CAE 465/526 Building Energy Conservation Technologies

Fall 2022

November 09, 2022

Building Retrofit and Energy Efficiency Measures (EEMs) – Part 2

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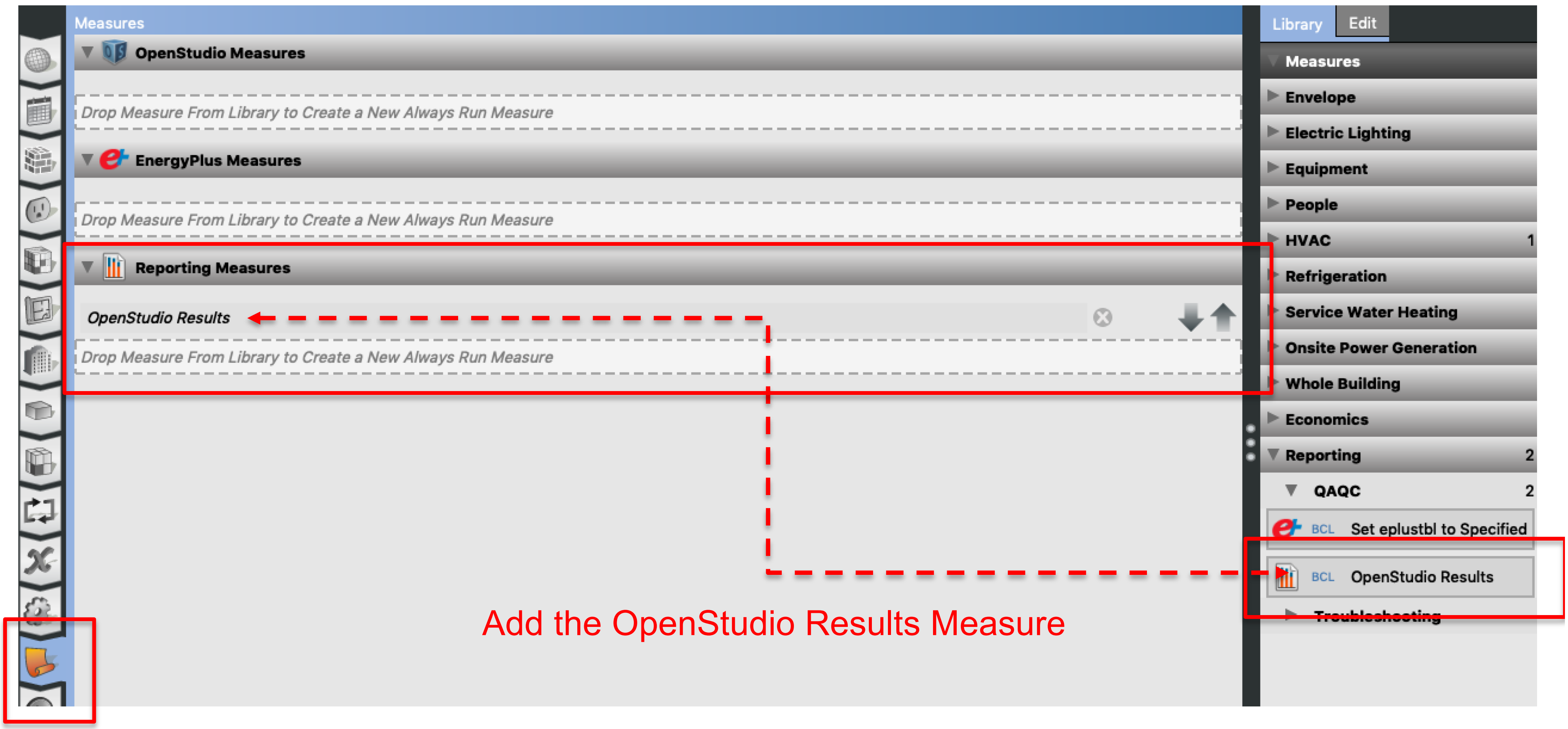
EXAM

PROJECT

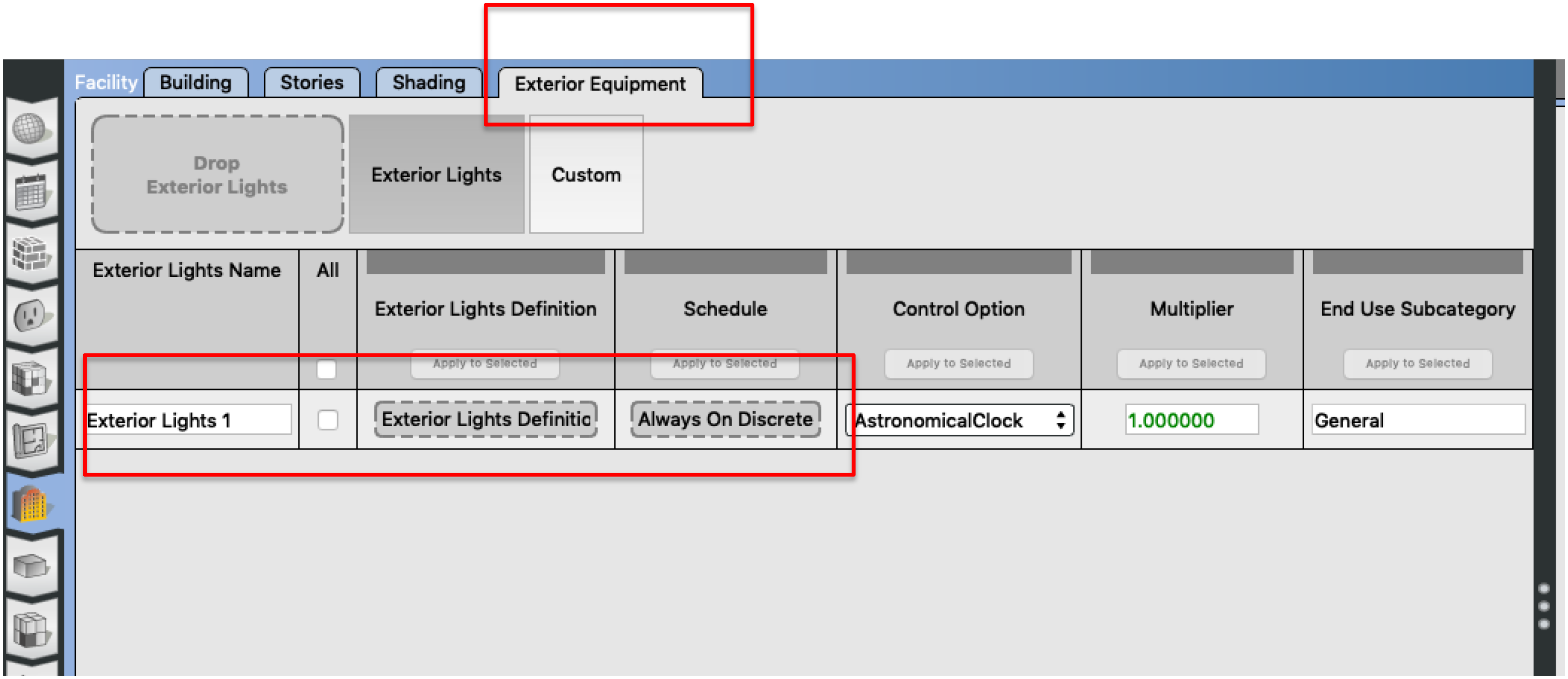
HOW TO EDIT OPENSTUDIO TEMPLATES

OPENSTUDIO TIPS FOR PART 2 AND 3 SUBMISSIONS

Add OpenStudio Results



External Lights



External Lights

- How to find out more information about the inputs

1.16.1 Exterior:Lights

1.16.1.1 Inputs

1.16.1.1.1 Field: Name

This descriptive name allows the values of exterior lights consumption to appear in the "normal" output variable list as well as the meters. It cannot be blank nor can it be duplicated by other Exterior:Lights statements.

1.16.1.1.2 Field: Schedule Name

A schedule will allow the exterior lights consumption to be operationally different, hour to hour as well as seasonally. Fractional values in the basic schedule will be applied to the design level field below.

1.16.1.1.3 Field: Design Level

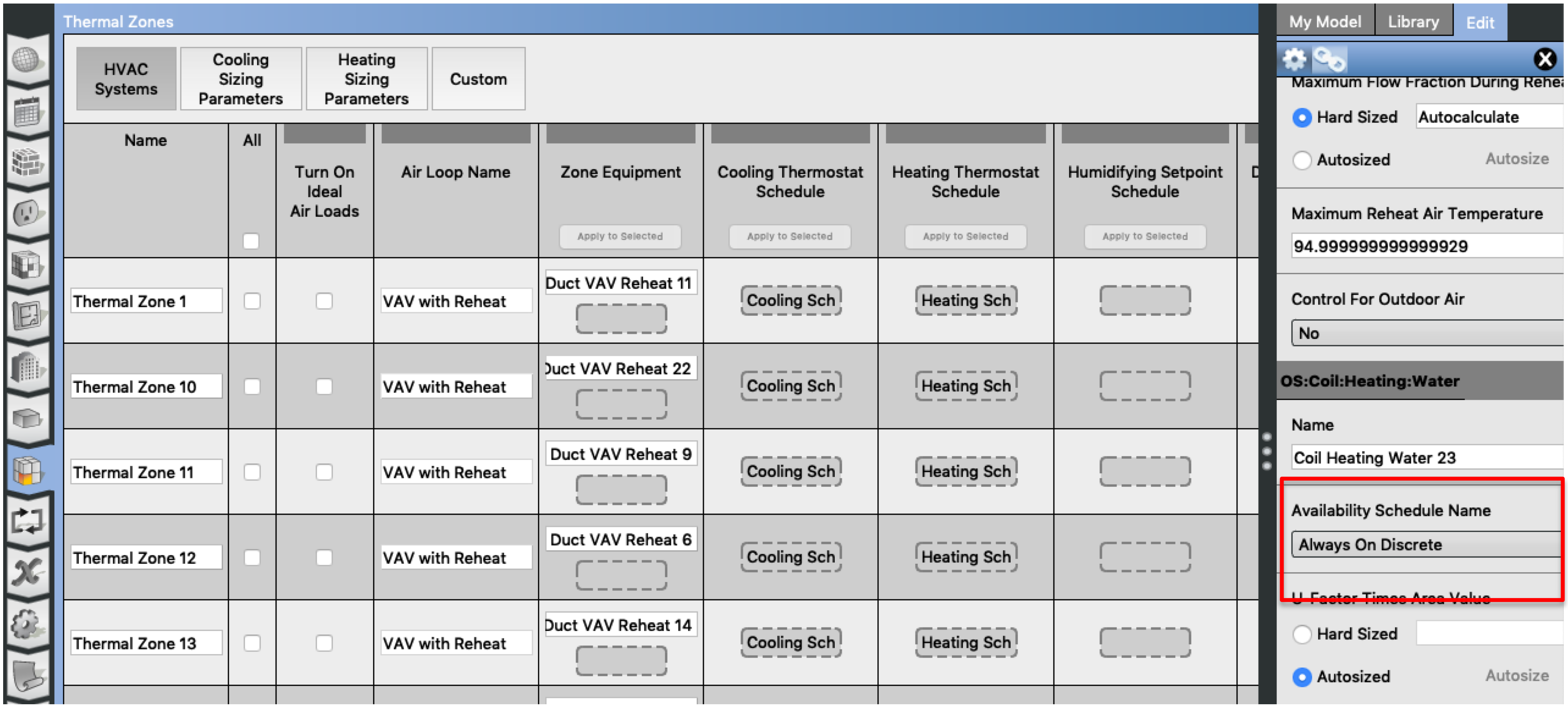
This field (in Watts) is typically used to represent the maximum electrical input to exterior lighting fixtures that is then multiplied by a schedule fraction (see previous field). In EnergyPlus, this is slightly more flexible in that the lighting design level could be a "diversity factor" applied to a schedule of real numbers. Note that while the schedule value can vary from hour to hour and seasonally, the design level field is constant for all simulation environments.

