CAE 465/526 Building Energy Conservation Technologies

Fall 2023

October 5, 2023

OpenStudio, sensitivity analysis, and Ladybug

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

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

ANNOUNCEMENT

Announcement

Announcement

- Assignment 4 is due next Monday (Tuesday is also fine)

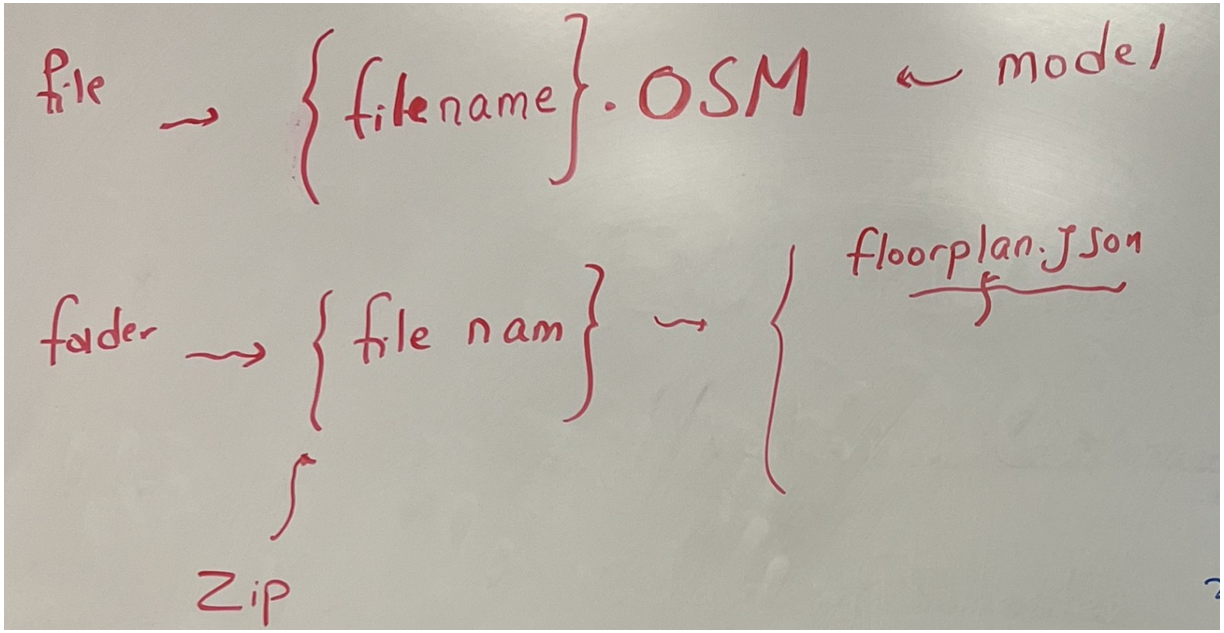
ASSIGNMENT 3 FEEDBACK

Assignment 3 Feedback

- Please follow the instructions

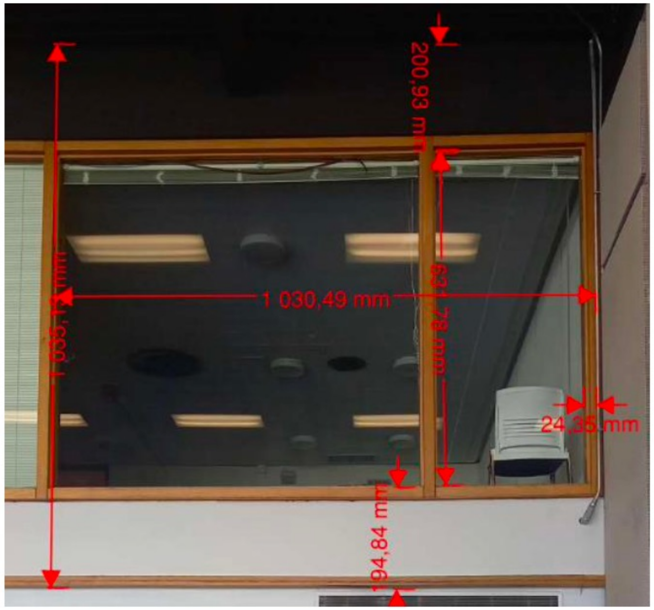
Submission files:

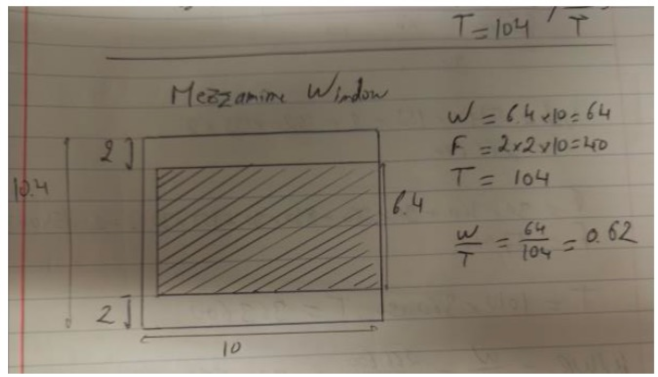
- CAE 526 students should submit the OpenStudio model (extension file is OSM), the associated folder (the folder should be compressed), and a short summary to respond to the parts.
- IPRO students do not need to follow this process exactly. They should create a simple one floor model and explore how the model and the results could be visualized in their master visualization plan.

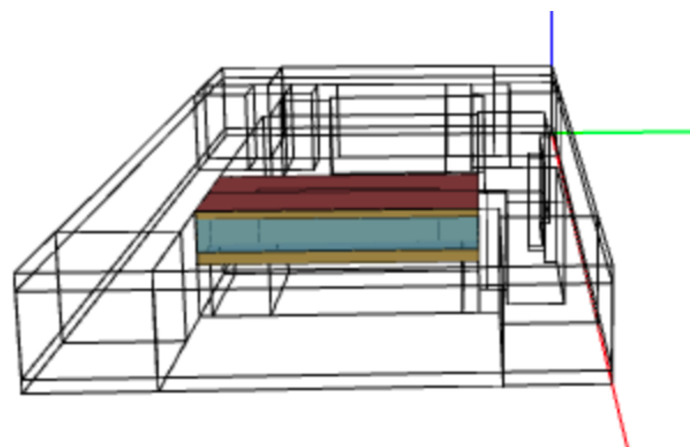


Assignment 3 Feedback

- What do you think about internal windows:

