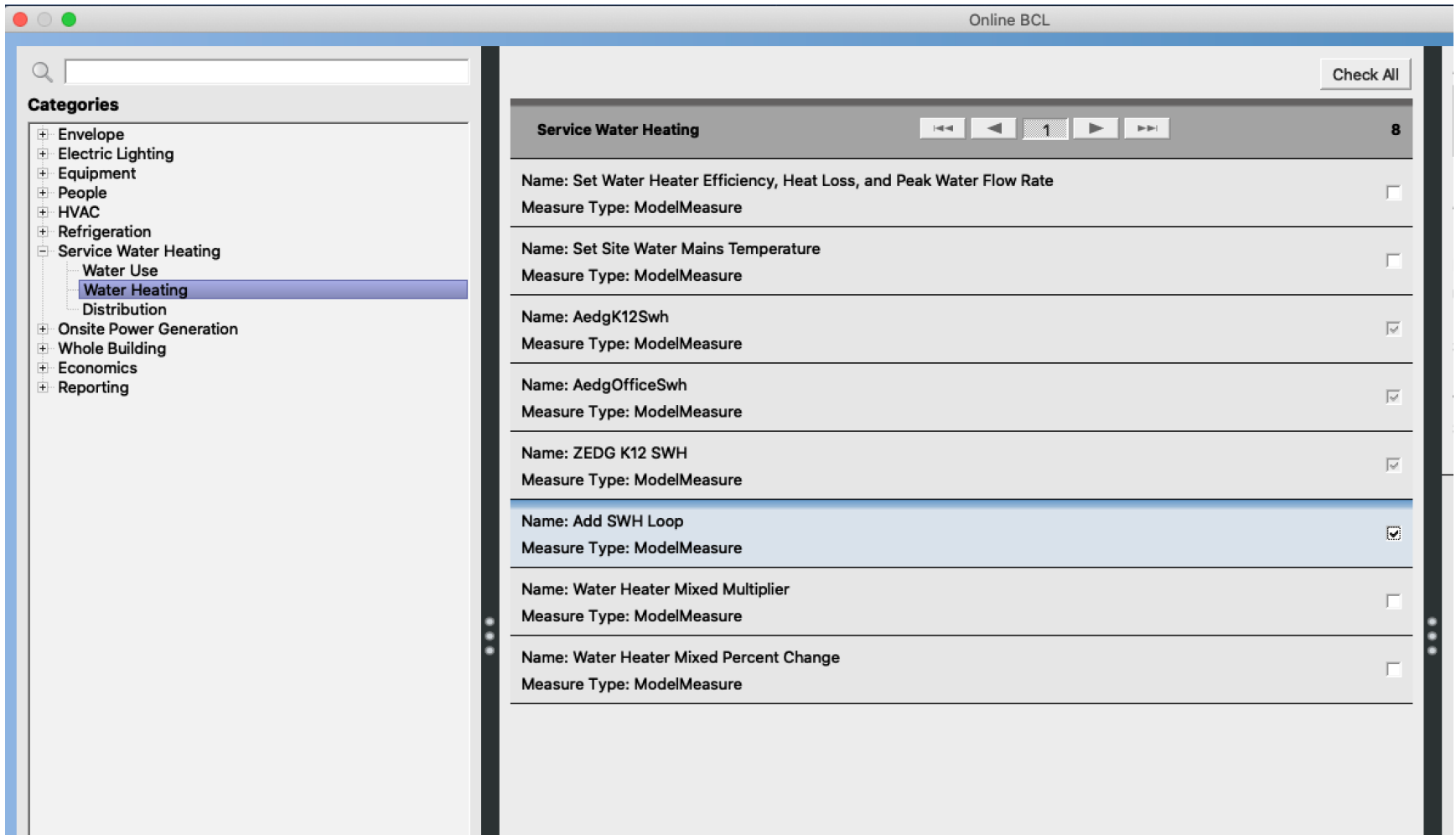
- Make reasonable assumptions for the water heater temperature:
 - Most households require about 120 °F
 - Some manufacturers set water heater thermostats at 140 °F, which also slows mineral buildup and corrosion in your water heater and pipes
 - Water heated at 140°F also poses a safety hazard (scalding)

Service Hot Water

- Make reasonable assumptions for the flow rates and sizes. For example, for residential units:
 - Small size: A 50 to 60-gallon storage tank is usually sufficient for 1 to 3 people
 - Medium size: A 80-gallon storage tank works well for 3 to 4 people
 - Large size: A large tank is appropriate for four to six people