1.16.1.1.4 Field: Control Option

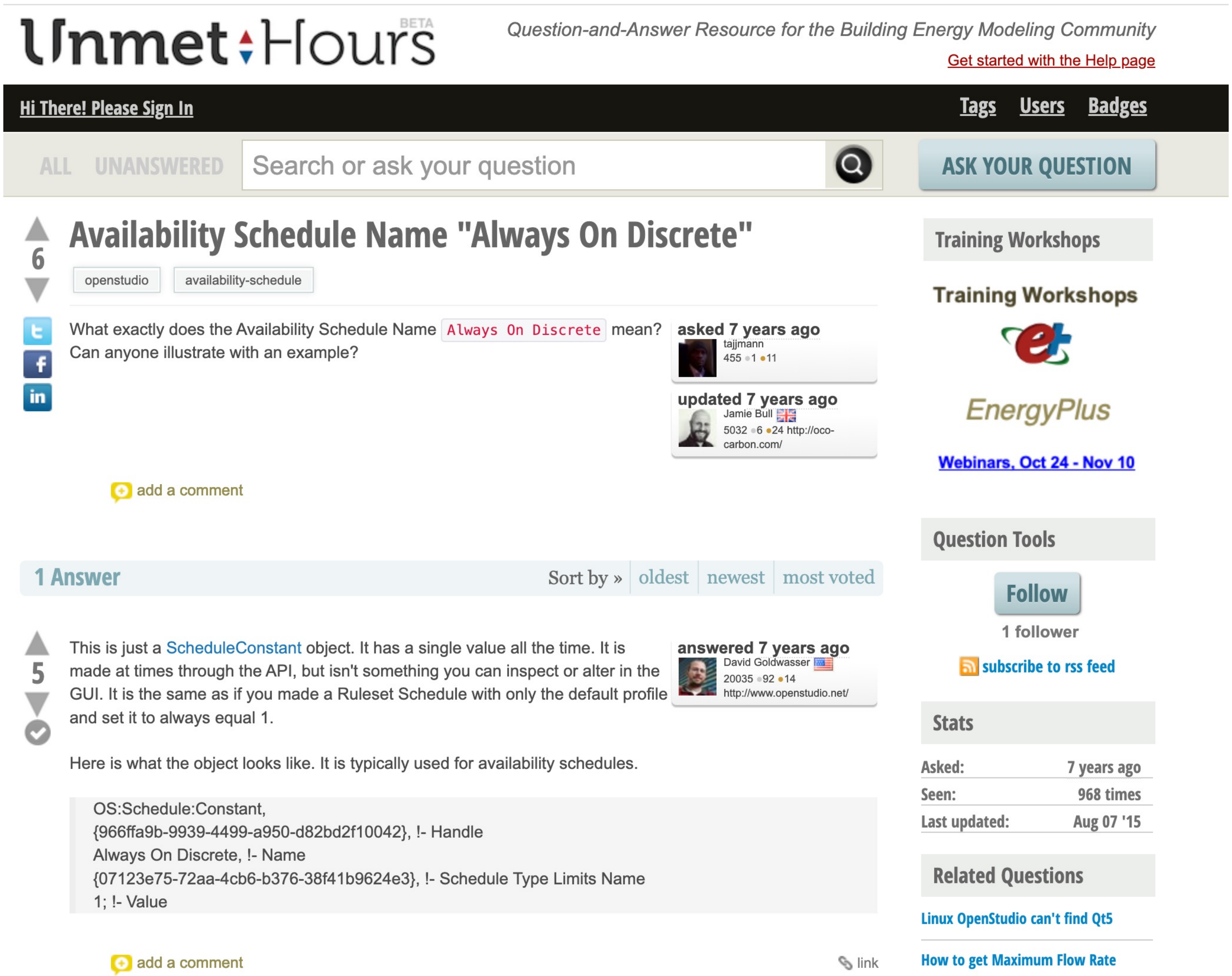
This field is used to determine how the exterior lights are controlled. There are currently two options, 'ScheduleNameOnly' and 'AstronomicalClock.' If this field is omitted or left blank then the program will default to Schedule Name Only mode. The 'ScheduleNameOnly' mode dictates that the exterior lights always follow the schedule named in the field above. The 'AstronomicalClock' mode dictates that despite what the schedule indicates, the exterior lights will not run when the sun is up. Using the Astronomical Clock mode makes it simple to model exterior lights that are controlled by a photocell or other controller that ensures that outdoor lights will not run during the daytime. However, the Astronomical Clock control works off of the position of the sun and therefore does not operate exactly like a photocell. During the night, the schedule values are still applied in the usual way.

https://energyplus.net/assets/nrel_custom/pdfs/pdfs_v9.6.0/InputOutputReference.pdf

System Availability

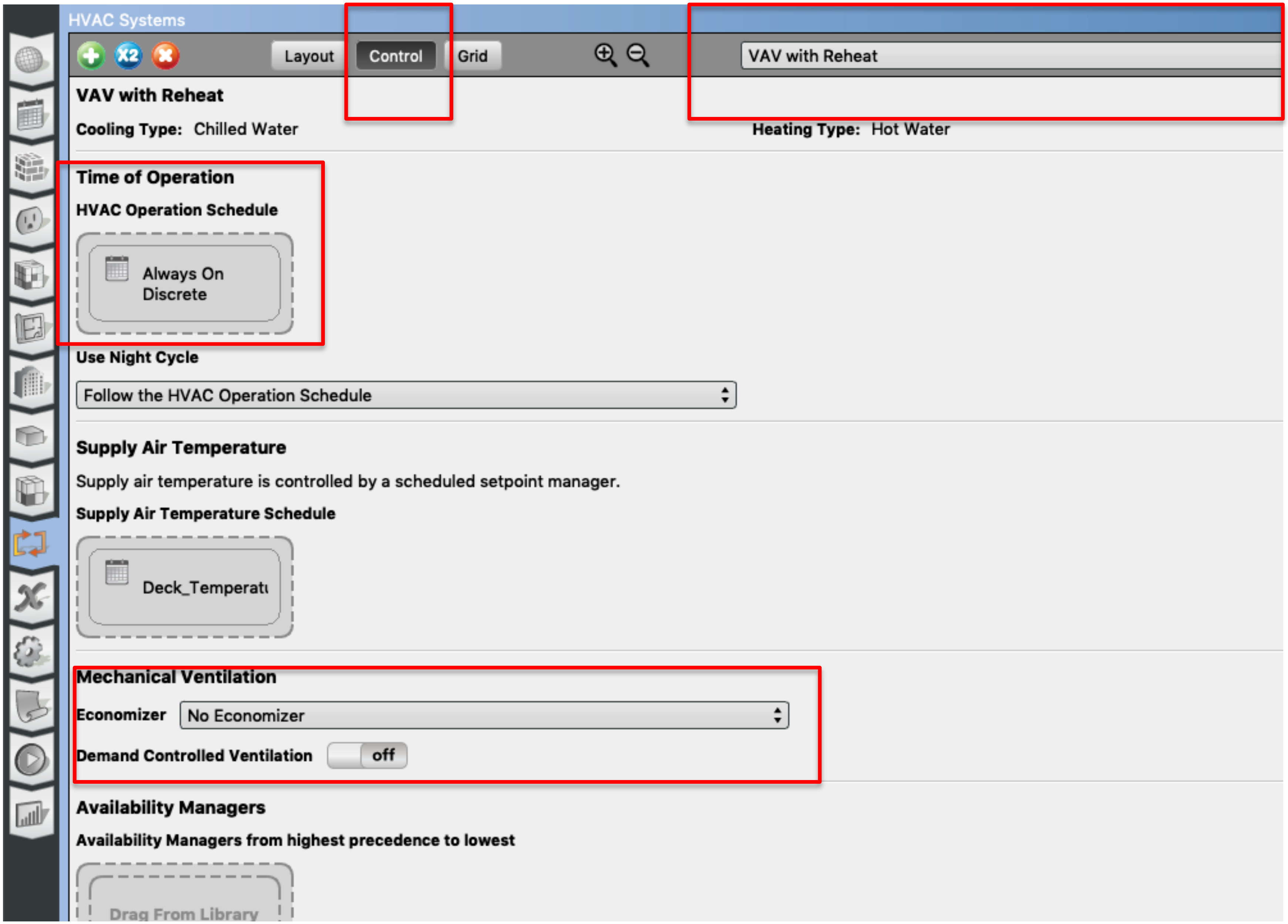


System Availability



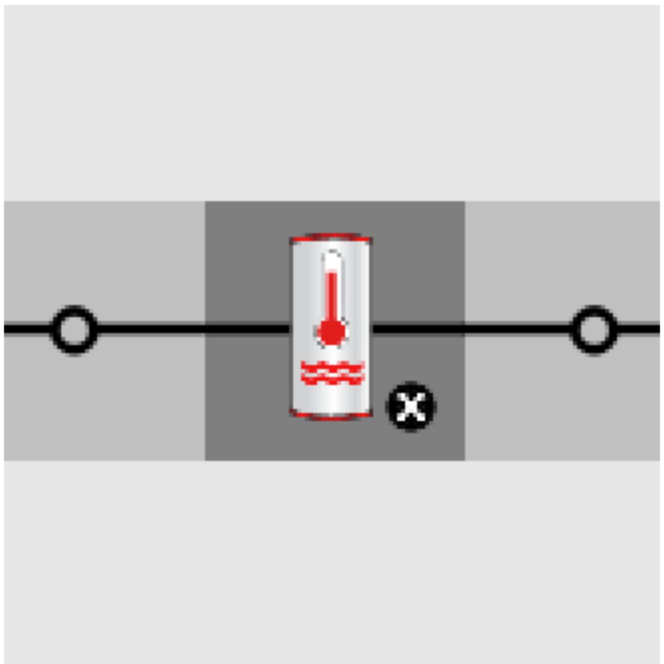
https://unmethours.com/question/10018/availability-schedule-name-always-on-discrete/