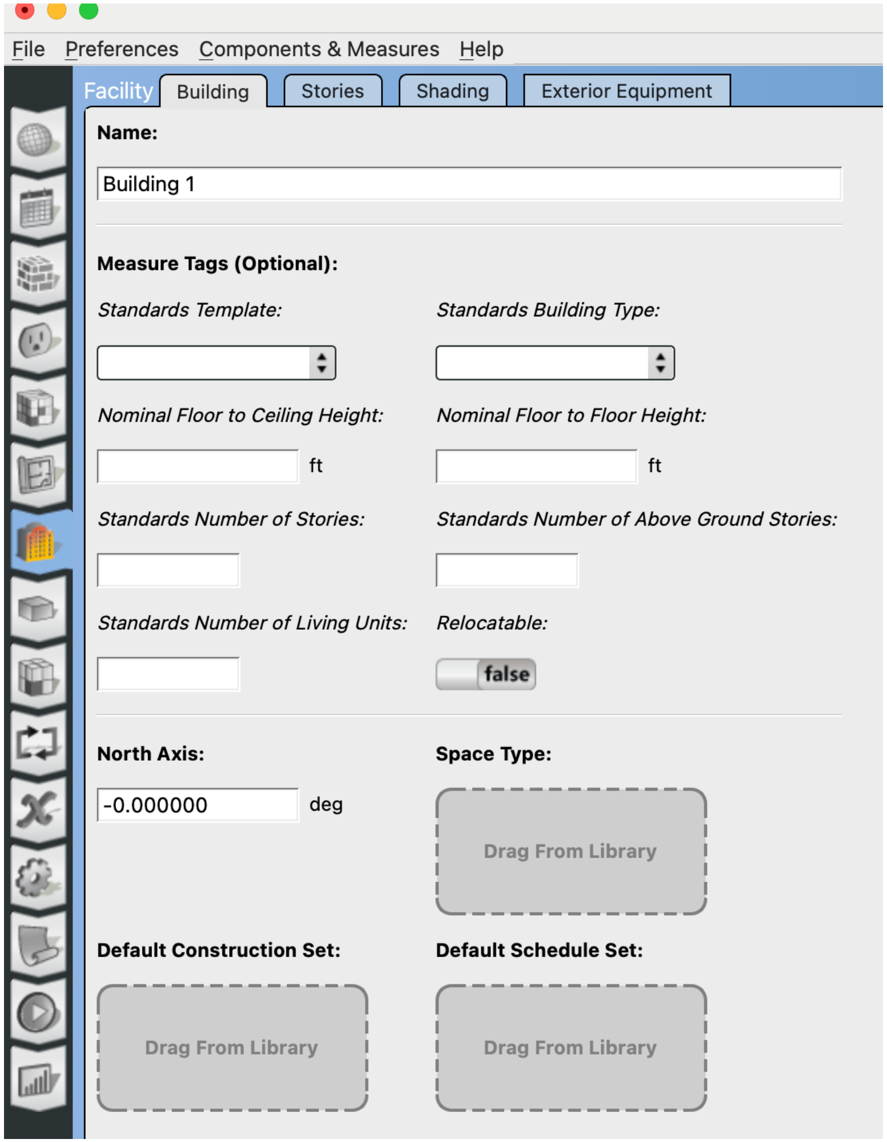






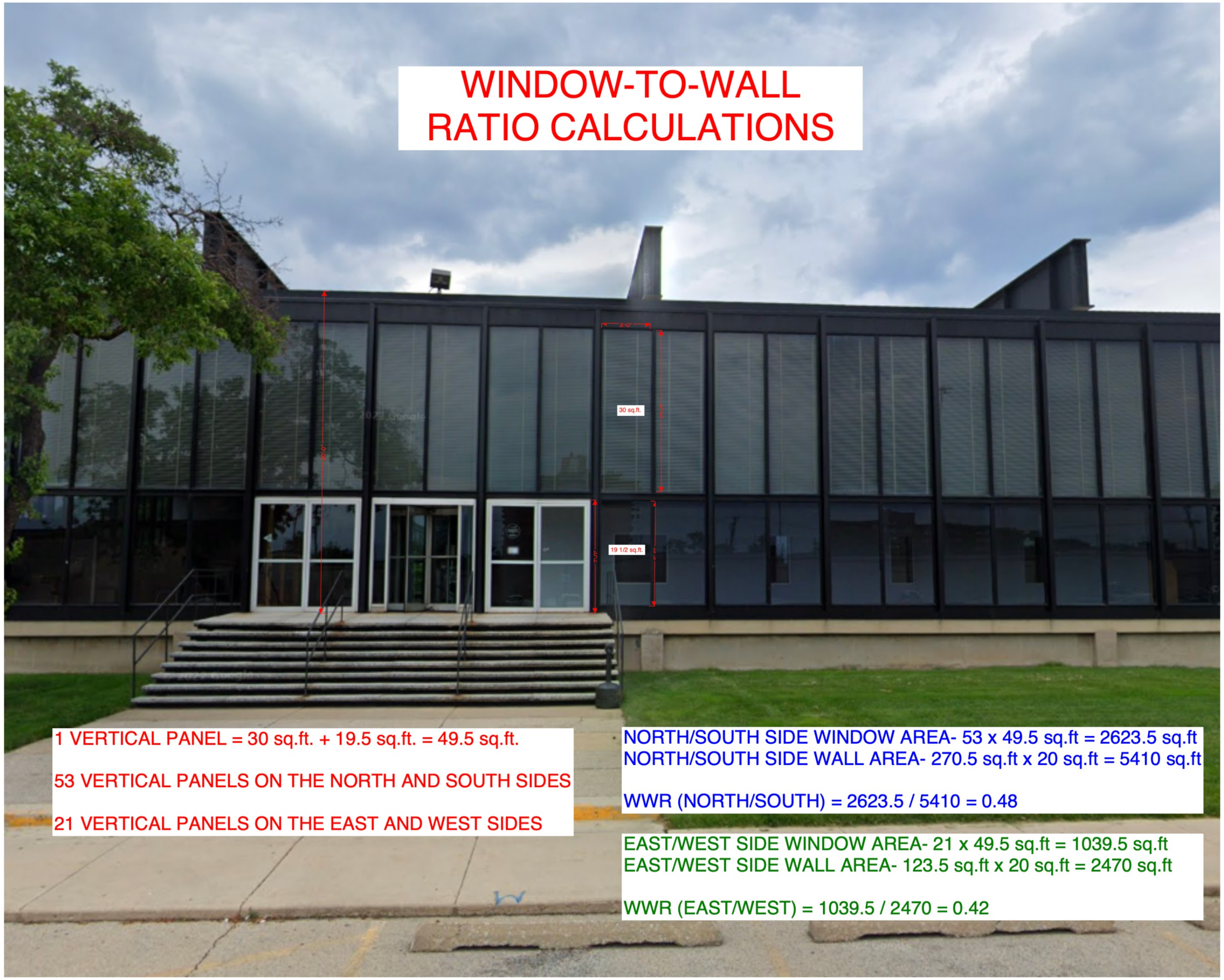
Assignment 3 Feedback

- Set the North Axis



Assignment 3 Feedback

- Window to Wall Ratio calculation:



Assignment 3 Feedback

- Window to Wall Ratio calculation:

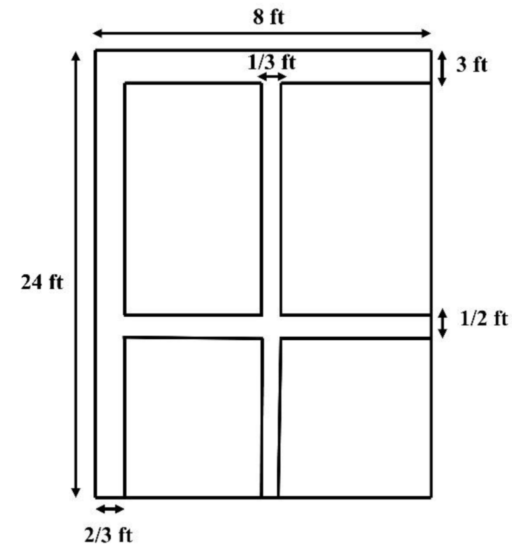


Figure 2 Geometrical characteristics of Hermann Hall's Façade

Each segment of the wall consists of a set of windows which is repeated for 44 times in the length of the building. Since the length of the building is approximately 350 ft, the length of each segment would be about 8ft:

Length of each segment: $\frac{350\,ft}{44} = 7.95\,ft \cong 8\,ft$

The WWR calculation is as follows:

Total area of each segment: $24 \times 8 = 192\,ft^2$

Window frame area: $(8 - \frac{2}{3} - \frac{1}{3})(3 + \frac{1}{2}) + (24)(\frac{2}{3} + \frac{1}{3}) = 48.5\,ft^2$

Window area: $192 - 48.5 = 143.5\,ft^2$

Window to wall ratio: $WWR = \frac{143.5}{192} = 0.74.74 \cong 0.75$

Assignment 3 Feedback

- Good comparisons:

To compare the obtained results, we have taken IIT Campus database is from 2017/2017 and CBECS database is from 2018.

Table 4: Site EUI comparison.

Data base	Site EUI mean (kBtu/ft^2)
Herman Hall building energy model	77.52
CBECS	84.3
Herman Hall Campus Data	230.68

Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	2,681,223 kBtu
Total Building Area	35,145 ft^2
Total Site EUI	76.29 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Assignment 3 Feedback

- Good comparisons:

Space Type	Cooling Design Load (ton)	Heating Design Load (kBtu/h)
Entrance Lobby	9.97	112.40
Lecture Hall	9.42	19.78
Offices	17.50	190.87
Restrooms	0.80	44.83

Table 5: U-factor comparison

Data base	U-factor (Btu/ft*h*F)
Energy building model	0.62
ASHRAE 90.1	0.083

Assignment 3 Feedback

- Good comparisons:

Table 2. Base surface constructions			
Construction	Net Area [ft²]	Surface Count	R Value [ft²*h*R/BTU]
Typical IEAD Roof R-13.89	33,48	28	13.11
Typical Insulated Steel Framed Exterior Wall R-6.41	3,152	16	5.56

In the case of the exterior wall construction, the code requires a R-value of 20, so it does not meet the code requirements. For the roof, ASHRAE 90.1 requires a R-value of 38. The model shows that Hermann Hall has a well insulated roof, but the exterior walls are under insulated.

Table 3. Subsurface constructions					
Construction	Net Area [ft²]	Surface Count	U-factor [Btu/ft²*h*R]	SHGC	VLT
U 0.62 SHGC 0.41 Simple Glazing Window U-0.62 SHGC 0.41	9,456	16	0.62	0.41	0.32

The U-factor of a window is a measure of its thermal resistance. The lower the U-factor, the better insulation and the less heat transfer through the window. The ASHRAE 90.1 code requirement for U-factor in Chicago is 0.47. Therefore, the subsurface construction in the model does not meet the code requirement.

Table 4. Window-to-wall ratio					
Description	Total [%]	North [%]	East [%]	South [%]	West [%]
Gross Window-Wall Ratio	75.00	75.00	75.00	75.00	75.00
Gross Window-Wall Ratio (Conditioned)	75.00	75.00	75.00	75.00	75.00

Assignment 3 Feedback

- Good summaries:

Table 4: LPD for different spaces

Space Name	Area (ft^2)	Total LPD (W/ft^2)
Auditorium	9546	1.8
East Corridor	8621	0.8
112 Office	1479	1.8
102 Office	2608	1.8
108	1508	2.56
Office 109	506	1.8
Storage	528	1
North Hall	6016	2.56
East Small Corridor	384	0.8
113 Office	1480	1.8
Stairs	288	0.8
South Hall	5356	2.56
Lobby	3394	1
Office 114	3008	2.56
Piano Hall	1456	2.56
Restroom	1034	0.8
Small West Corridor	437	0.8
West Corridor	4354	0.8
West Office	3837	1.8
Office Level 2	4042	1.8

Assignment 3 Feedback

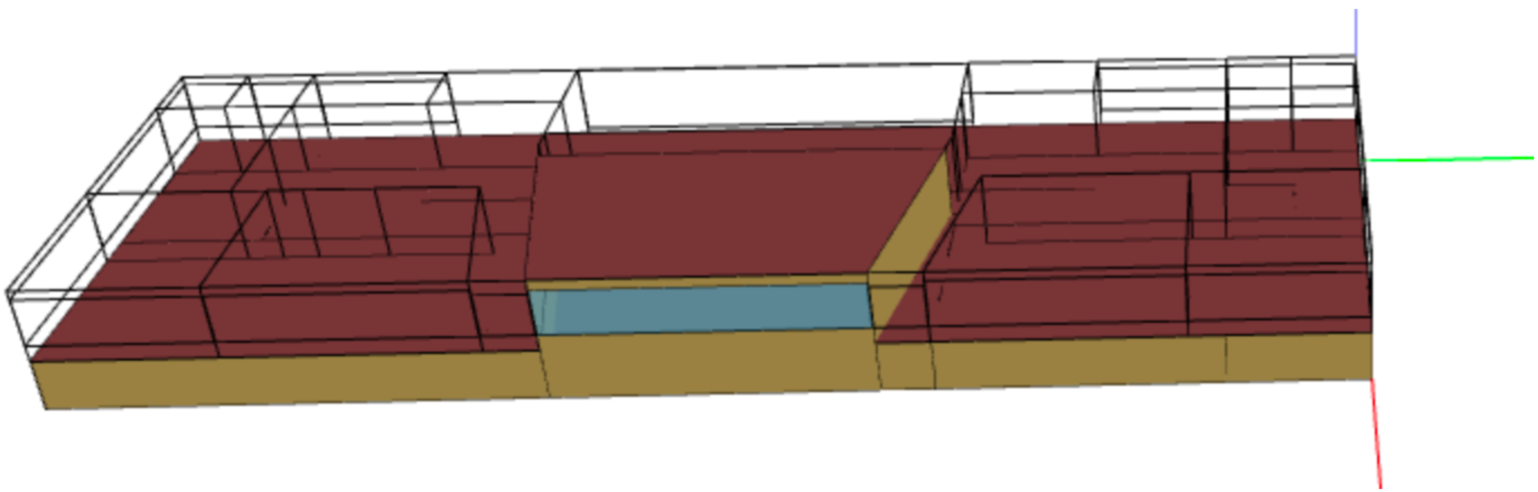
- Good summaries:

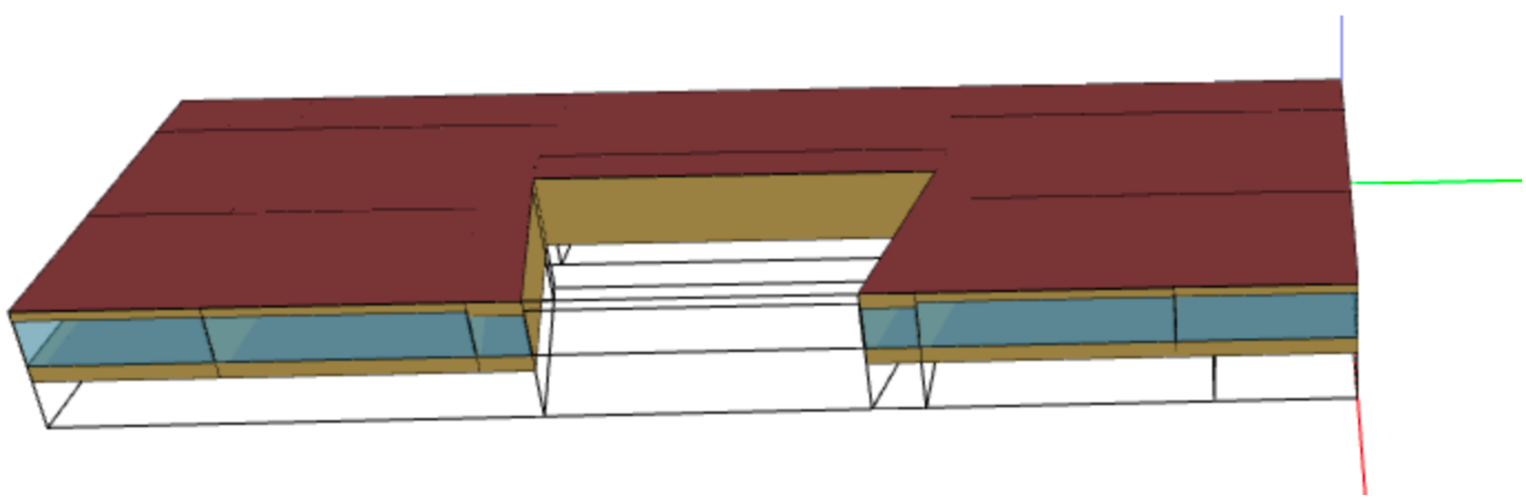
Table 1: Space types for different spaces