Service Hot Water

- You can use the OpenStudio measures:



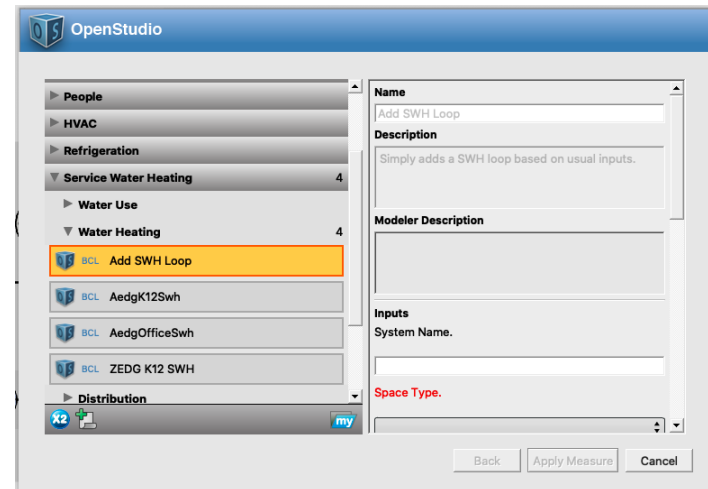
The screenshot shows the OpenStudio Online BCL interface. On the left, a 'Categories' sidebar lists various building systems, with 'Service Water Heating' expanded to show 'Water Heating' selected. The main panel displays a list of measures under the 'Service Water Heating' category, with a 'Check All' button in the top right. The measures are listed with their names and measure types, and checkboxes to indicate their selection status.

Measure Name	Measure Type	Selected
Name: Set Water Heater Efficiency, Heat Loss, and Peak Water Flow Rate	ModelMeasure	<input type="checkbox"/>
Name: Set Site Water Mains Temperature	ModelMeasure	<input type="checkbox"/>
Name: AedgK12Swh	ModelMeasure	<input checked="" type="checkbox"/>
Name: AedgOfficeSwh	ModelMeasure	<input checked="" type="checkbox"/>
Name: ZEDG K12 SWH	ModelMeasure	<input checked="" type="checkbox"/>
Name: Add SWH Loop	ModelMeasure	<input checked="" type="checkbox"/>
Name: Water Heater Mixed Multiplier	ModelMeasure	<input type="checkbox"/>
Name: Water Heater Mixed Percent Change	ModelMeasure	<input type="checkbox"/>

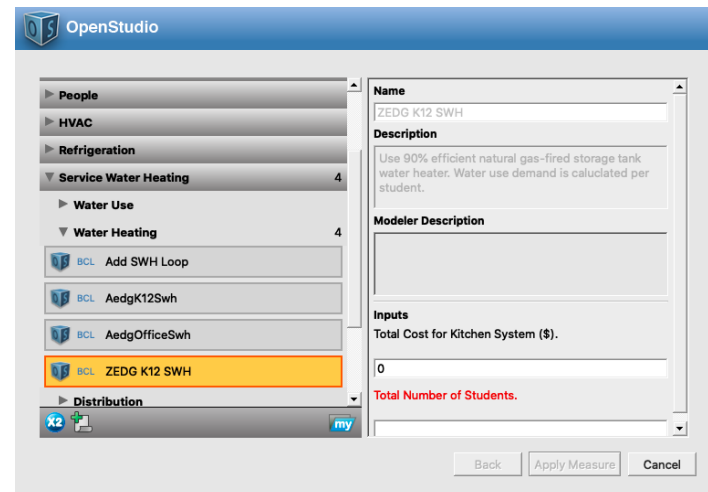
Service Hot Water

- You can use the OpenStudio measures:

- First, use “Add SHW Loop”