Economizer or Demand Control Ventilation



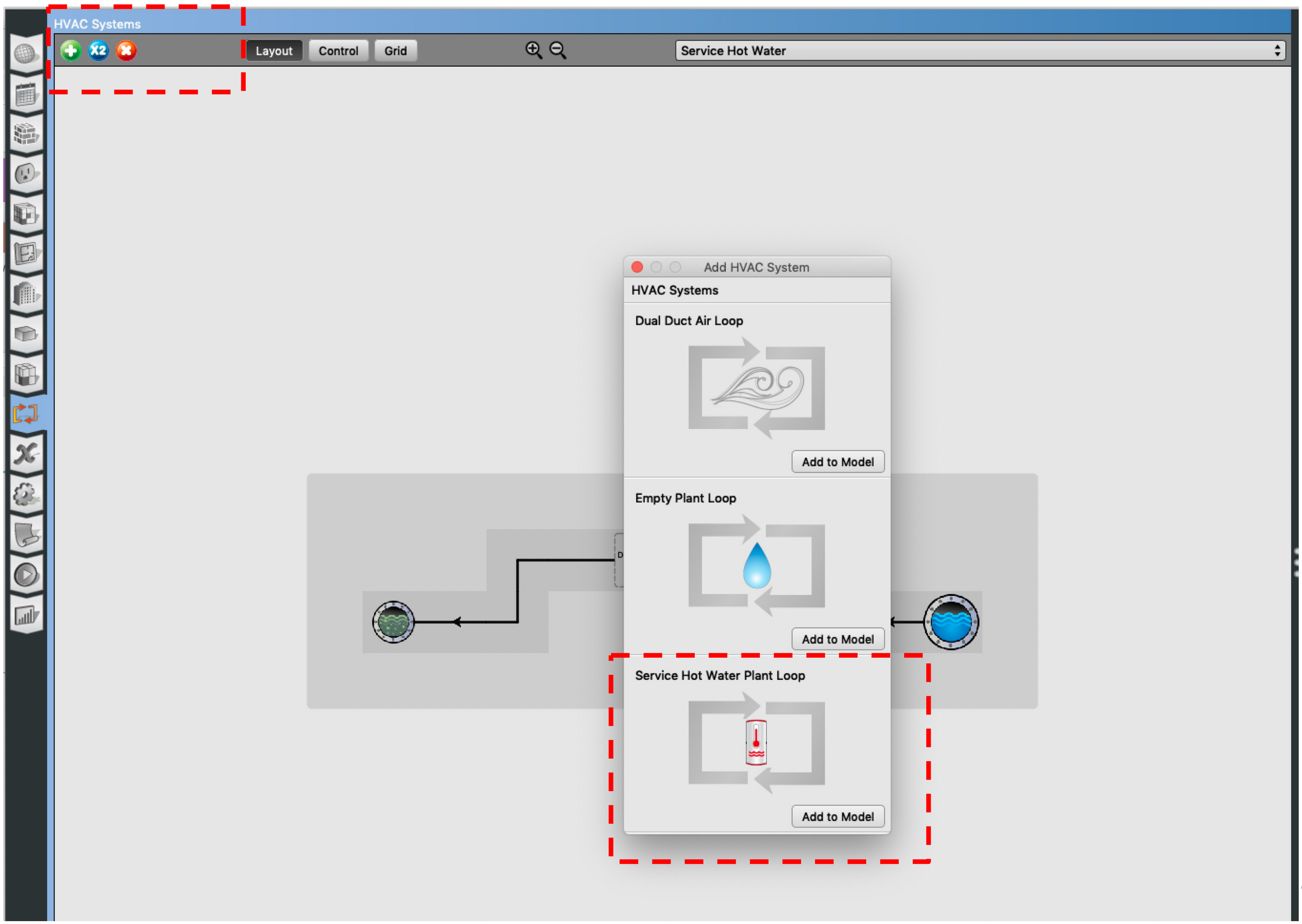
SERVICE HOT WATER

Service Hot Water



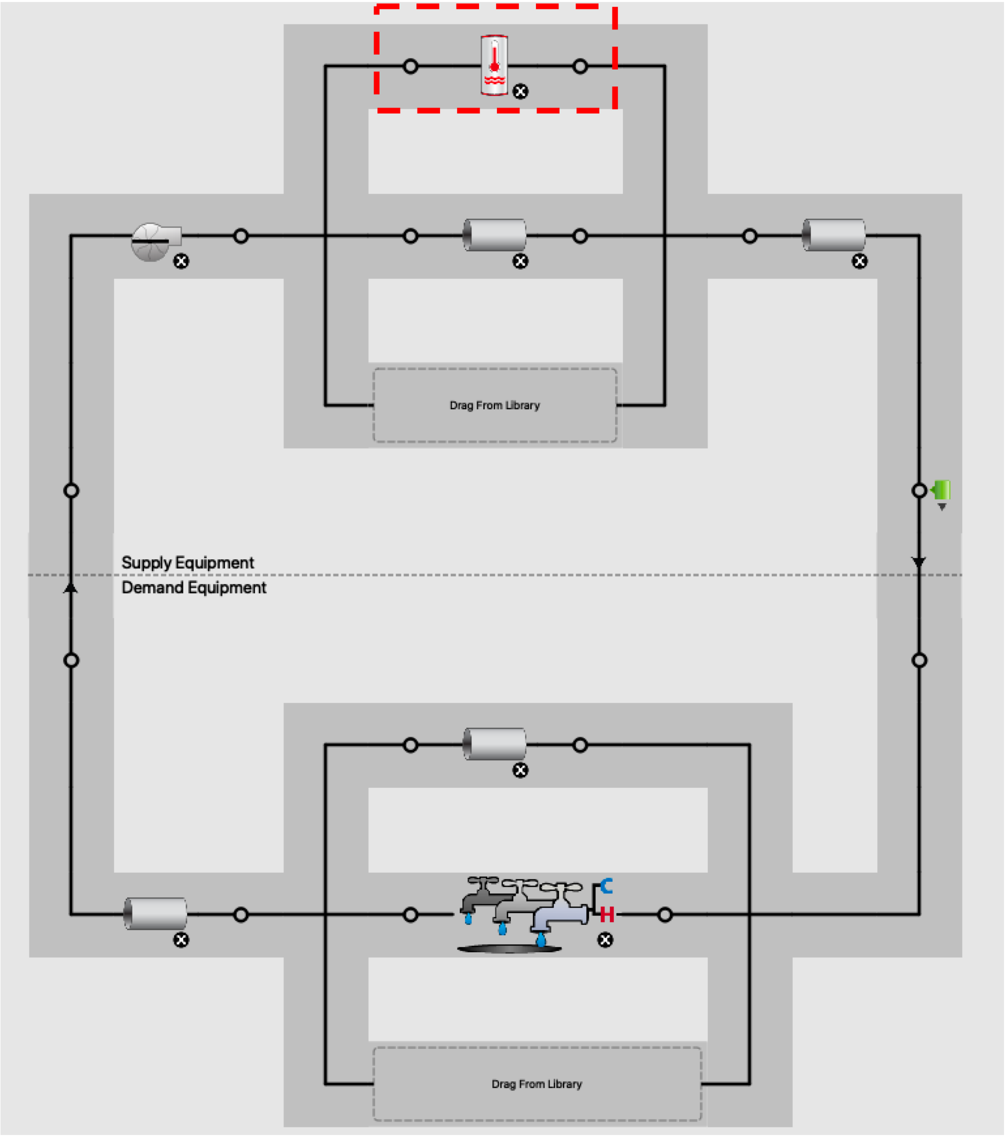
Service Hot Water

- Add a water heater tank to a plant loop:



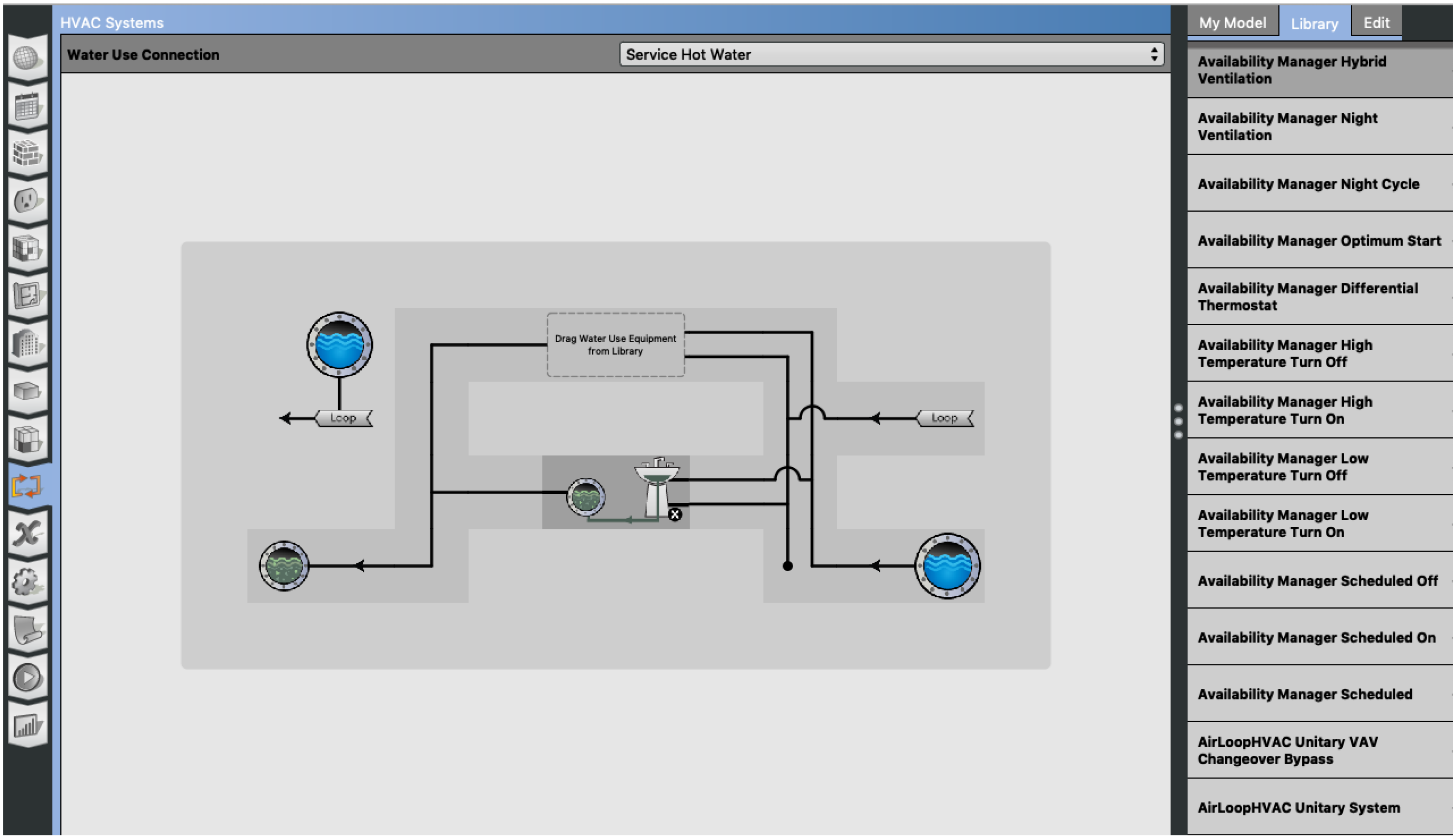
Service Hot Water

- Add service hot water plant loop:

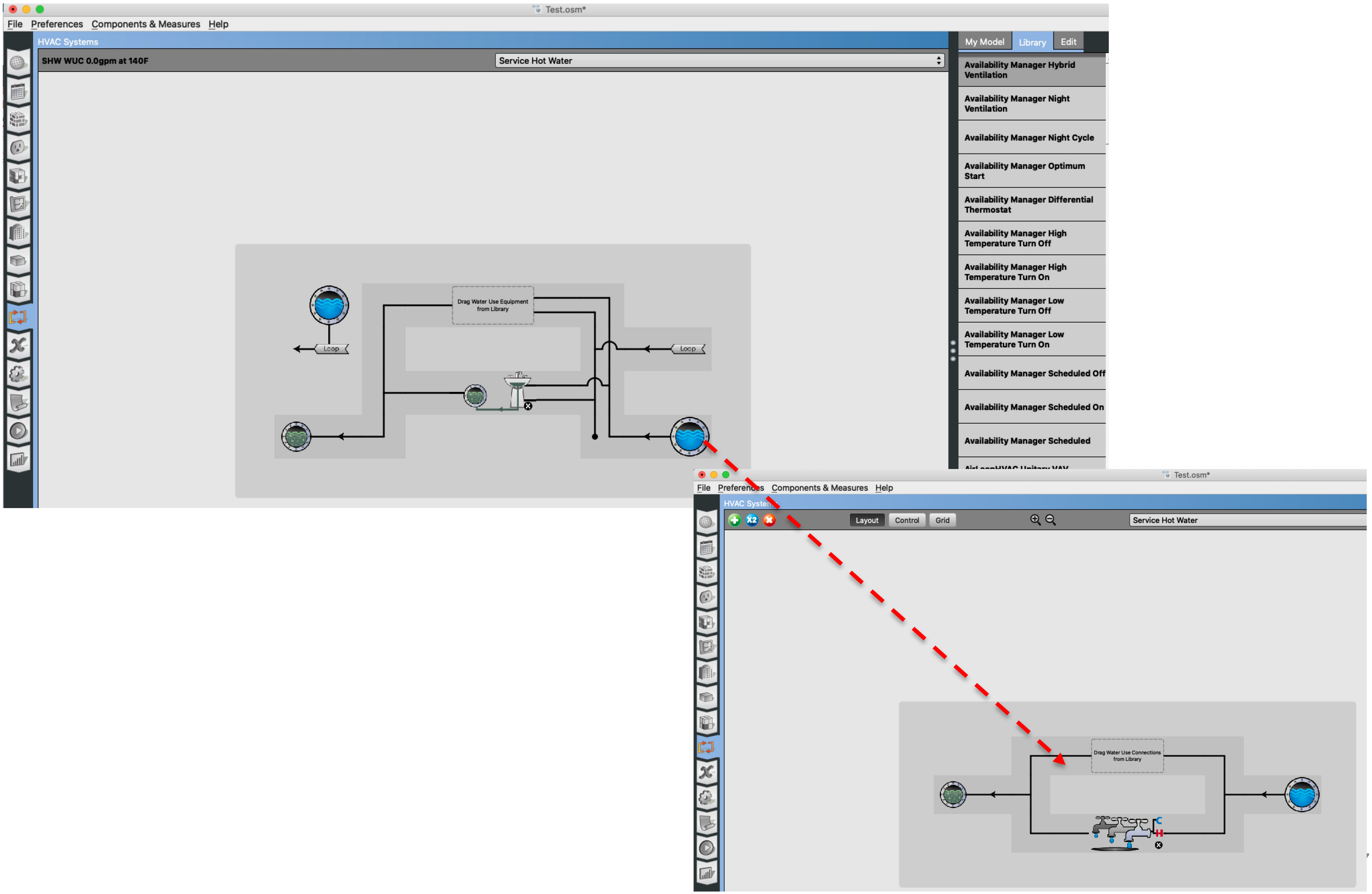


Service Hot Water

- Add a fixture:

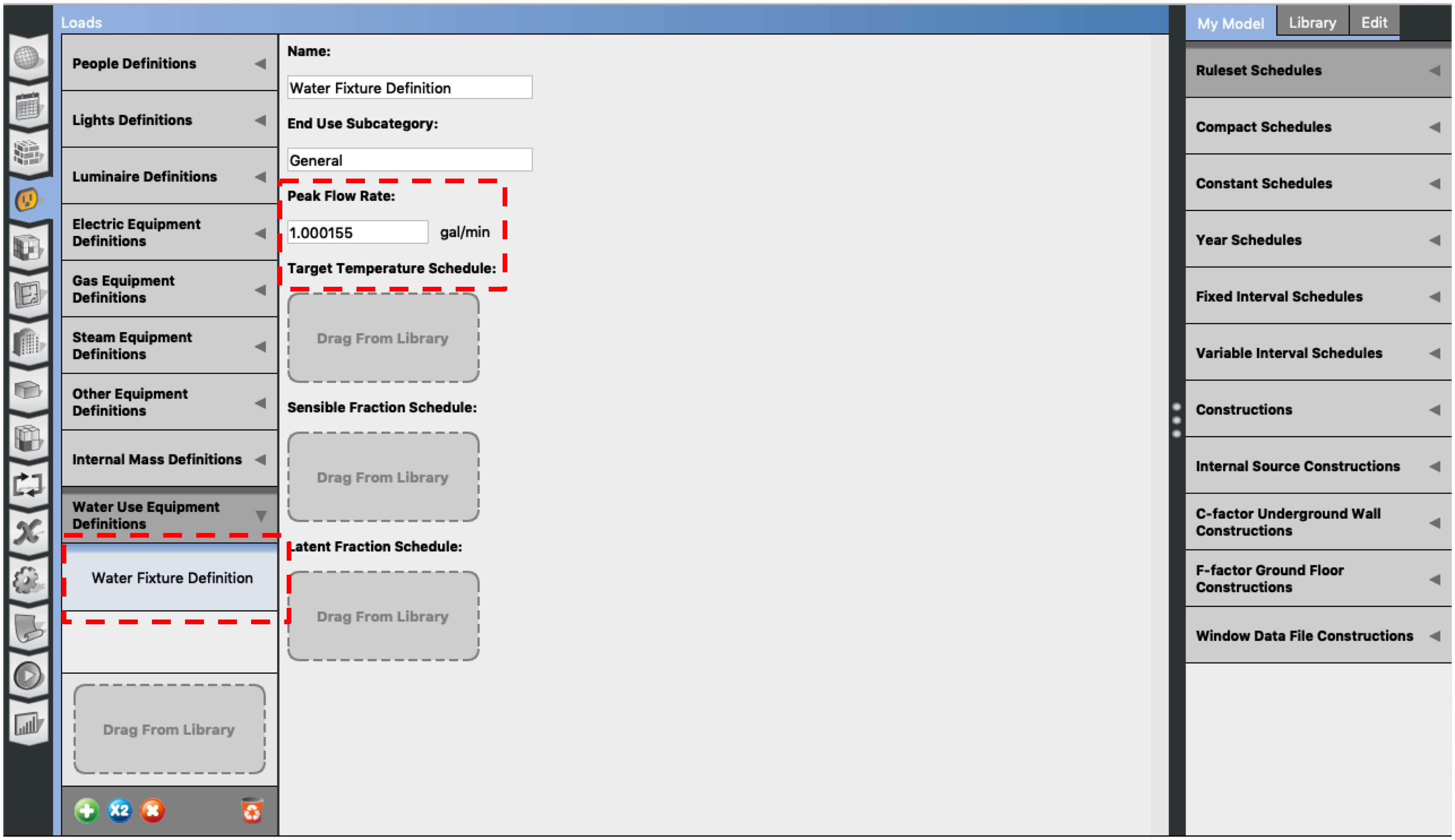


Service Hot Water



Service Hot Water

- Add service hot water definition



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	ºF	ºC	
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

https://www.nrel.gov/docs/fy11osti/46861.pdf

Service Hot Water

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

https://www.energy.gov/energysaver/heat-and-cool/water-heating
https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-lower-water-heating

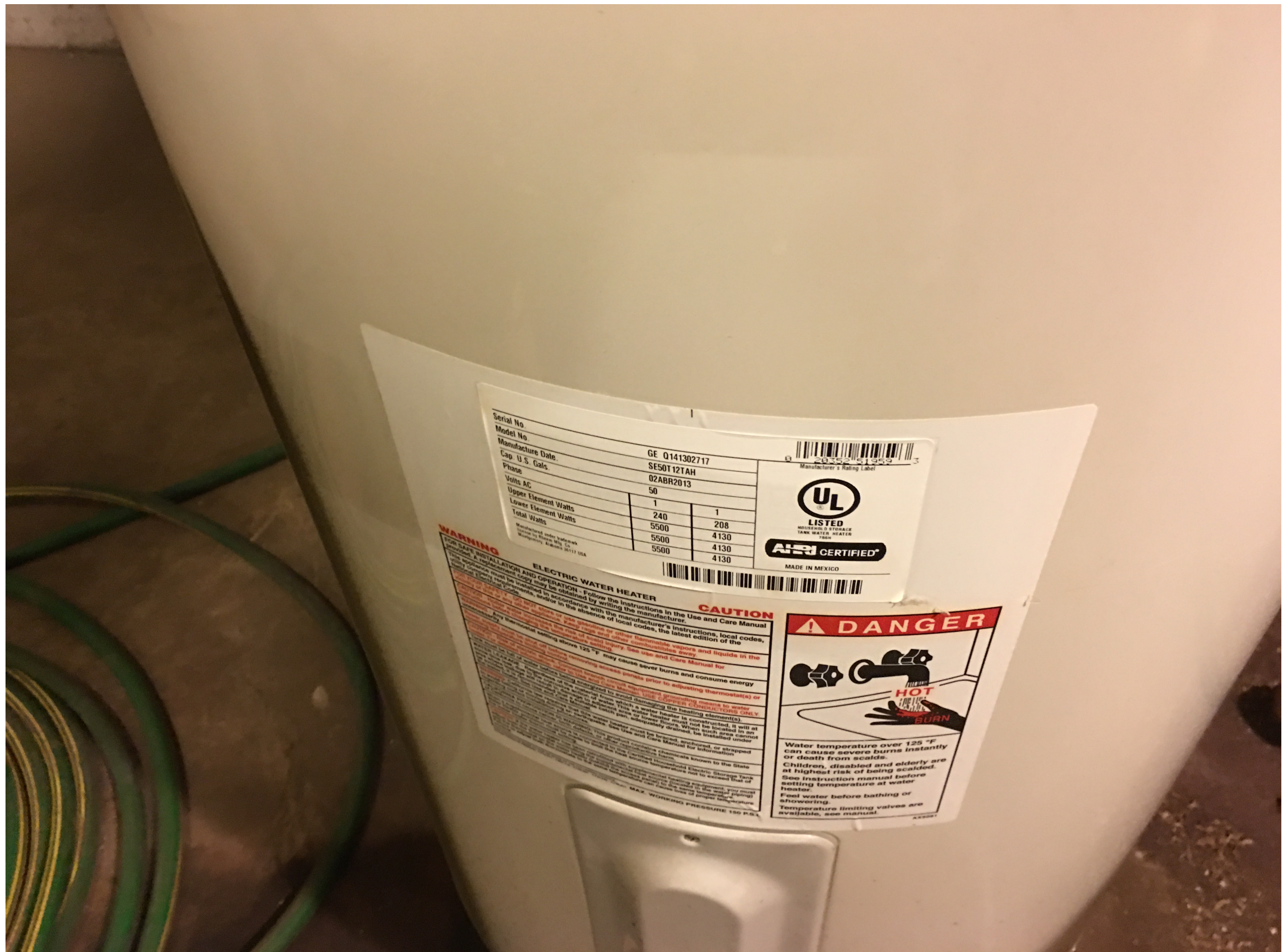
Service Hot Water

- 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

https://www.energy.gov/energysaver/heat-and-cool/water-heating
https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-lower-water-heating

Service Hot Water

- Service Hot Water



Service Hot Water

- Service Hot Water

Photo Not Available

GE® Electric Water Heater

Model #: SE50T12TAH |

About This Product Related Products Spec

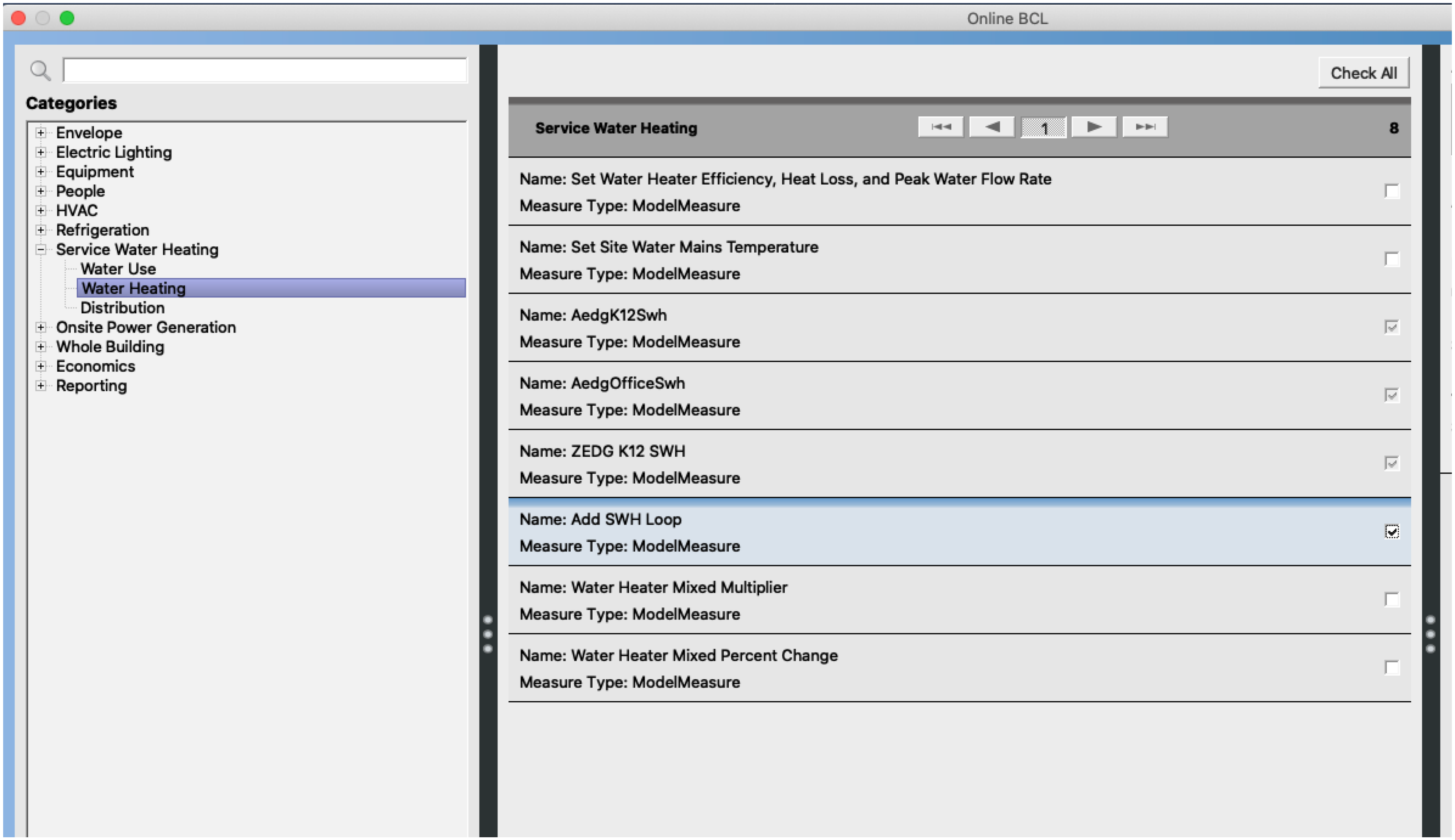
CAPACITY	
Unit Capacity	50 Gallons

FEATURES	
Fuel Type	Electric
Height Description	Tall

POWER / RATINGS	
First Hour Delivery GPH	67.0 gal/h
Heating - Electric - Heater Watts	5500
Integrated Energy Factor	0.94
Voltage (MAX)	240.0 V