Space Type	**Space Name**
College Office	109
	112
	114
	113
	102
	West Office
Large Hotel Banquet	108
	South Hall
	Piano Hall
	North Hall
College Corridor	East Corridor
	East Small Corridor
	Stairs
	Small West Corridor
	West Corridor
College Conference	Auditorium
College Entrance Lobby	Lobby
College Restroom	Restroom
College Storage	Storage

Assignment 3 Feedback

- Good summaries:





Assignment 3 Feedback

- Good summaries:

OpenStudio Results

Model Summary

Building Summary

Data	Value
Building Name	Building 1
Total Site Energy	3,373,897 kBtu
Total Building Area	28,617 ft^2
Total Site EUI	117.90 kBtu/ft^2
OpenStudio Standards Building Type	College

ANOTHER VISUALIZATION TOOL

Another Visualization Tool

- DView is another visualization tool:

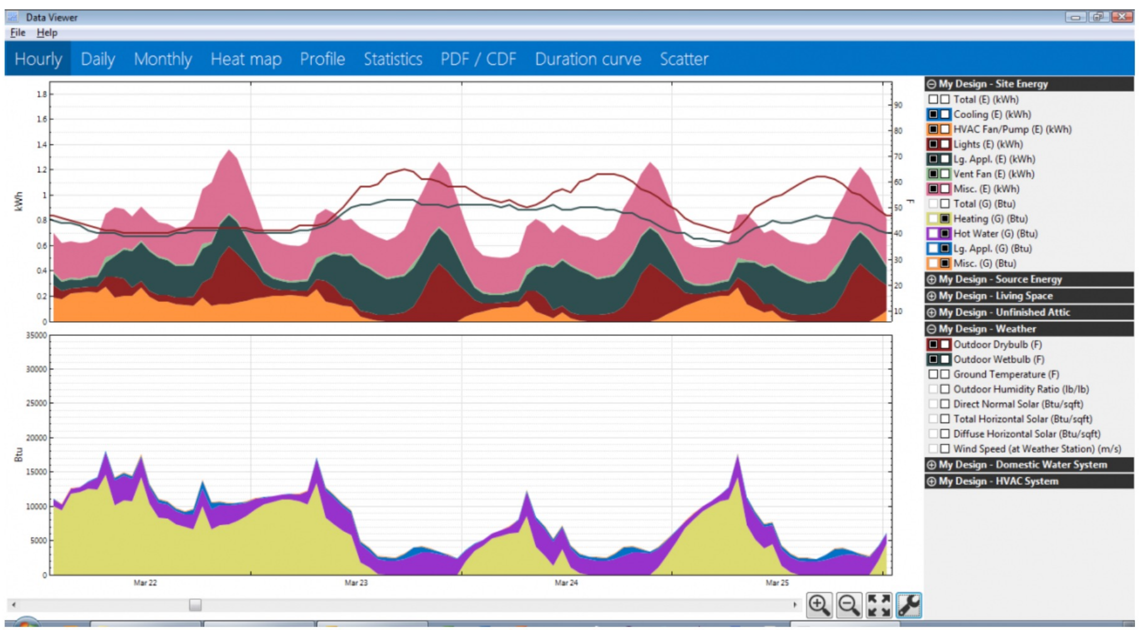
DView

Scott Horowitz edited this page on May 16, 2022 · 25 revisions

DView is used by **OpenStudio**, **BEopt**, and **SAM** for visualizing time series simulation output. It is also available as a standalone application for visual analysis of time-series data at any timestep (e.g., hourly or sub-hourly). DView opens CSV files and also recognizes several weather data file formats, including TMY2, TMY3, and EPW files. See the DataFileTemplate.pdf for more detail. DView can also load EnergyPlus .sql output files.

DView automatically displays data in a variety of graphical/tabular formats, and can be driven by a command line interface.

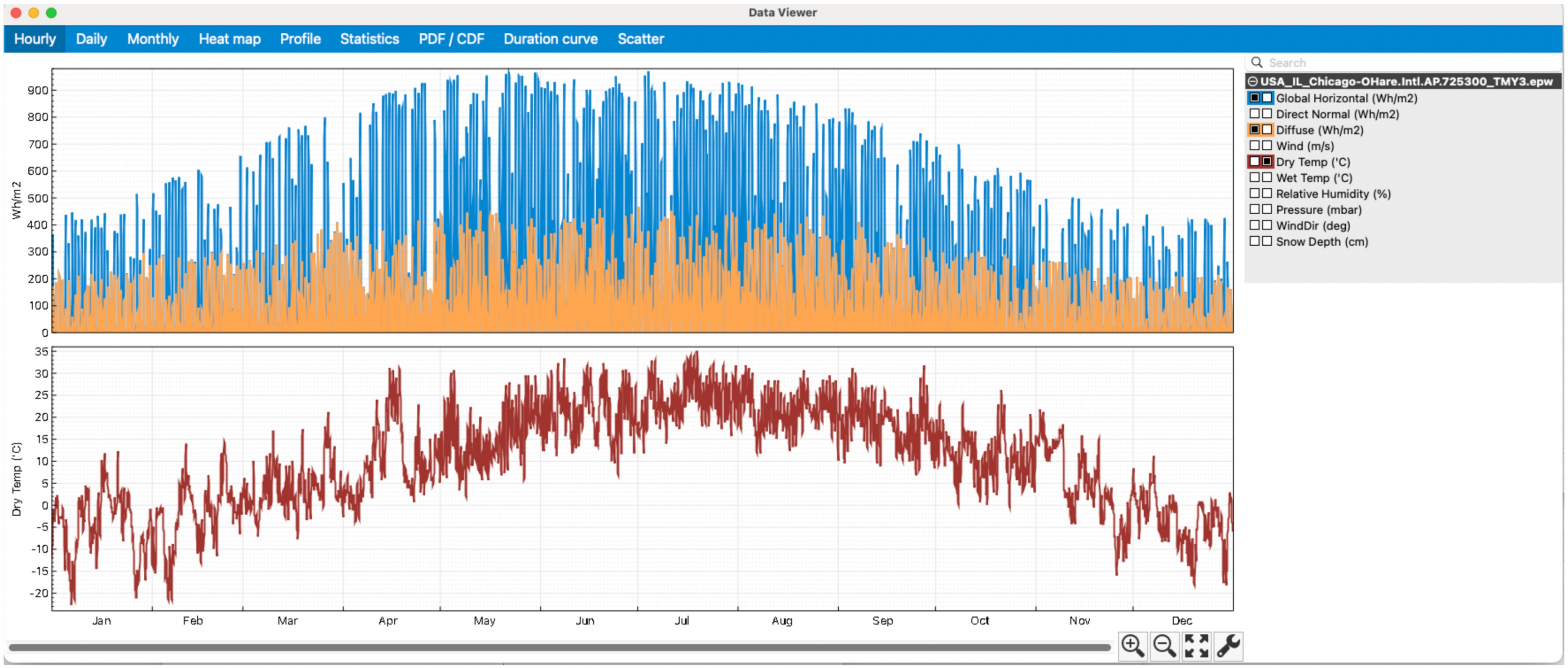
The **Hourly**, **Daily**, and **Monthly** graphs allow you to turn variables on or off with a single click, and to zoom and pan very easily. DView has the ability to display simultaneous line and stacked areas as demonstrated in the Hourly graph below.



Hourly graph

Another Visualization Tool

- DView is another visualization tool:



Another Visualization Tool

- DView is another visualization tool:

DView

DView is provided with BEopt for visualizing time series (e.g., hourly or subhourly) simulation output. It is also available as a stand-alone application for visual analysis of other types of time series data. DView opens CSV files and recognizes several weather data file formats, including TMY2, TMY3, and EPW files.

The stand-alone application can be downloaded in the following versions:

DView 1.2 Windows

DView 1.2 Darwin

DView 1.0 Windows

Additional information can be found on the DView wiki.

https://www.nrel.gov/buildings/beopt.html?utm_medium=print&utm_source=buildings&utm_campaign=beopt

CALIBRATION

Calibration

- Building energy modeling approaches typically require hours or days of intensive data gathering and tuning the building energy model, a process known as ***calibration***.

- Calibration is the process of (i) validate and (2) verify the "*results of a building energy model with the metered energy data*".

- The calibration process is critical for:
  - Establishing quality control of modeling
  - Creating reliable energy modeling results
  - Designing and retrofitting buildings

Calibration

- ASHRAE Guideline 14-2014 has two calibration metrics:

  1. Coefficient of variation of the root mean square error (CVRMSE)

  2. Normalized Mean Biased Error (NMBE)

- CVRMSE shows how well the model match some months much better than others

- NMBE indicates how well the model tend to over or underestimate actual use?

Calibration

$$CVRMSE = 100 * \frac{1}{\bar{y}}\left[\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n-p}\right]^{1/2}$$

$$NMBE = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{(n-p)*\bar{y}} * 100$$

n= number of data periods (at least 12 months ⟶ n=12)
p = number of parameters in baseline model (p=1)
y_i = meter energy data for period i
$\bar{y}$ = mean of meter energy data
$\hat{y}_i$ = simulation-predicted energy data for period i

ASHRAE Guideline 14-2014

Calibration

- Calibration requirements:

Statistic	Monthly	Hourly
CV(RMSE)	15%	30%
NMBE	5%	10%

Calibration

- If possible, we would like to calibrate for all end-uses, similar to the following case study:

	CVRSME	NMBE	Months
All Electricity	6.1%	-0.6%	All
Plug Loads	5.9%	-2.1%	All
Lighting	4.9%	2.6%	All
Fans	9.3%	-1.2%	Omit December
Cooling	12.6%	3.6%	Omit December
All Gas	12.0%	2.3%	Omit December
Heating	12.6%	1.7%	Omit December
Service Hot Water	9.5%	2.3%	Omit April and May

Dahlhausen, Penn State 2014

Calibration

- For our campus buildings, what can use to calibrate buildings?

SENSITIVITY ANALYSIS

Sensitivity Analysis

1. One-factor-at-a-time (+/- 20%, +/- 1 standard deviation):

- ❑ It only considers the local variation and no interaction between parameters (Why this is an issue?)

- ❑ Using standard deviation is preferred but requires assuming a distribution (e.g., boiler efficiency 0.88 +- 20% can give an efficiency of 1.06!)