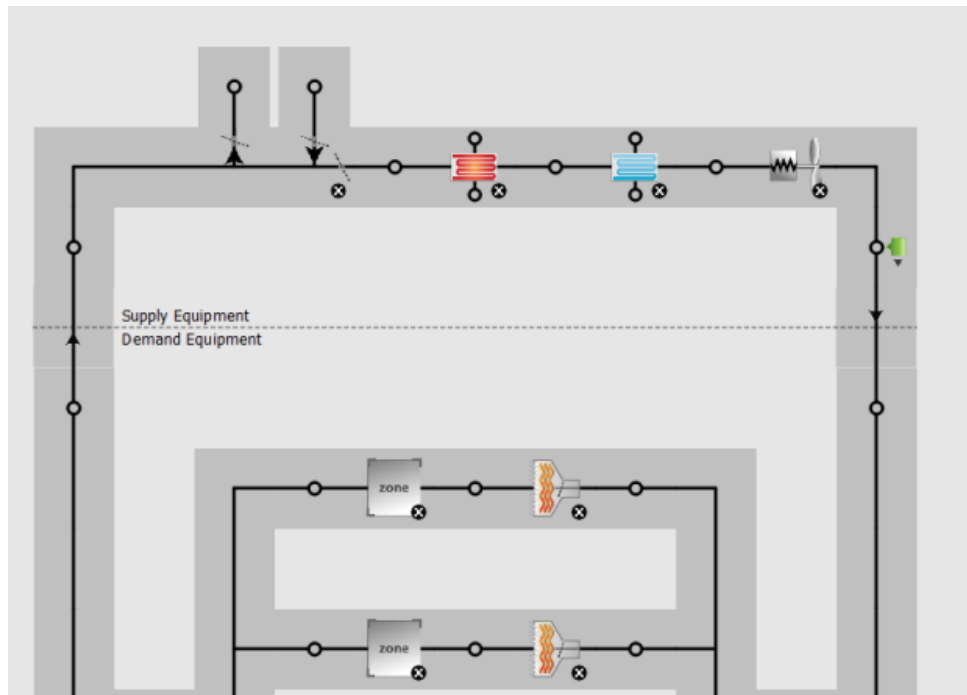
- Second, use “ZEDG K12 SHW”



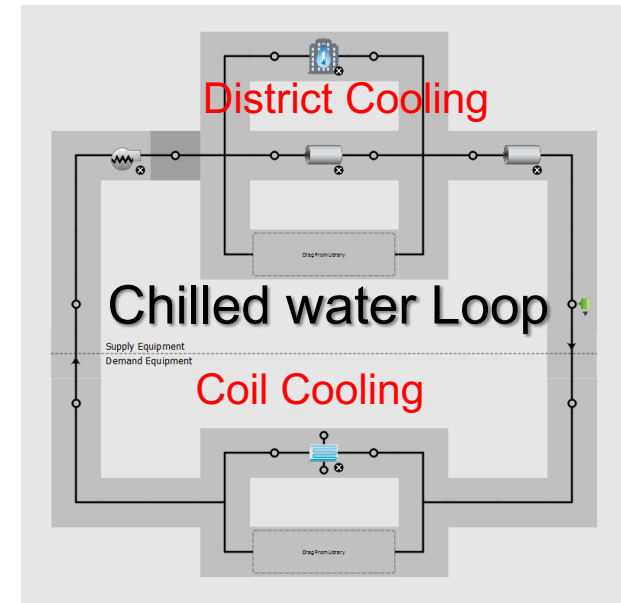
DISTRICT HEATING AND COOLING

District Heating and Cooling

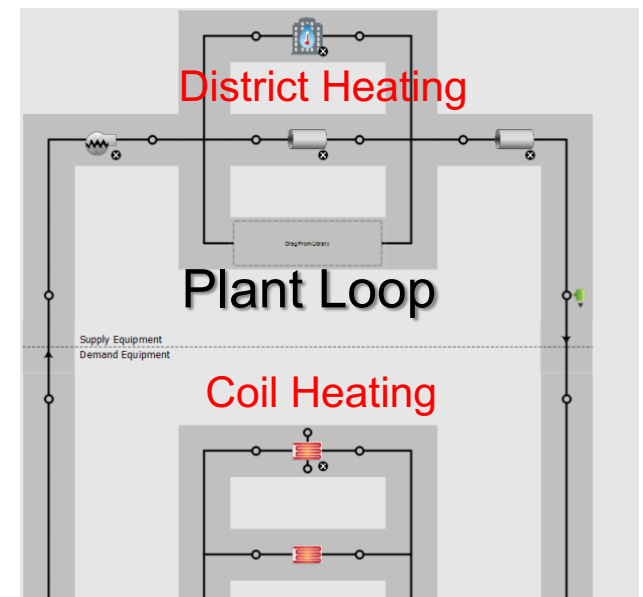
- District heating and cooling:
 - No assumption required on:
 - Steam
 - Chilled water generation



Air Loop



Chilled water Loop



Plant Loop