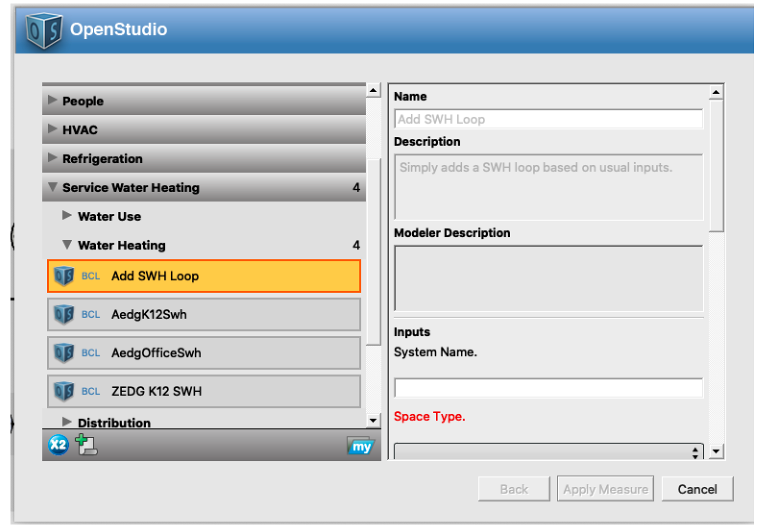
Service Hot Water

- You can use the OpenStudio measures:

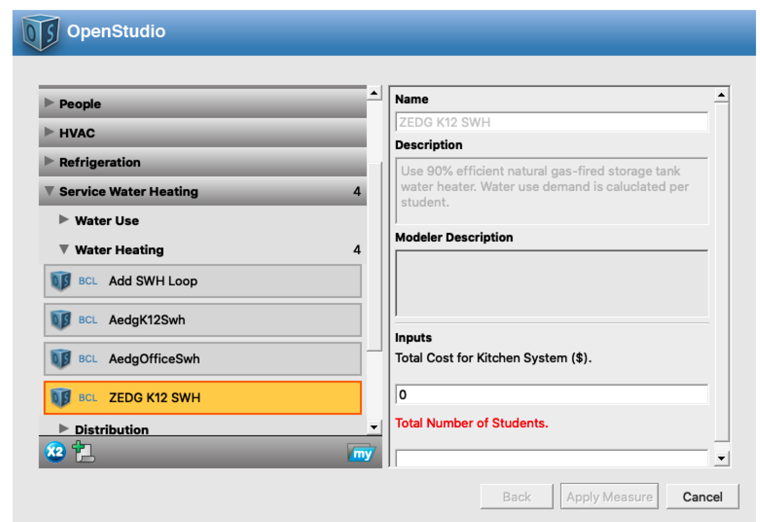


Service Hot Water

- You can use the OpenStudio measures:
  - First, use "Add SHW Loop"



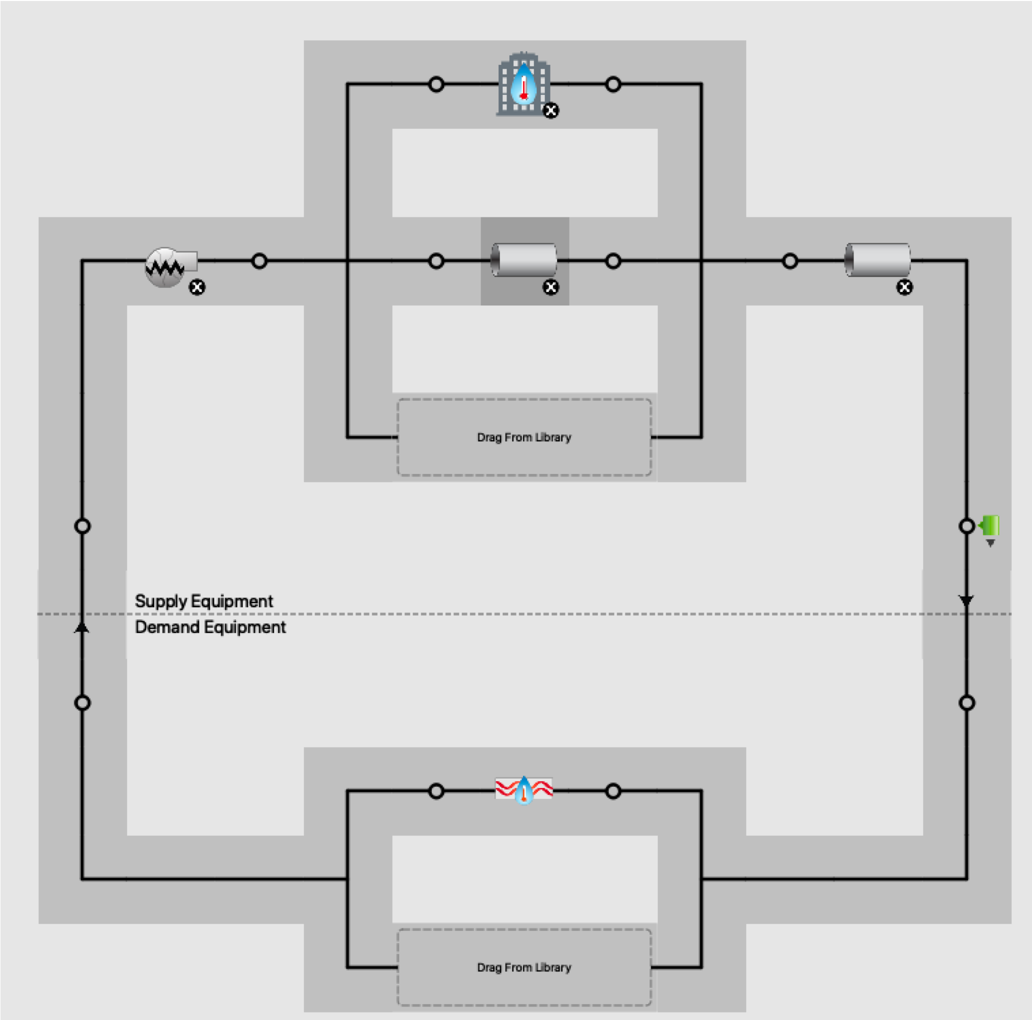
  - Second, use "ZEDG K12 SHW"



BASEBOARD

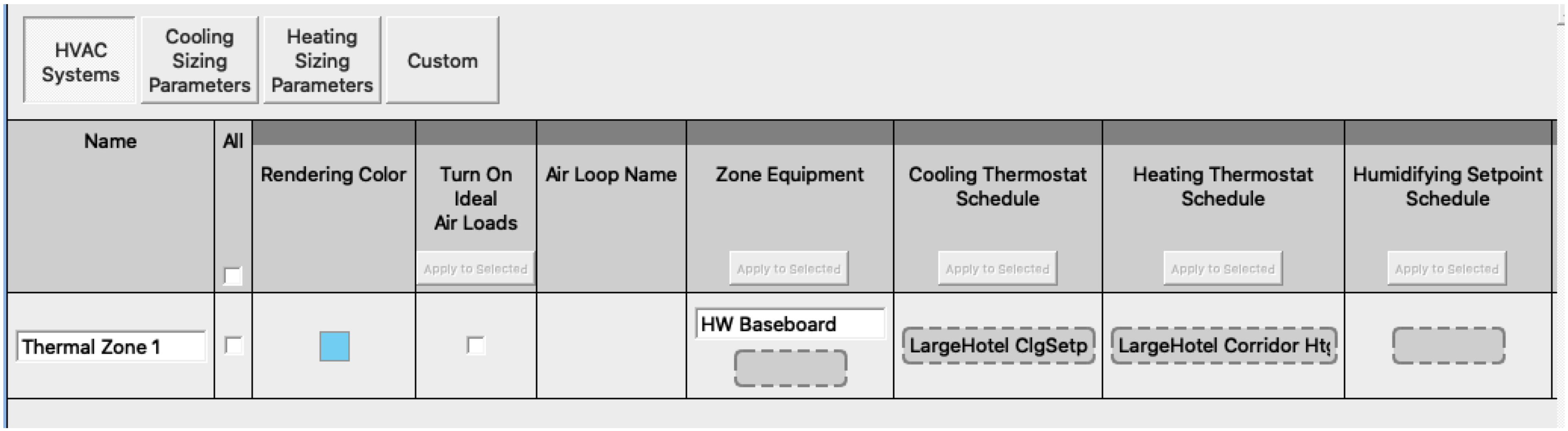
Baseboard

- Follow the hot water loop from the HVAC templates
- Add a district heating or a boiler to the empty plant loop