Sensitivity Analysis

2. Partial Derivatives

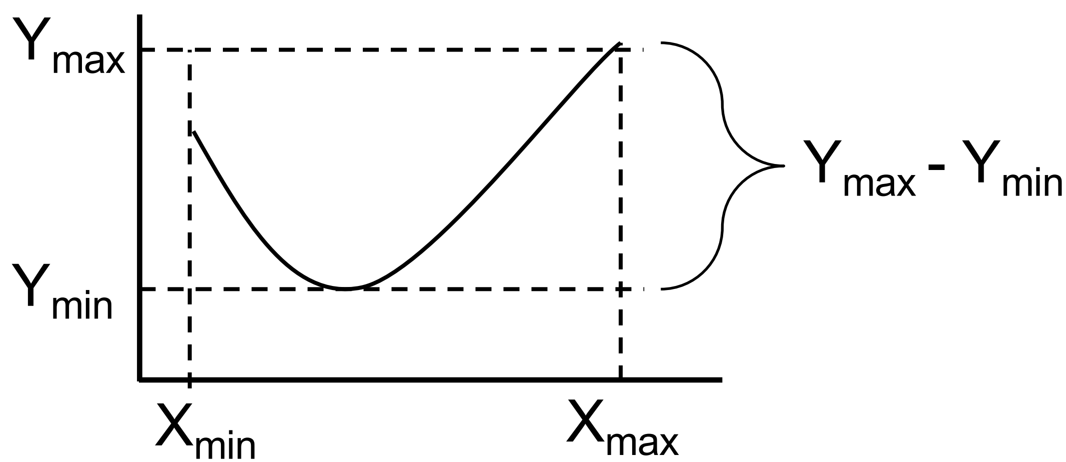
$$sensitivity = \frac{\partial Y}{\partial X_i} = \frac{\Delta Y}{\Delta X_i}$$

For each parameter Xi, i = 1,…,n

Sensitivity Analysis

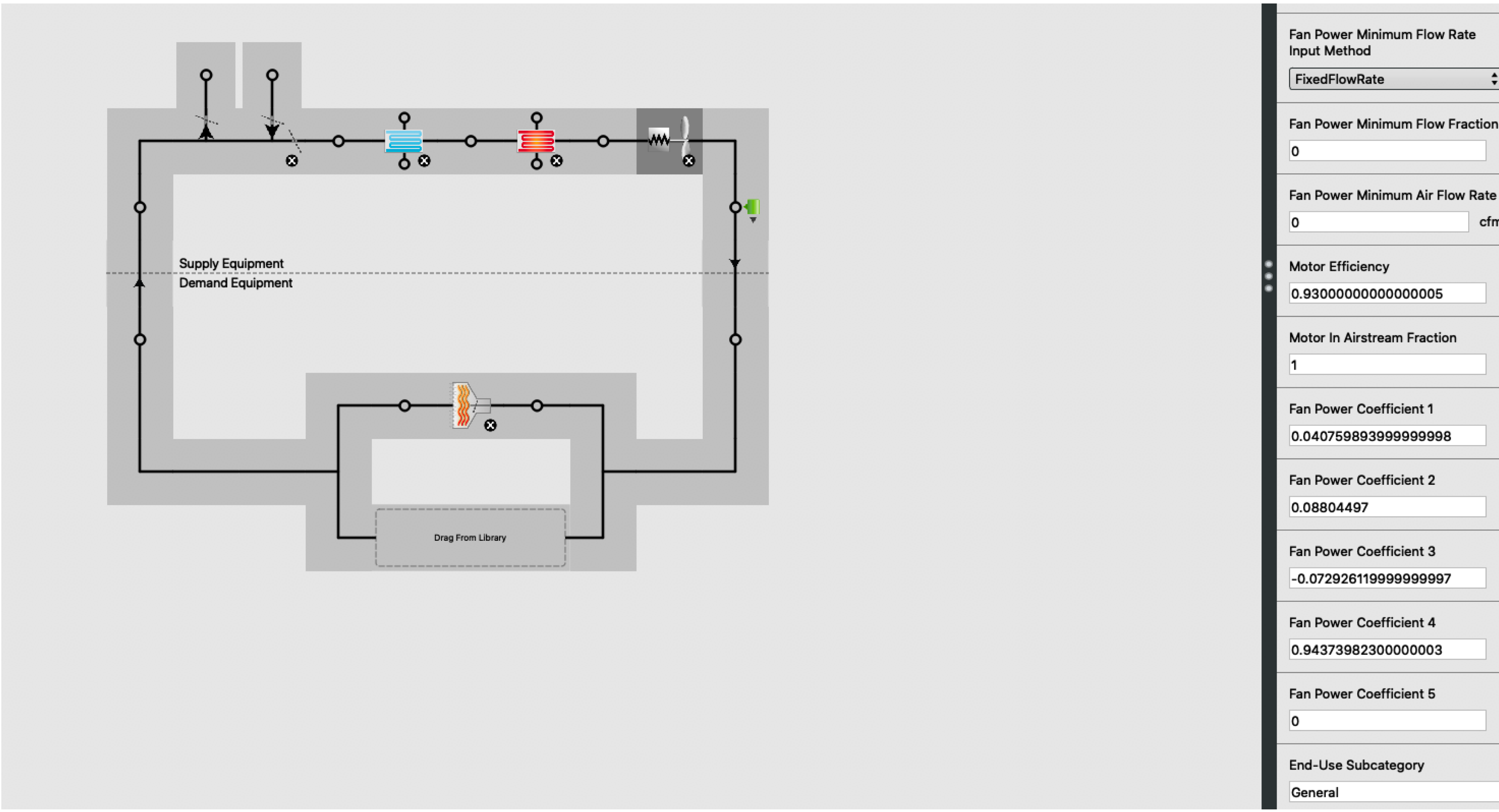
3. Sensitivity Index (Hoffman & Gardener 1983):

$$sensitivity = \frac{Y_{max} - Y_{min}}{Y_{max}}$$

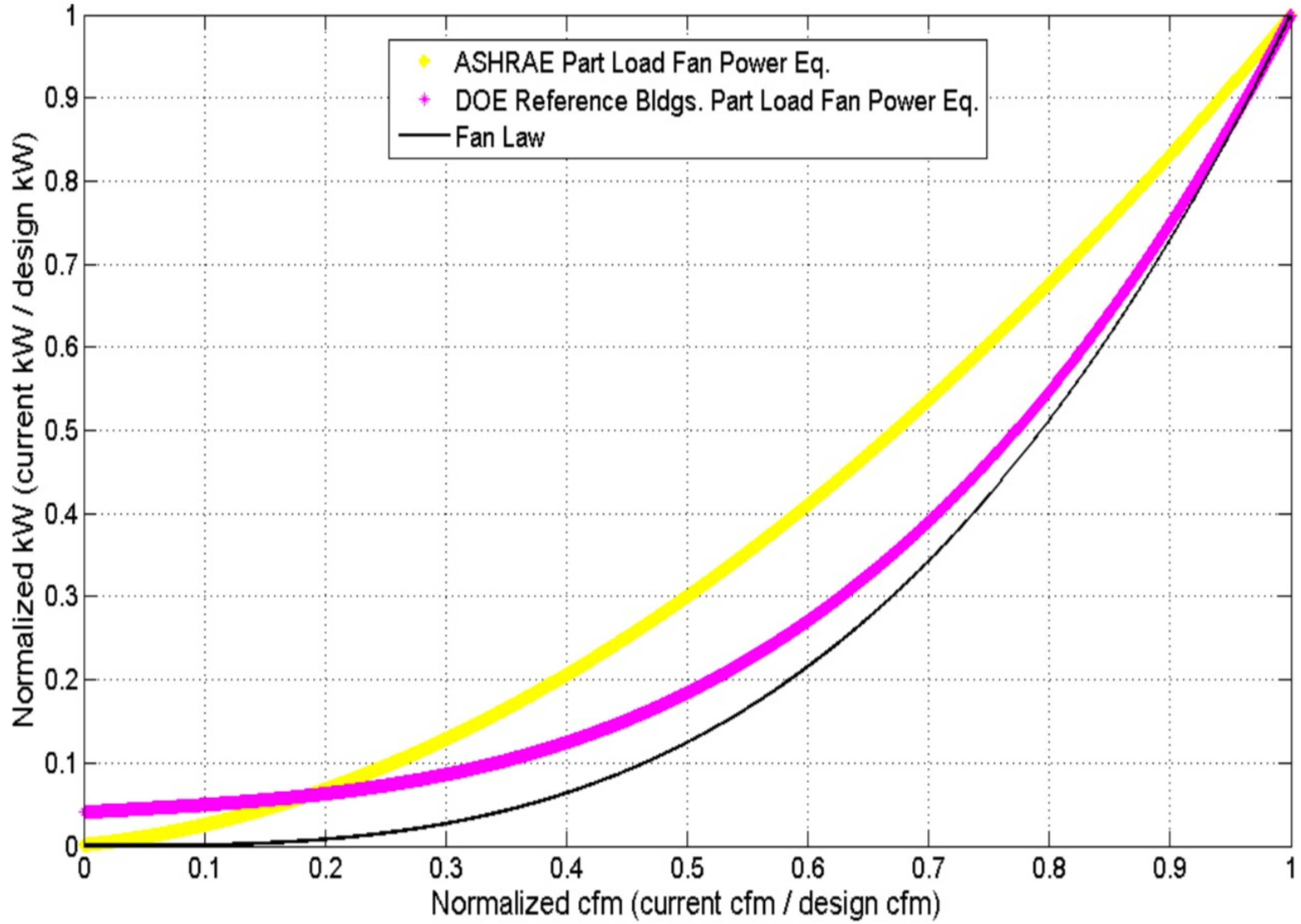


FAN CURVES

Fan Performance



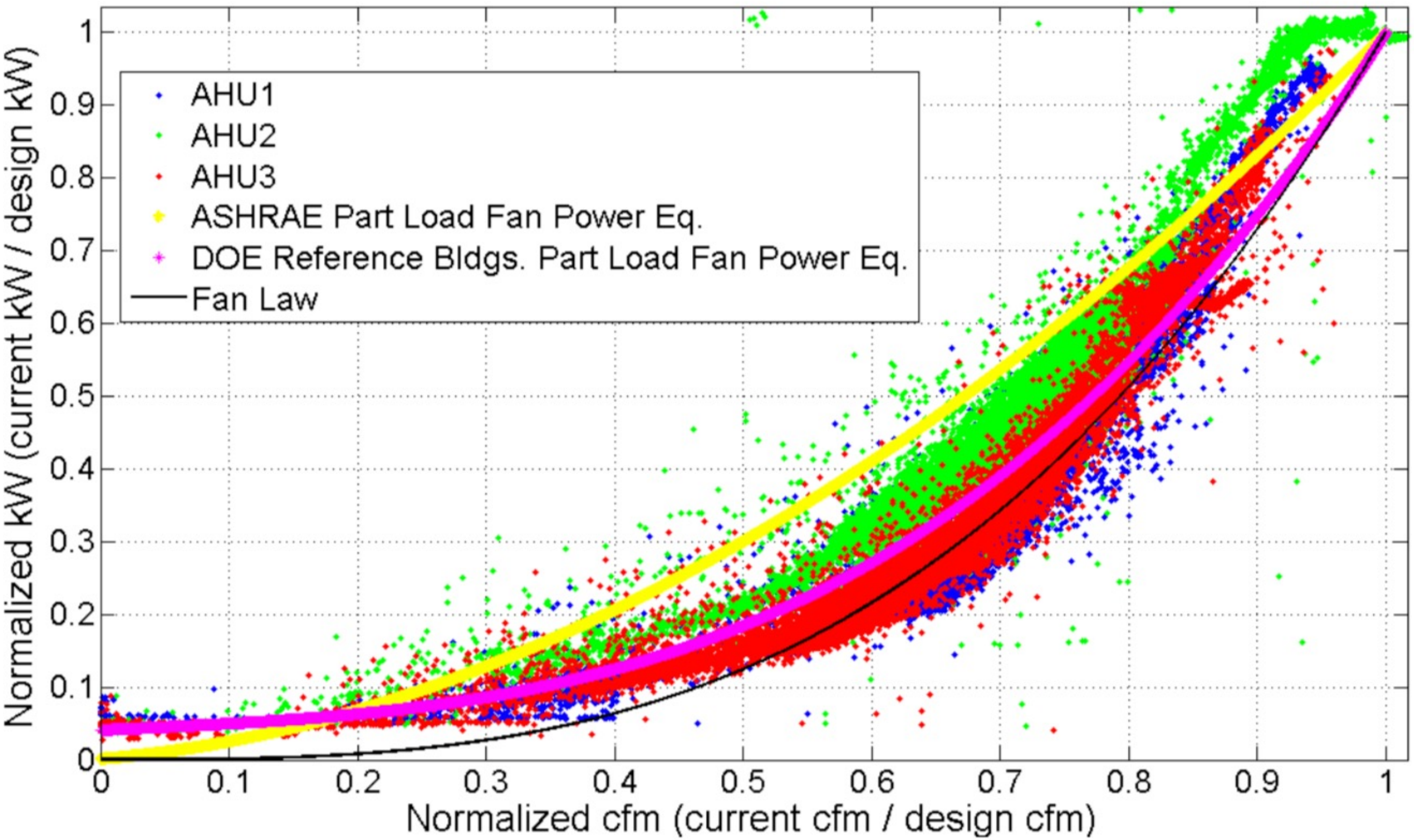
Fan Performance



$$P_{fan} = 0.0013 + 0.1470\,X + 0.9506\,X^2 - 0.0998X^3$$

Salimifard, P, 2015, Masters Thesis, PSU

Fan Performance



Salimifard, P, 2015, Masters Thesis, PSU

Fan Performance

Variable Speed Fan Model

The model for the variable speed fan is similar to the simple single-speed fan model except for a part load factor that multiplies the fan power consumption.