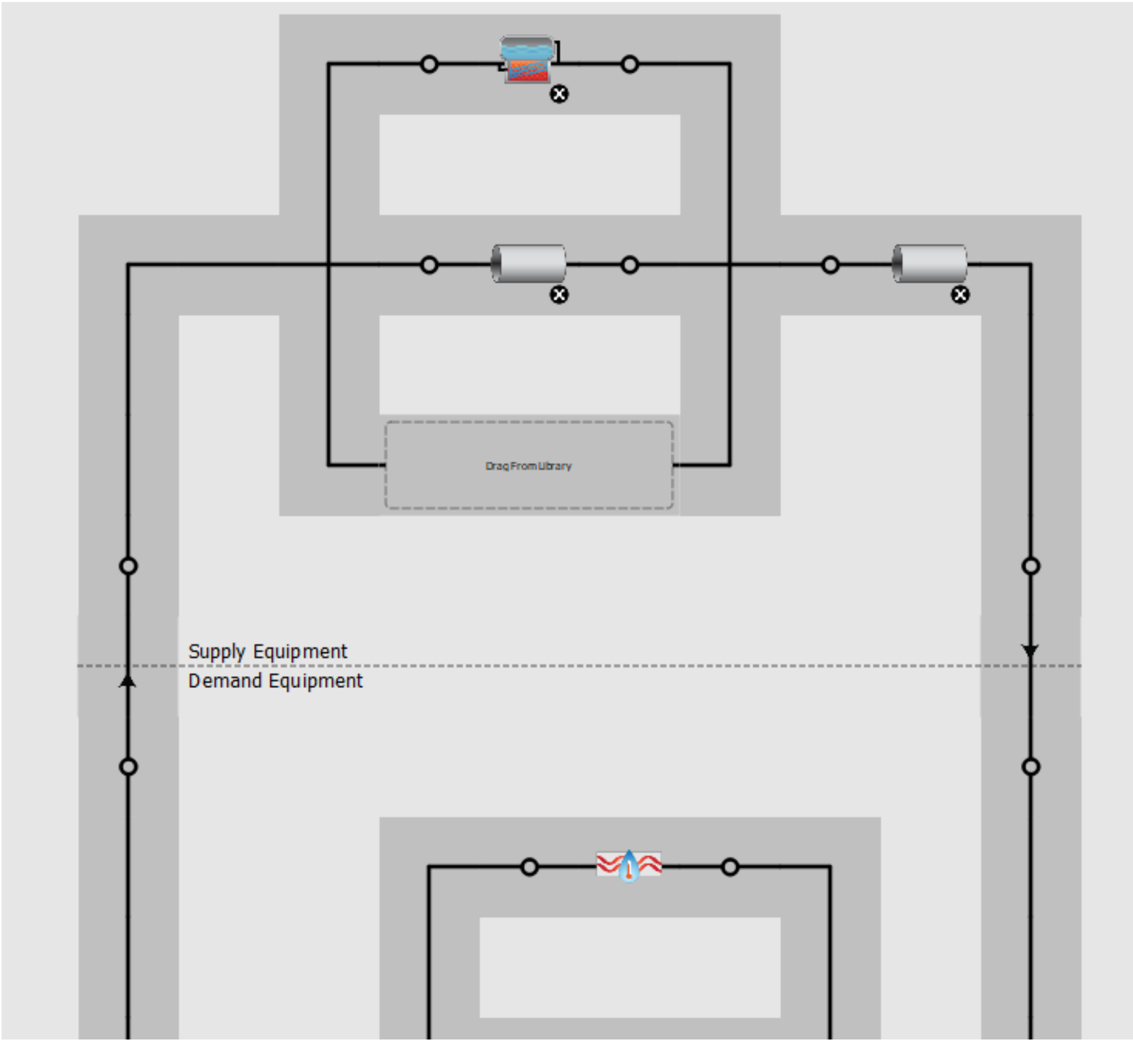
Baseboard

- Add the convector and assign it to a loop



Baseboard

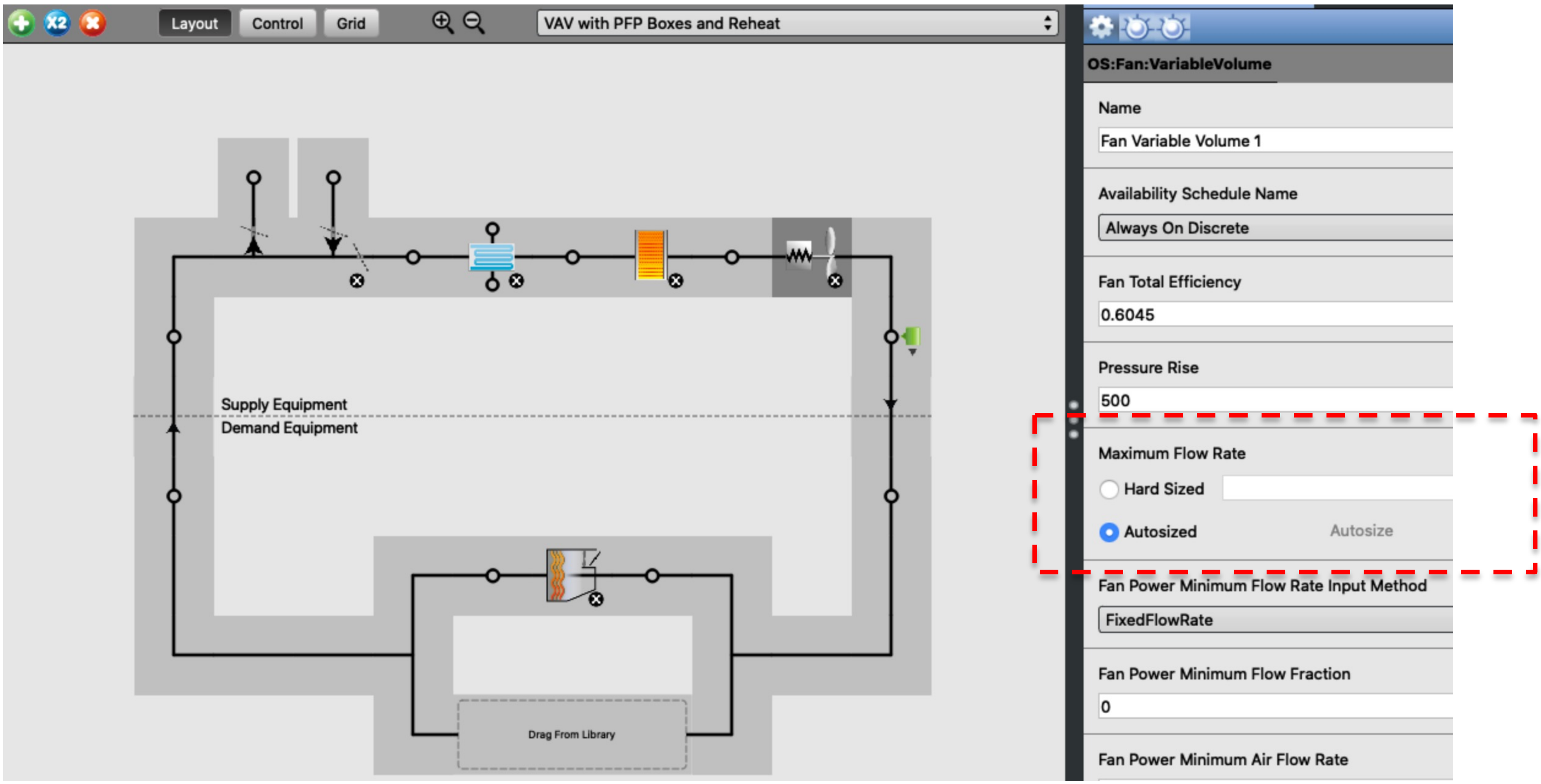
- Make sure all the components are in the loop
- Review the error messages for feedback



OPENSTUDIO
(HVAC SIZING)

HVAC Sizing

- What does autosizing and hard sizing mean?



HVAC Sizing

- You can find the autosize fields in advance:

```
Fan:VariableVolume,
  Supply Fan 1,                    !- Name
  FanAvailSched,                   !- Availability Schedule Name
  0.7,                                      !- Fan Efficiency
  600.0,                                  !- Pressure Rise {Pa}
  autosize,                             !- Maximum Flow Rate {m3/s}
  autosize,                             !- Minimum Flow Rate {m3/s}
  0.9,                                      !- Motor Efficiency
  1.0,                                      !- Motor In Airstream Fraction
  0.35071223,                         !- Fan Coefficient 1
  0.30850535,                         !- Fan Coefficient 2
  -0.54137364,                       !- Fan Coefficient 3
  0.87198823,                         !- Fan Coefficient 4
  0.000,                                  !- Fan Coefficient 5
  Main Heating Coil 1 Outlet Node,  !- Air Inlet Node Name
  VAV Sys 1 Outlet Node;      !- Air Outlet Node Name


  FanPerformance:NightVentilation,
  Supply Fan 1,                    !- Fan Name
  0.7,                                      !- Fan Total Efficiency
  67.0,                                    !- Pressure Rise {Pa}
  autosize,                             !- Maximum Flow Rate {m3/s}
  0.9,                                      !- Motor Efficiency
  1.0;                                      !- Motor in Airstream Fraction
```

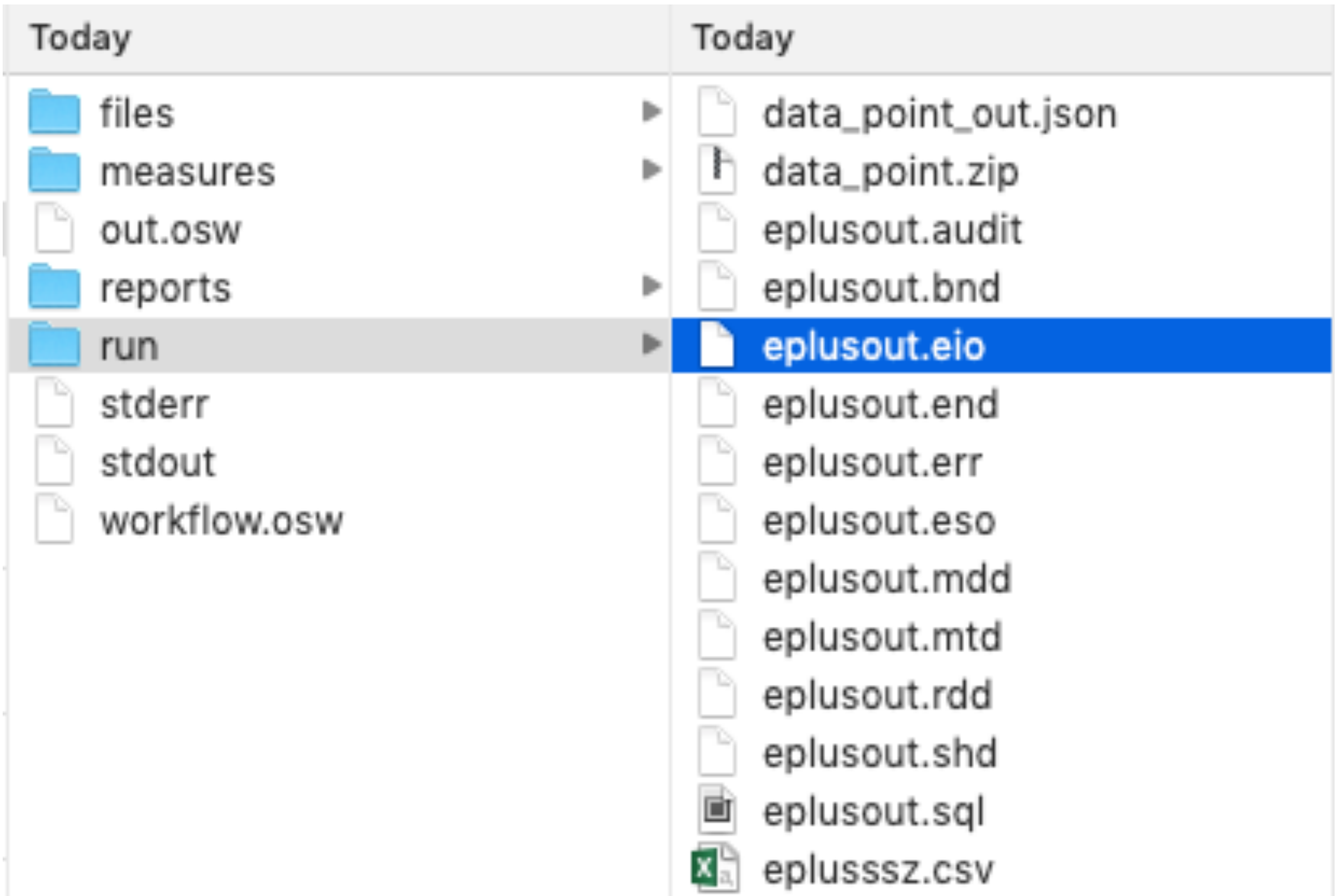
https://energyplus.net/assets/nrel_custom/pdfs/pdfs_v9.6.0/InputOutputReference.pdf

HVAC Sizing

- Approach 1:
  - ❑ Find from EnergyPlus results

HVAC Sizing

- Approach 2:
  - Open the EIO extension file



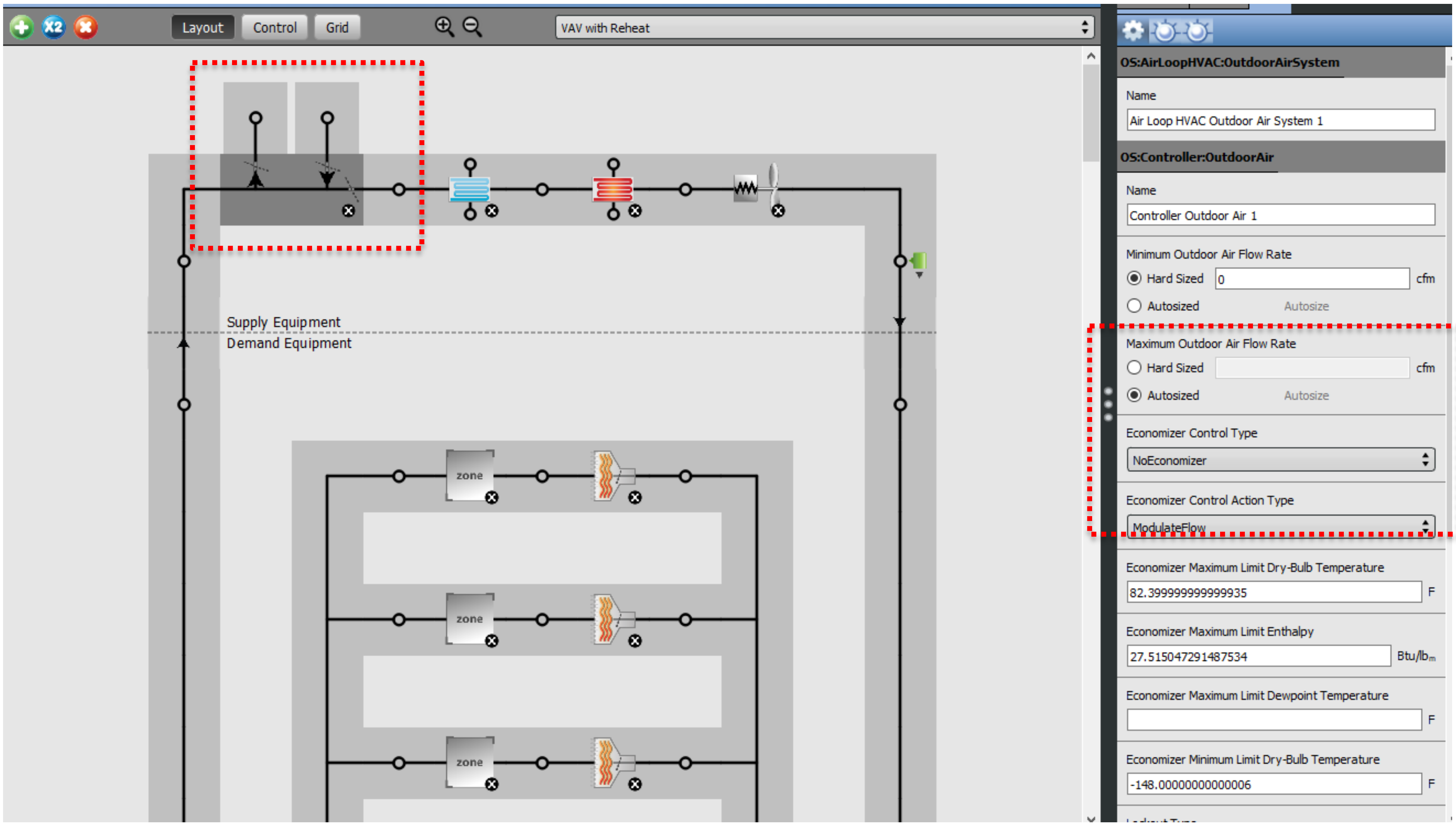
HVAC Sizing

- Approach 2:
  - Find the autosize values

```
! <System Sizing Information>, System Name, Load Type, Peak Load Kind, User Design Capacity, Calc Des Air Flow Rate [m3/s], User Des Air Flow Rate [m3/s], Design Day Name, Date/Time of Peak
 System Sizing Information, VAV WITH REHEAT, Cooling, Sensible, 3874937.65, 145.49122, 145.49122, MD_COLLEGE-PARK ANN CLG 0.4% CONDNS DB=>MCWB, 7/21 00:00:00
 System Sizing Information, VAV WITH REHEAT, Heating, Sensible, 1095941.11, 44.72717, 44.72717, MD_COLLEGE-PARK ANN HTG 99.6% CONDNS DB, 1/21 08:00:00
! <Component Sizing Information>, Component Type, Component Name, Input Field Description, Value
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Air Flow Rate [m3/s], 0.36239
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Constant Minimum Air Flow Fraction, 8.33684E-002
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, User-Specified Constant Minimum Air Flow Fraction, 0.30000
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Minimum Air Flow Rate [m3/s], 0.10872
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Flow per Zone Floor Area during Reheat [m3/s-m2], 2.74205E-003
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Flow Fraction during Reheat [], 0.30000
 Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Reheat Water Flow Rate [m3/s], 6.54338E-005
```