$$f_{flow} = \dot{m}/\dot{m}_{design}$$

$$f_{pl} = c_1 + c_2 \cdot f_{flow} + c_3 \cdot f_{flow}^2 + c_4 \cdot f_{flow}^3 + c_5 \cdot f_{flow}^4$$

$$\dot{Q}_{tot} = f_{pl}\dot{m}_{design}\Delta P / (e_{tot}\rho_{air})$$

The rest of the calculation is the same as for the simple fan.

Nomenclature for Simple Models

$\dot{Q}_{tot}$ is the fan power in watts;

$\dot{m}$ is the air mass flow in kg/s;

$\dot{m}_{design}$ is the design (maximum) air flow in kg/s;

ΔP is the fan design pressure increase in Pascals;

e_{tot} is the fan total efficiency;

ρ_{air} is the air density at standard conditions in kg/m^3;

e_{motor} is the motor efficiency;

$\dot{Q}_{shaft}$ is the fan shaft power in watts;

$\dot{Q}_{toair}$ is the power entering the air in watts;

N_{ratio} is the ratio of actual fan flow rate (or speed) to maximum fan flow rate (or speed)

h_{in}, h_{out} are the inlet and outlet air stream specific enthalpies in J/kg;

w_{in}, w_{out} are the inlet and outlet air stream humidity ratios;

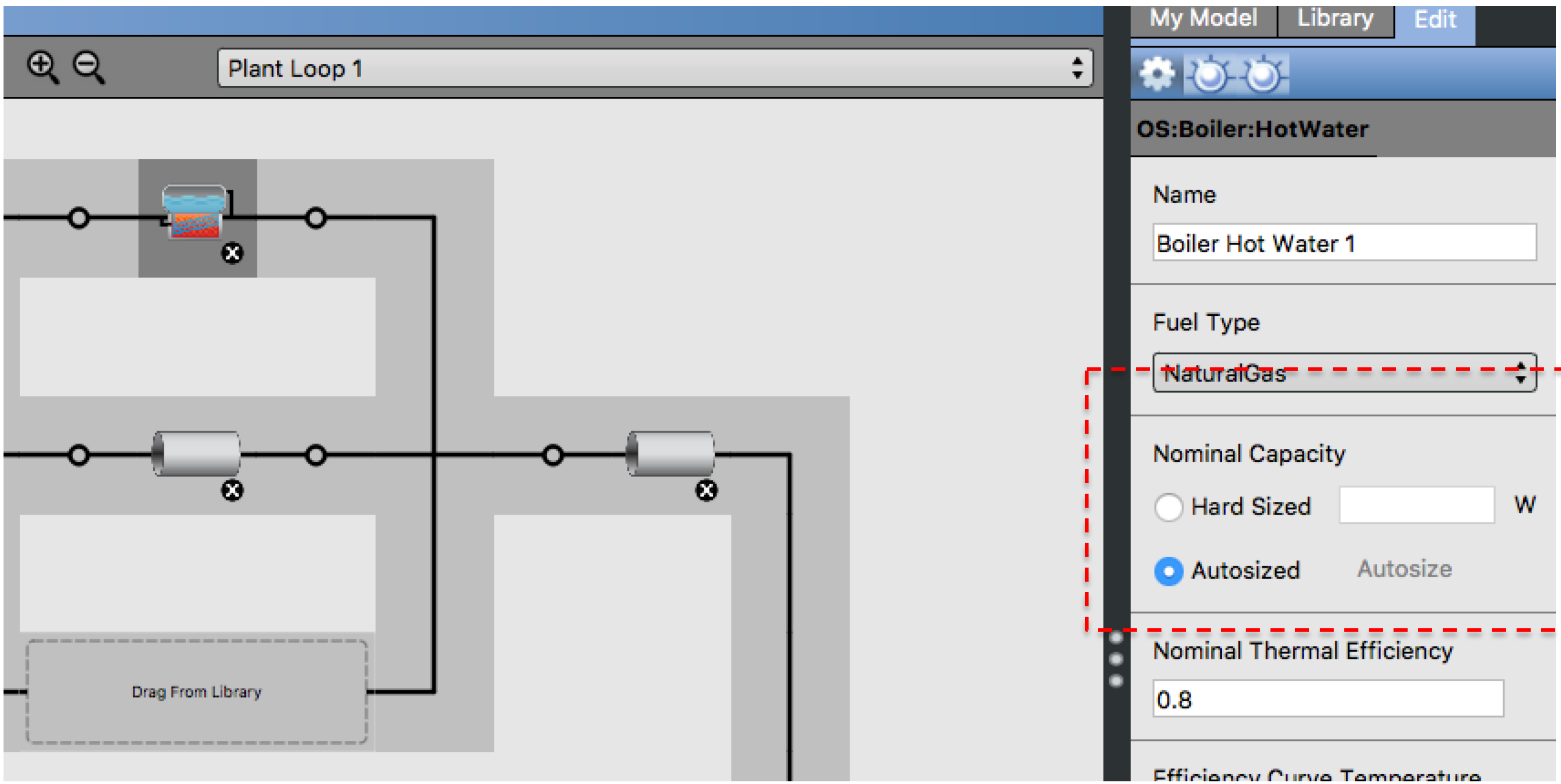
T_{out} is the outlet air temperature in degrees C;

https://bigladdersoftware.com/epx/docs/8-3/engineering-reference/air-system-fans.html#:~:text=For%20these%20input%20objects%2C%20EnergyPlus,be%20modeled%20using%20this%20approach.

AUTOSIZE

Autosize

- EnergyPlus allows sizing the HVAC components based on the loads



Autosize

- Read EIO file to see the sizing values:

eplusout.eio

```
3.8200E-008,0,20
 People Internal Gains Nominal, BB_ONLY_L116 LL-PD,LARGELAB_OCC_SCH,BB_ONLY_L116,225.48,22.4,22.4,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE
ACTIVITY,No,3.8200E-008,0,22
 People Internal Gains Nominal, BB_ONLY_L119 LL-PD,LARGELAB_OCC_SCH,BB_ONLY_L119,146.04,14.5,14.5,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE
ACTIVITY,No,3.8200E-008,0,14
 People Internal Gains Nominal, BB_ONLY_L123 LL-PD,LARGELAB_OCC_SCH,BB_ONLY_L123,42.36,4.2,4.2,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE ACTIVITY,No,
3.8200E-008,0,4
 People Internal Gains Nominal, BB_ONLY_L221 LL-PD,LARGELAB_OCC_SCH,BB_ONLY_L221,53.51,5.3,5.3,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE ACTIVITY,No,
3.8200E-008,0,5
 People Internal Gains Nominal, PTAC_L119A LL-PD,LARGELAB_OCC_SCH,PTAC_L119A,21.18,2.1,2.1,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE ACTIVITY,No,
3.8200E-008,0,2
 People Internal Gains Nominal, PTAC_L120 LL-PD,LARGELAB_OCC_SCH,PTAC_L120,85.84,8.5,8.5,9.929E-002,10.072,0.300,0.700,AutoCalculate,MEDIUM OFFICE ACTIVITY,No,
3.8200E-008,0,9
! <Lights Internal Gains Nominal>,Name,Schedule Name,Zone Name,Zone Floor Area {m2},# Zone Occupants,Lighting Level {W},Lights/Floor Area {W/m2},Lights per person {W/
person},Fraction Return Air,Fraction Radiant,Fraction Short Wave,Fraction Convected,Fraction Replaceable,End-Use Category,Nominal Minimum Lighting Level {W},Nominal
Maximum Lighting Level {W}
 Lights Internal Gains Nominal, C.O_C1 3,OFFICE_LIGHT_SCH_9-8,RTU1 1,124.95,2.1,55.059,0.441,25.970,0.000,0.648,0.200,0.152,1.000,General,0.000,55.059
 Lights Internal Gains Nominal, C.O_C1 5,OFFICE_LIGHT_SCH_9-8,RTU1 1,124.95,2.1,55.059,0.441,25.970,0.000,0.648,0.200,0.152,1.000,General,0.000,55.059
 Lights Internal Gains Nominal, C.O_C1 7,OFFICE_LIGHT_SCH_9-8,RTU1 1,124.95,2.1,80.470,0.644,37.956,0.000,0.648,0.200,0.152,1.000,General,0.000,80.470
 Lights Internal Gains Nominal, C.O_C2 3,OFFICE_LIGHT_SCH_9-8,RTU1 1,124.95,2.1,100.000,0.800,47.168,0.000,0.648,0.200,0.152,1.000,General,0.000,100.000
 Lights Internal Gains Nominal, COR-C1 6,BLDG LIGHT 24 HR,RTU1 1,124.95,2.1,120.000,0.960,56.601,0.000,0.648,0.200,0.152,1.000,General,120.000,120.000
 Lights Internal Gains Nominal, C.O_R2 2,OFFICE_LIGHT_SCH_9-8,RTU2 1,101.45,2.7,81.000,0.798,30.264,0.000,0.333,0.200,0.467,1.000,General,0.000,81.000
 Lights Internal Gains Nominal, C.O_R3 3,OFFICE_LIGHT_SCH_9-8,RTU2 1,101.45,2.7,162.000,1.597,60.527,0.000,0.333,0.200,0.467,1.000,General,0.000,162.000
 Lights Internal Gains Nominal, C.O_R_3,OFFICE_LIGHT_SCH_9-8,RTU2 1,101.45,2.7,54.000,0.532,20.176,0.000,0.333,0.200,0.467,1.000,General,0.000,54.000
 Lights Internal Gains Nominal, C.O_R2 1,OFFICE_LIGHT_SCH_9-8,RTU5 1,409.61,9.7,84.375,0.206,8.676,0.000,0.333,0.200,0.467,1.000,General,0.000,84.375
 Lights Internal Gains Nominal, C.O_R3 1,OFFICE_LIGHT_SCH_9-8,RTU5 1,409.61,9.7,175.781,0.429,18.075,0.000,0.333,0.200,0.467,1.000,General,0.000,175.781
 Lights Internal Gains Nominal, C.O_R3 2,OFFICE_LIGHT_SCH_9-8,RTU5 1,409.61,9.7,260.156,0.635,26.750,0.000,0.333,0.200,0.467,1.000,General,0.000,260.156
 Lights Internal Gains Nominal, C.O_R_2,OFFICE_LIGHT_SCH_9-8,RTU5 1,409.61,9.7,48.316,0.118,4.968,0.000,0.333,0.200,0.467,1.000,General,0.000,48.316
 Lights Internal Gains Nominal, COR-R1 2,BLDG LIGHT 24 HR,RTU5 1,409.61,9.7,106.176,0.259,10.918,0.000,0.333,0.200,0.467,1.000,General,106.176,106.176
 Lights Internal Gains Nominal, LIGHTS 10,L117_LGT_SCH_9-5,RTU5 1,409.61,9.7,515.061,1.257,52.961,0.000,0.648,0.200,0.152,1.000,General,0.000,515.061
 Lights Internal Gains Nominal, LIGHTS 9,L117_LGT_SCH_9-5,RTU5 1,409.61,9.7,432.824,1.057,44.505,0.000,0.648,0.200,0.152,1.000,General,0.000,432.824
 Lights Internal Gains Nominal, LIGHTS 11,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,299.250,0.500,N/A,0.000,0.648,0.200,0.152,1.000,General,299.250,299.250
 Lights Internal Gains Nominal, LIGHTS 12,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,65.835,0.110,N/A,0.000,0.648,0.200,0.152,1.000,General,65.835,65.835
 Lights Internal Gains Nominal, LIGHTS 13,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,212.625,0.355,N/A,0.000,0.648,0.200,0.152,1.000,General,212.625,212.625
 Lights Internal Gains Nominal, LIGHTS 14,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,88.515,0.148,N/A,0.000,0.648,0.200,0.152,1.000,General,88.515,88.515
 Lights Internal Gains Nominal, LIGHTS 15,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,17.640,2.947E-002,N/A,0.000,0.648,0.200,0.152,1.000,General,17.640,17.640
 Lights Internal Gains Nominal, LIGHTS 16,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,325.080,0.543,N/A,0.000,0.648,0.200,0.152,1.000,General,325.080,325.080
 Lights Internal Gains Nominal, LIGHTS 17,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,428.400,0.716,N/A,0.000,0.648,0.200,0.152,1.000,General,428.400,428.400
 Lights Internal Gains Nominal, LIGHTS 18,BLDG LIGHT 24 HR,UNCON_BASE,598.67,0.0,133.875,0.224,N/A,0.000,0.648,0.200,0.152,1.000,General,133.875,133.875
```

Autosize

- Look for the “HVAC System Sizing”:

file:///Volumes/GoogleDrive/My%20Drive/Courses/cae526_f18/Project/P

Table of Contents

Autosize

- What are the pro and cons of using the autosizing feature?

CLASS ACTIVITY

Class Activity

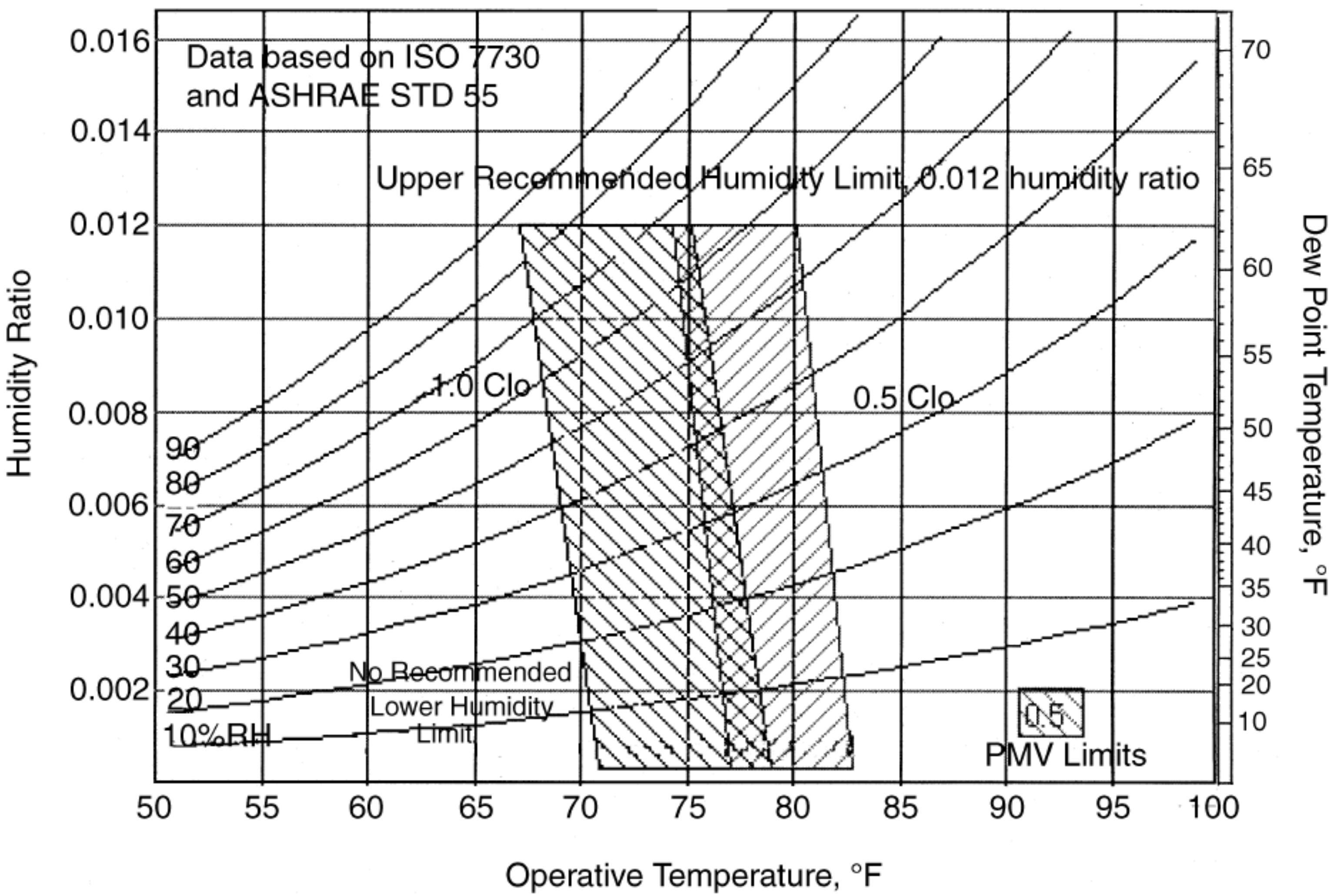
- Find six or seven autosize values and replace them in the model.

- Create a new model "save as" and increase or decreases the sizes and comment on the results

https://docs.google.com/spreadsheets/d/1eUYbP00uv7EYl3cB5poRmNHMOfJb292LX-gPelbX1Yo/edit#gid=1275549135

SETPOINTS

Setpoints

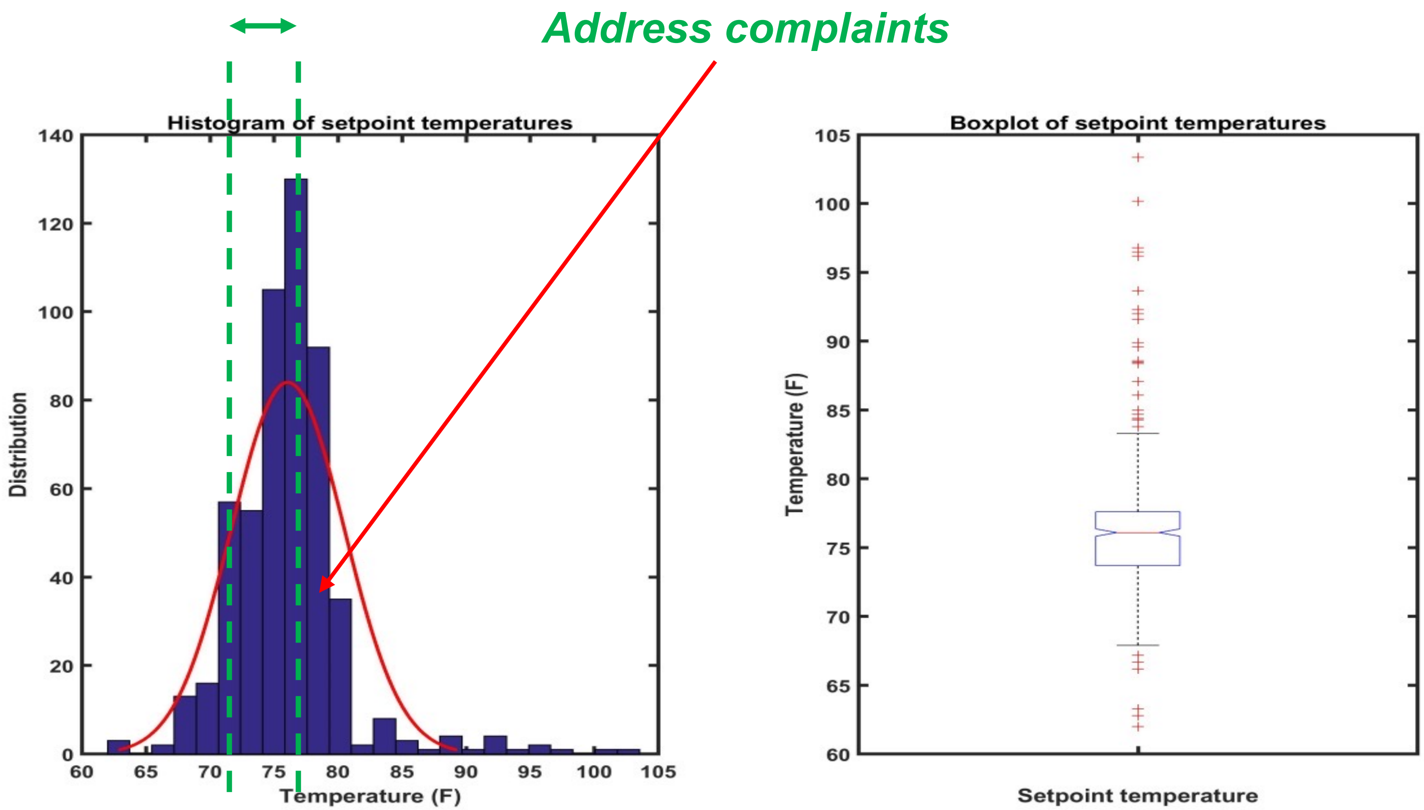


ANSI/ASHRAE Standard 55-2004

Setpoints

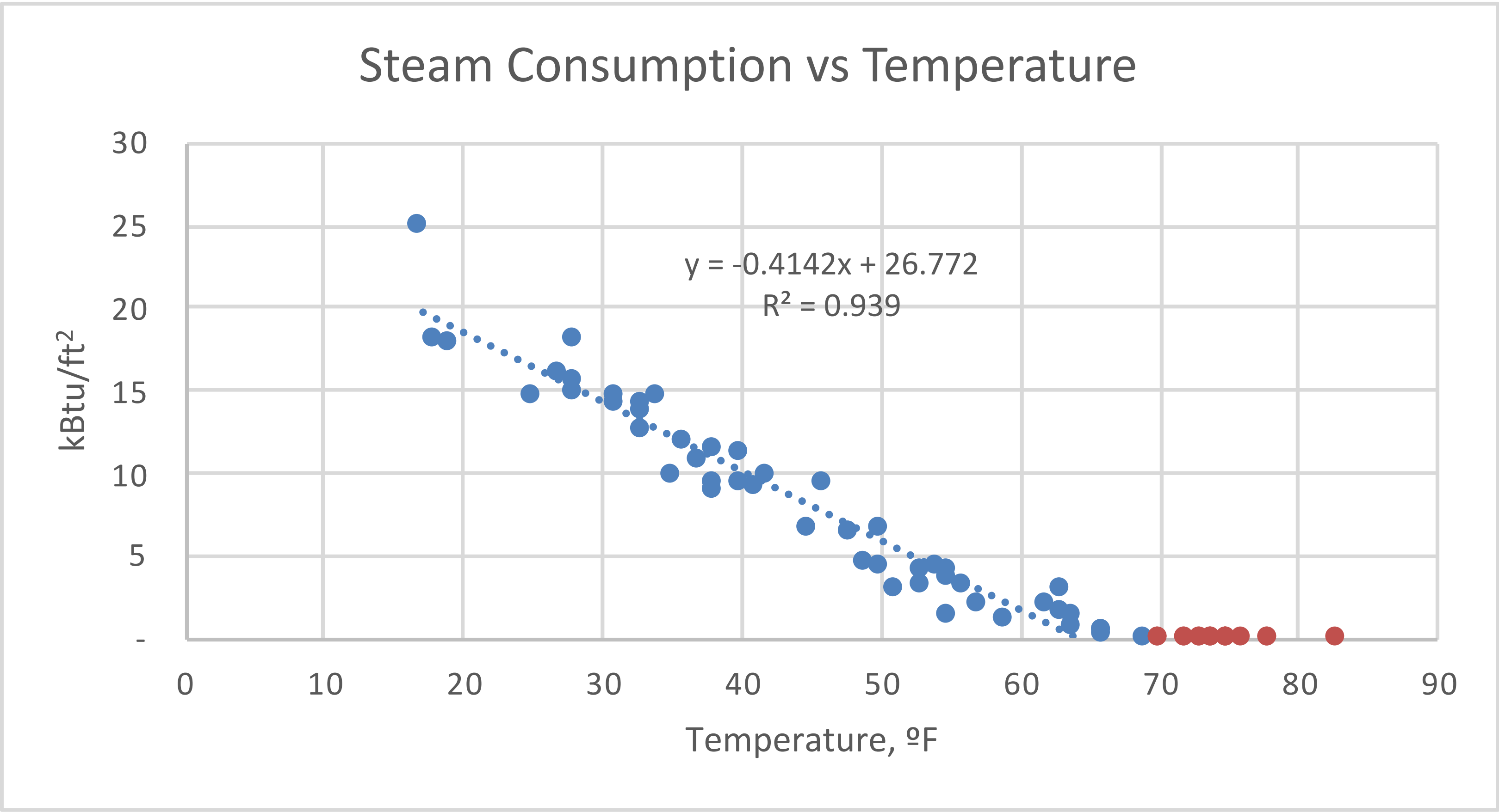
- Poor management of temperature setpoints in the buildings

Thermal comfort range



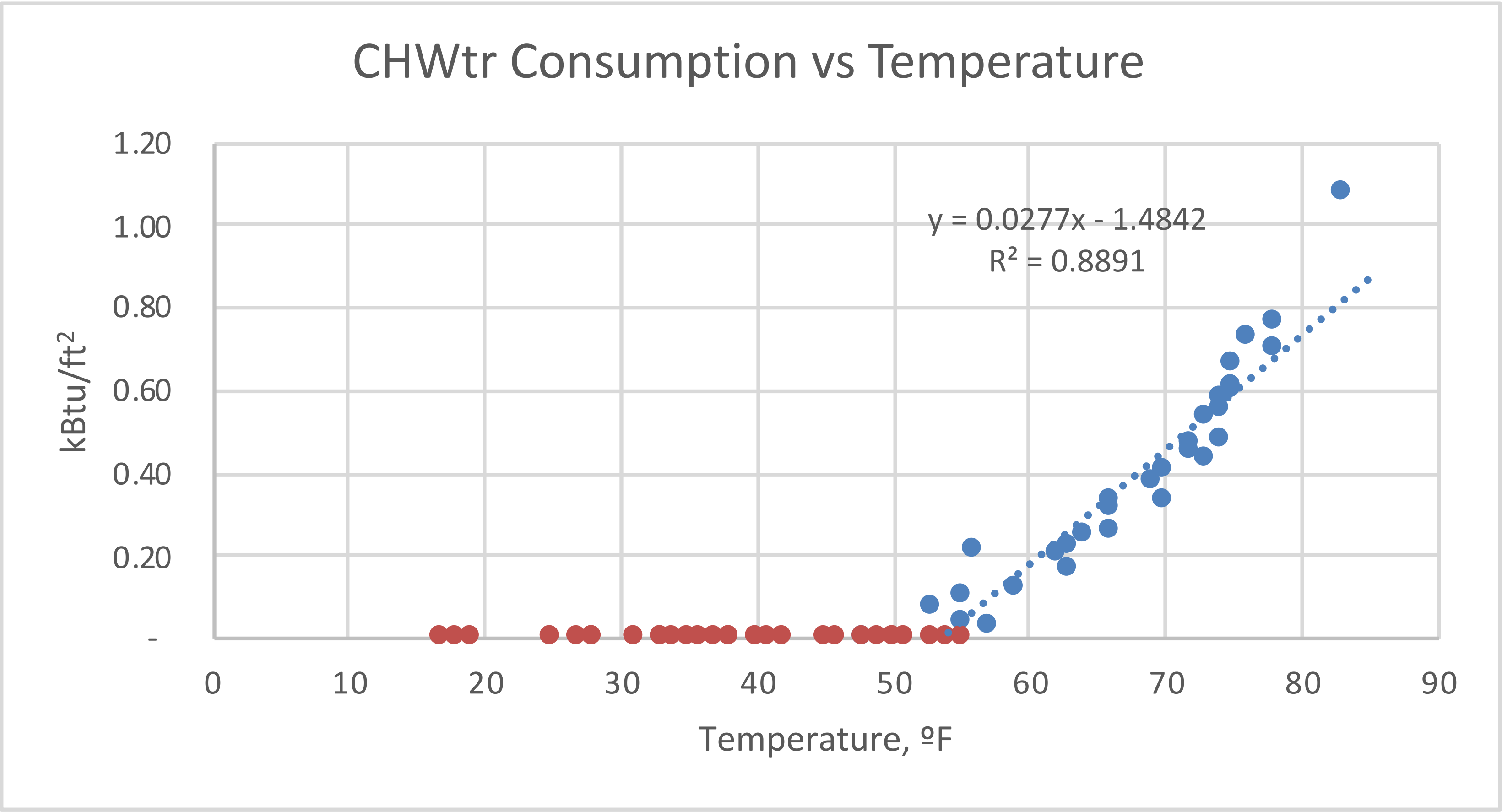
Setpoints

- Wishnick Hall monthly data:



Setpoints

- Wishnick Hall monthly data:



DESIGN VENTILATION

Outdoor Air

- Minimum outdoor air fraction very important

- EnergyPlus options:
  - OA per person (default 20 cfm)
  - OA per floor area
  - OA per zone
  - OA air change per hour
  - Use ~0.1-0.2CFM/ft^2 (or 20% design flow rate)
  - Look at floor plans & ASHRAE 62.1

INFILTRATION

Infiltration

- Infiltration options in E+:
  - Design Flow Rate:

$$Infiltration = \left(I_{Design}\right)\left(F_{Schedule}\right)\left[A + B\left[T_{Zone} - T_{Out}\right] + C(Wind\ Speed) + D(Wind\ Speed)\right]$$

  - Effective Leakage Area:

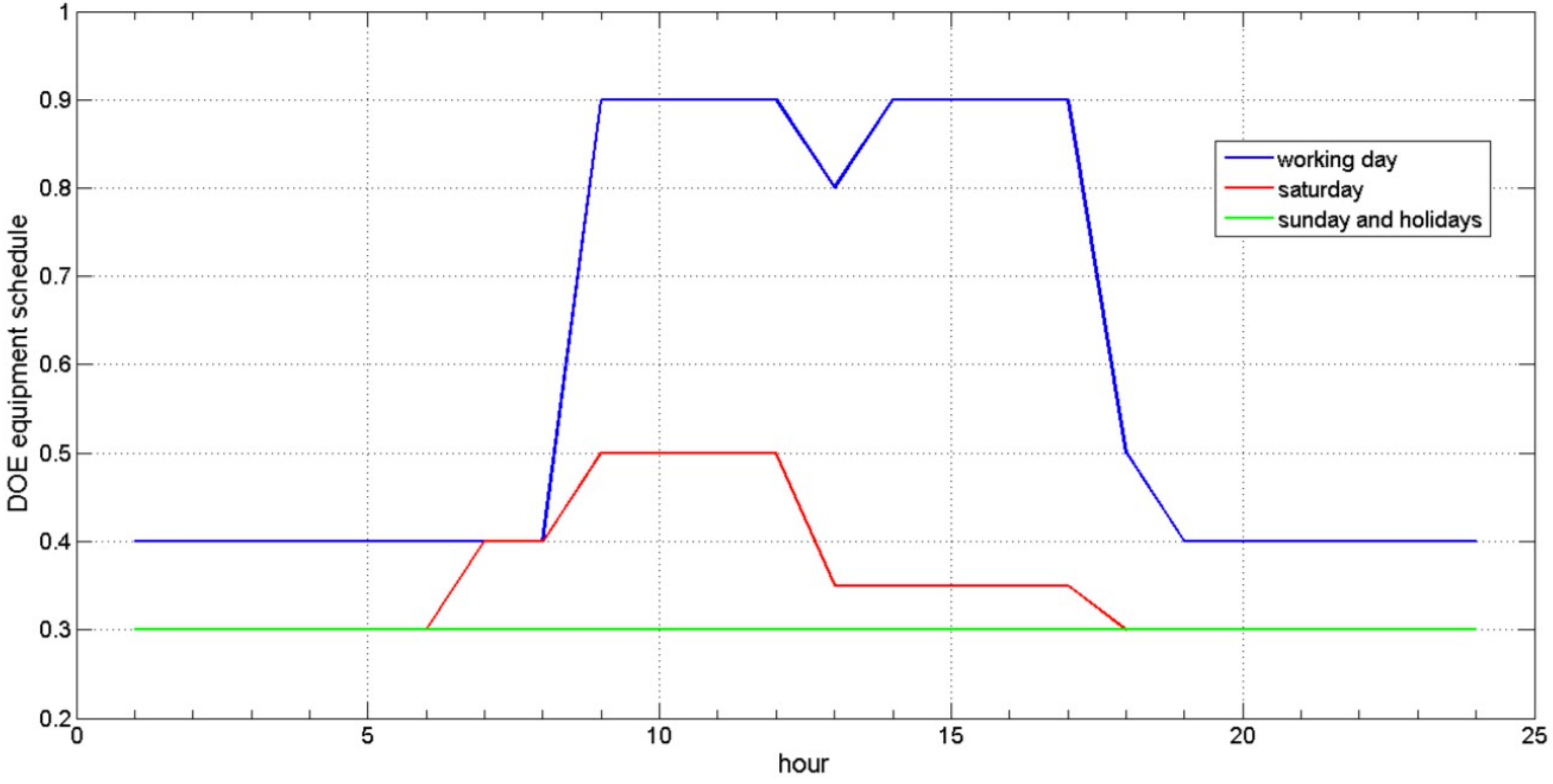
$$Infiltration = \left(F_{Schedule}\right)\frac{A_L}{1000}\sqrt{C_S \Delta T + C_W (Wind\ Speed)^2}$$

  - Flow Coefficient

$$Infiltration = \left(F_{Schedule}\right)\sqrt{\left(c C_S \Delta T^n\right)^2 + \left(c C_W (s \times Wind\ Speed)^{2n}\right)^2}$$

PLUG LOAD

Plug Load Schedule



Is this close to the reality?

Salimifard, P, 2015, Masters Thesis, PSU

Plug Load Schedule

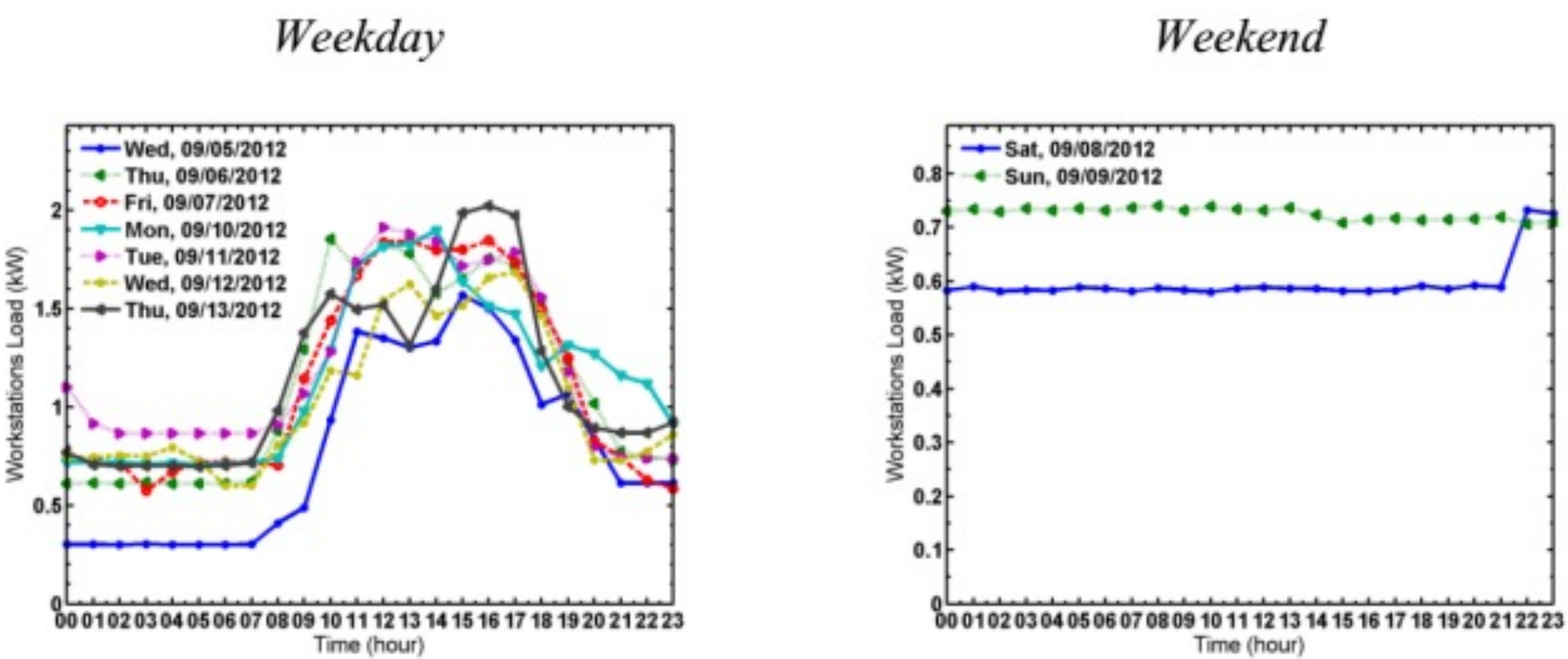


Figure 4. Plug load profiles for workstations.

Delogoshaei et al. (2013) Hourly plug load measurements... AEI 2013

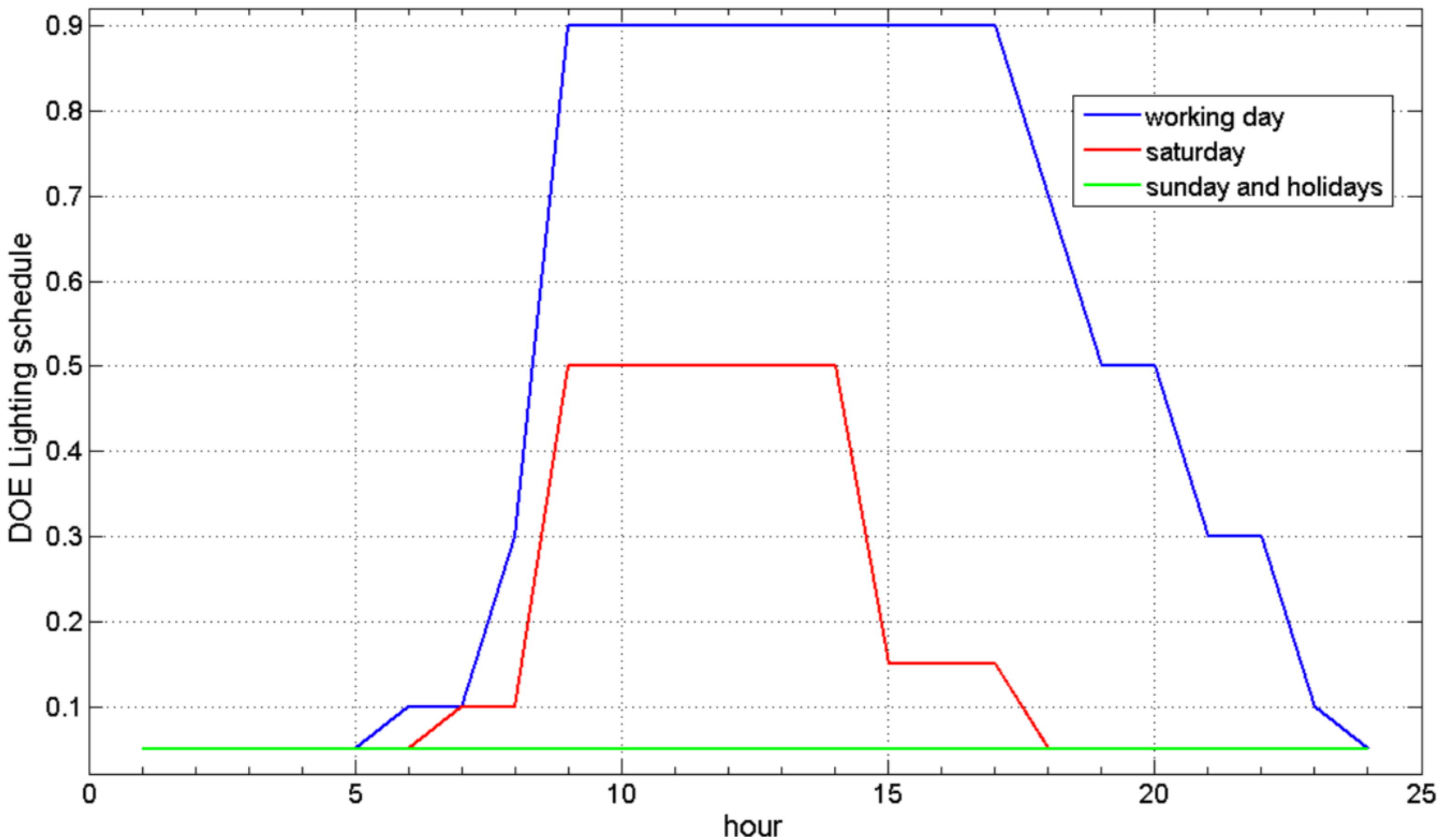
LIGHTING

Lighting Load

$f_{convected}$ = 1.0 – (Fraction Latent + Fraction Radiant + Fraction Lost)

Lighting Schedule

- Suggested DOE Reference building lighting schedule



Is this close to the reality?

Salimifard, P, 2015, Masters Thesis, PSU

Lighting Power Density

- Lighting Power Density (LPD)

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.82
Convention center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	1.00
Health-care clinic	0.87
Hospital	1.21
Hotel	1.00
Library	1.18
Manufacturing facility	1.11
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.06
Office	0.90
Parking garage	0.25
Penitentiary	0.97
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.40
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.66
Workshop	1.20

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Is this close to the reality?

ASHRAE 90.1-2010

Lighting Power Use

- Lighting power use is equal to =

$$Diversity\ Factor \times LPD \times Area$$

CLASS ACTIVITY

Class Activity

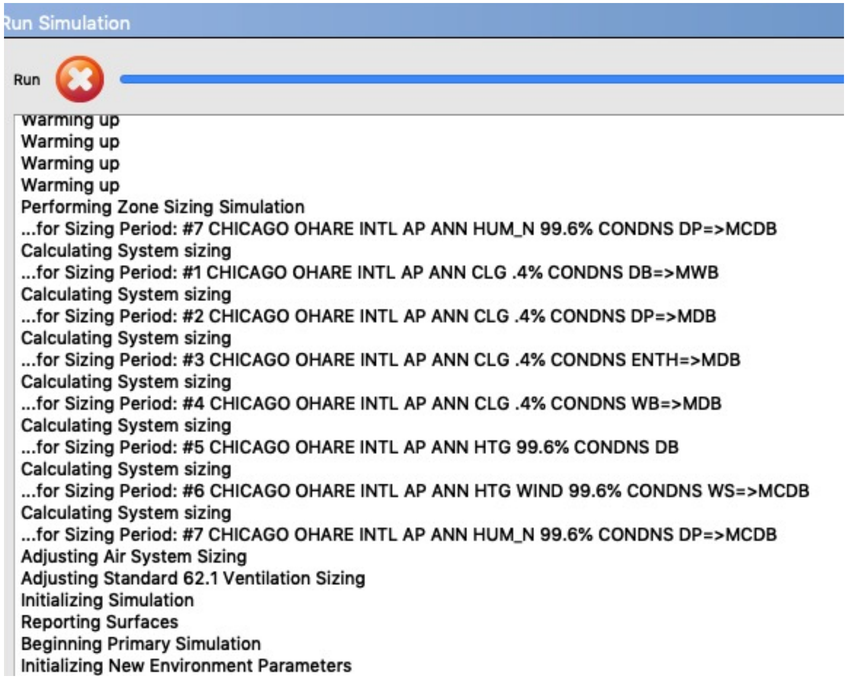
- Calculate the LPD, occupancy, plug load, and associated schedules for this room:

https://docs.google.com/spreadsheets/d/1eUYbP00uv7EYI3cB5poRmNHMOfJb292LX-gPeIbX1Yo/edit#gid=1480758816

SIMULATION

Convergence Tolerances

- Convergence tolerances during warm up days:
  - ❑ Design days or run periods repeat until the simulation reaches to the desired convergence tolerances
  - ❑ There will be a warning is the convergence is not met during the load calculations
  - ❑ It is possible to increase the number of warm up days



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 v1.6. 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
- Download the sample model and the instructions uploaded on Blackboard