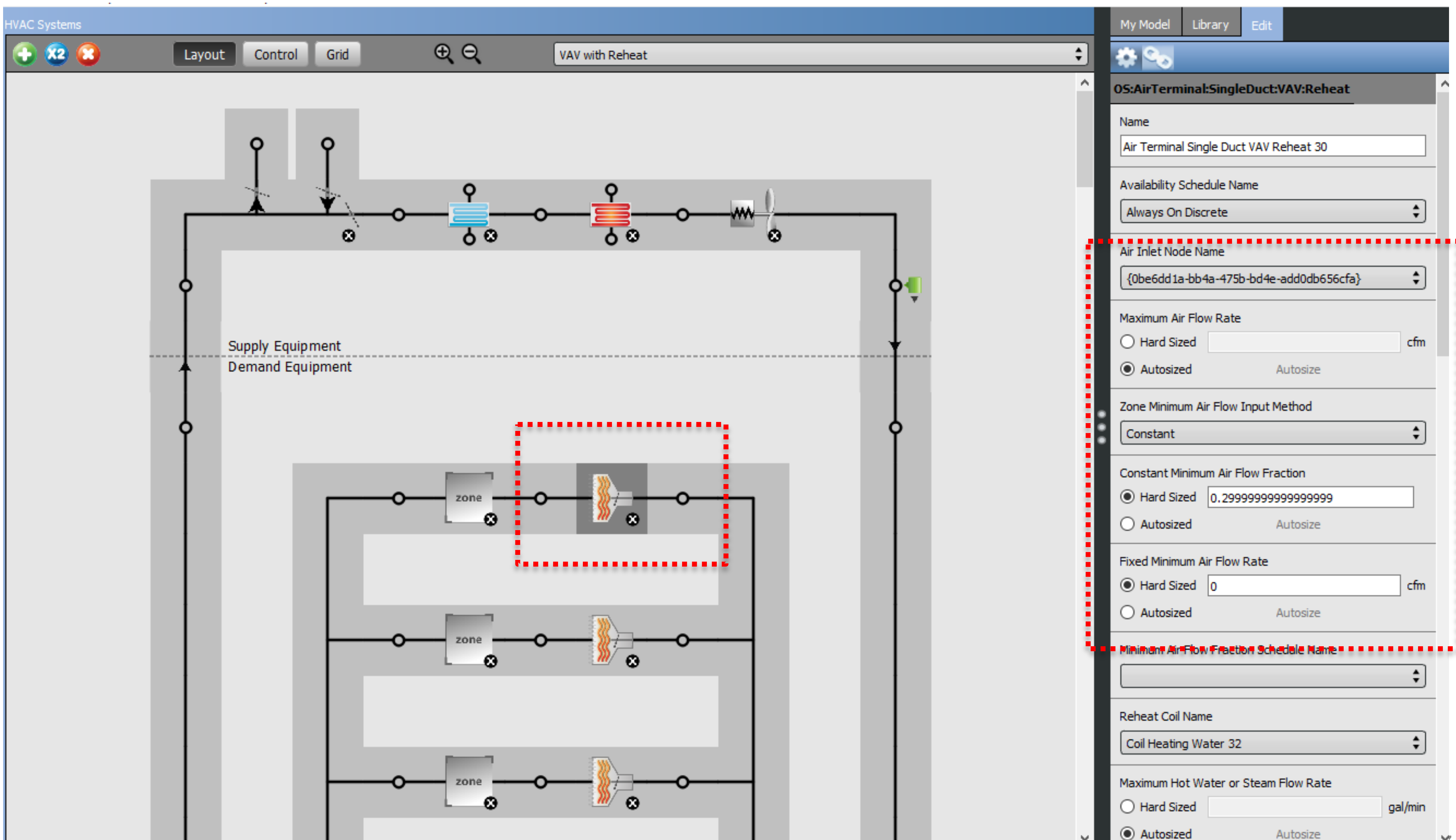
HVAC Sizing

- Hard size all components



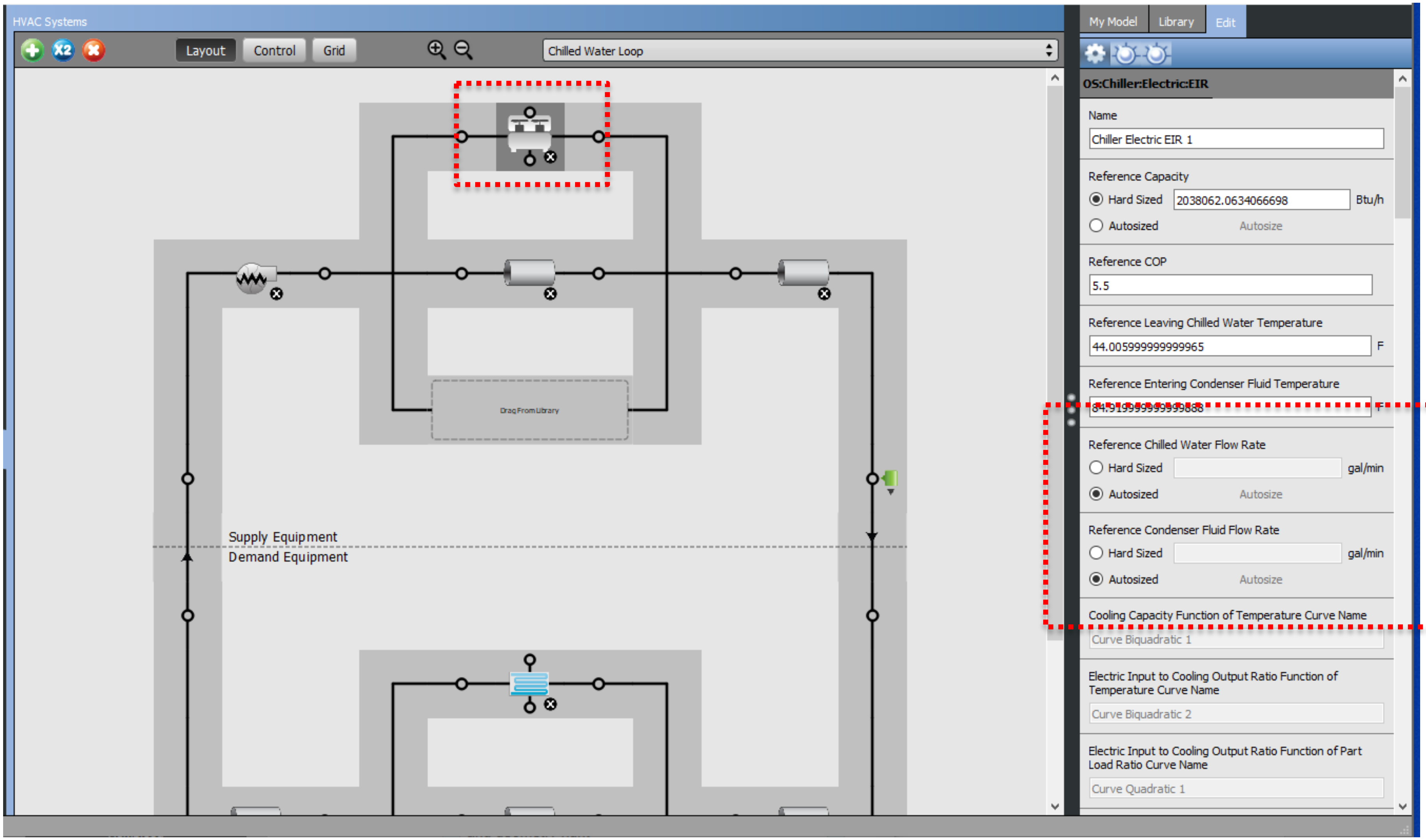
HVAC Sizing

- Hard size all components



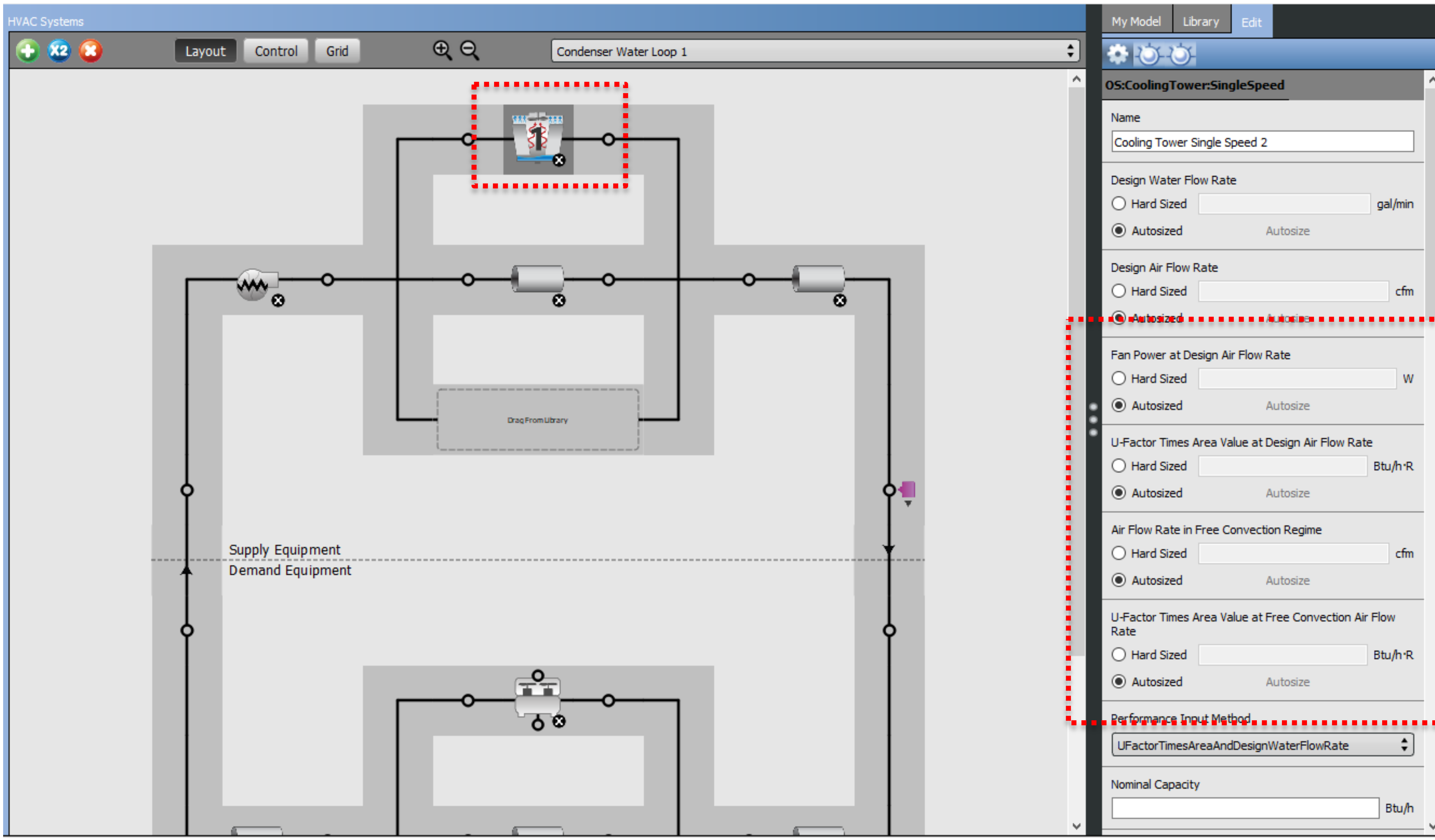
HVAC Sizing

- Hard size all components



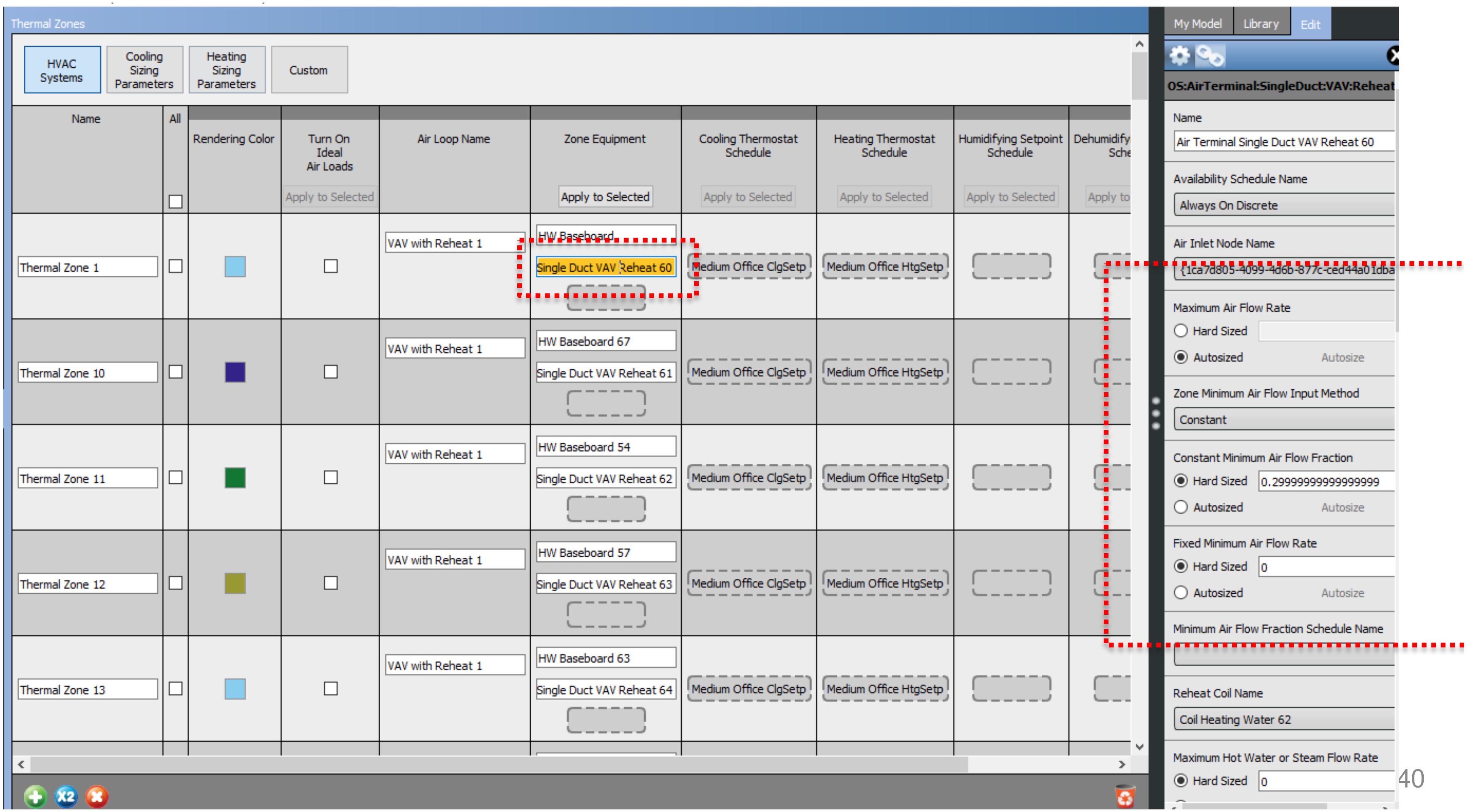
HVAC Sizing

- Hard size all components



HVAC Sizing

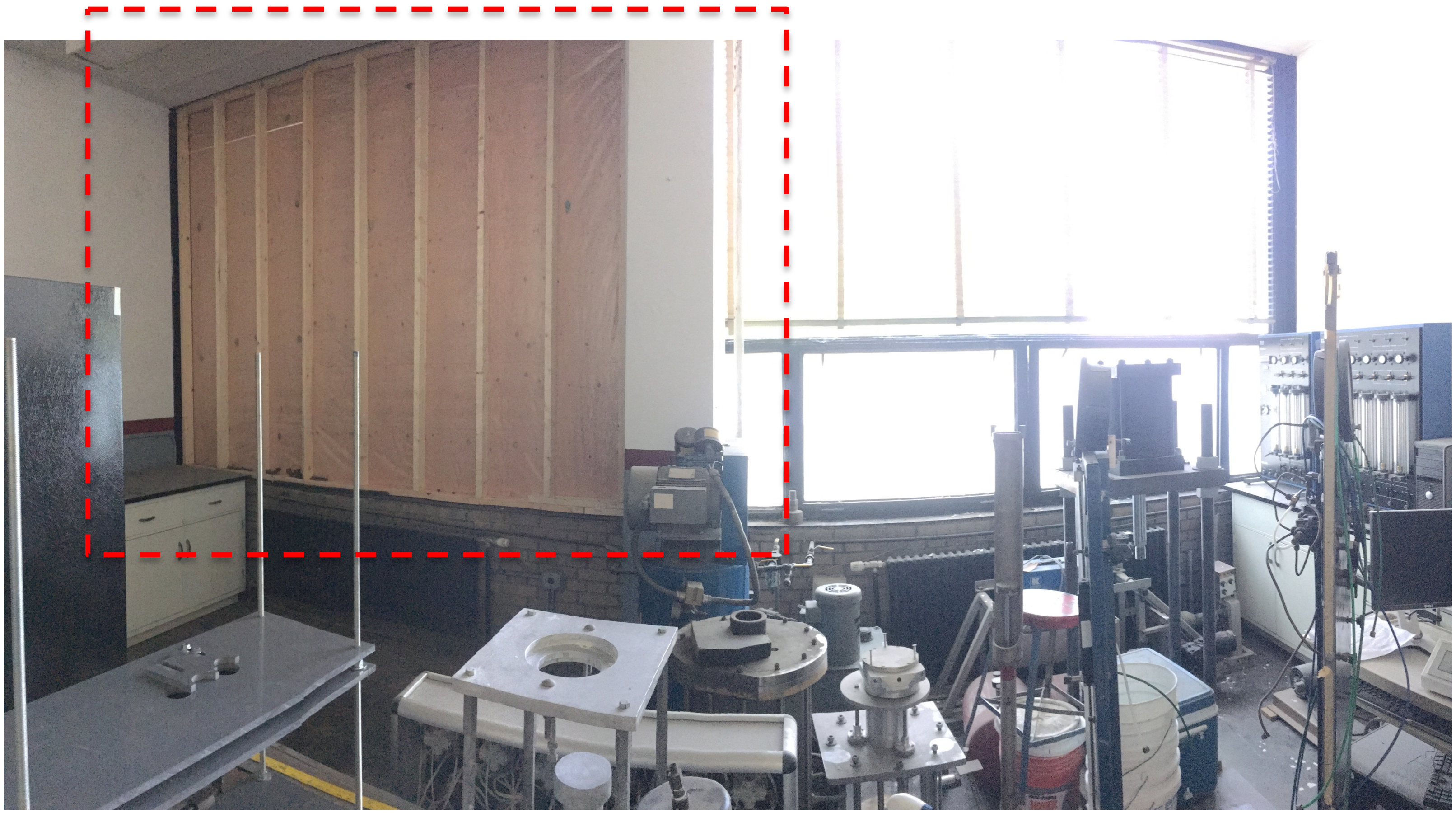
- Hard size all components



BUILDING RETROFIT EEMS

Building Retrofit EEM

- Window replacement in AM Hall:
  - Remove the old windows
  - Build a temp wall within the spaces approximately 10-12 inch off the window/brick wall



Building Retrofit EEM

Building Retrofit EEM

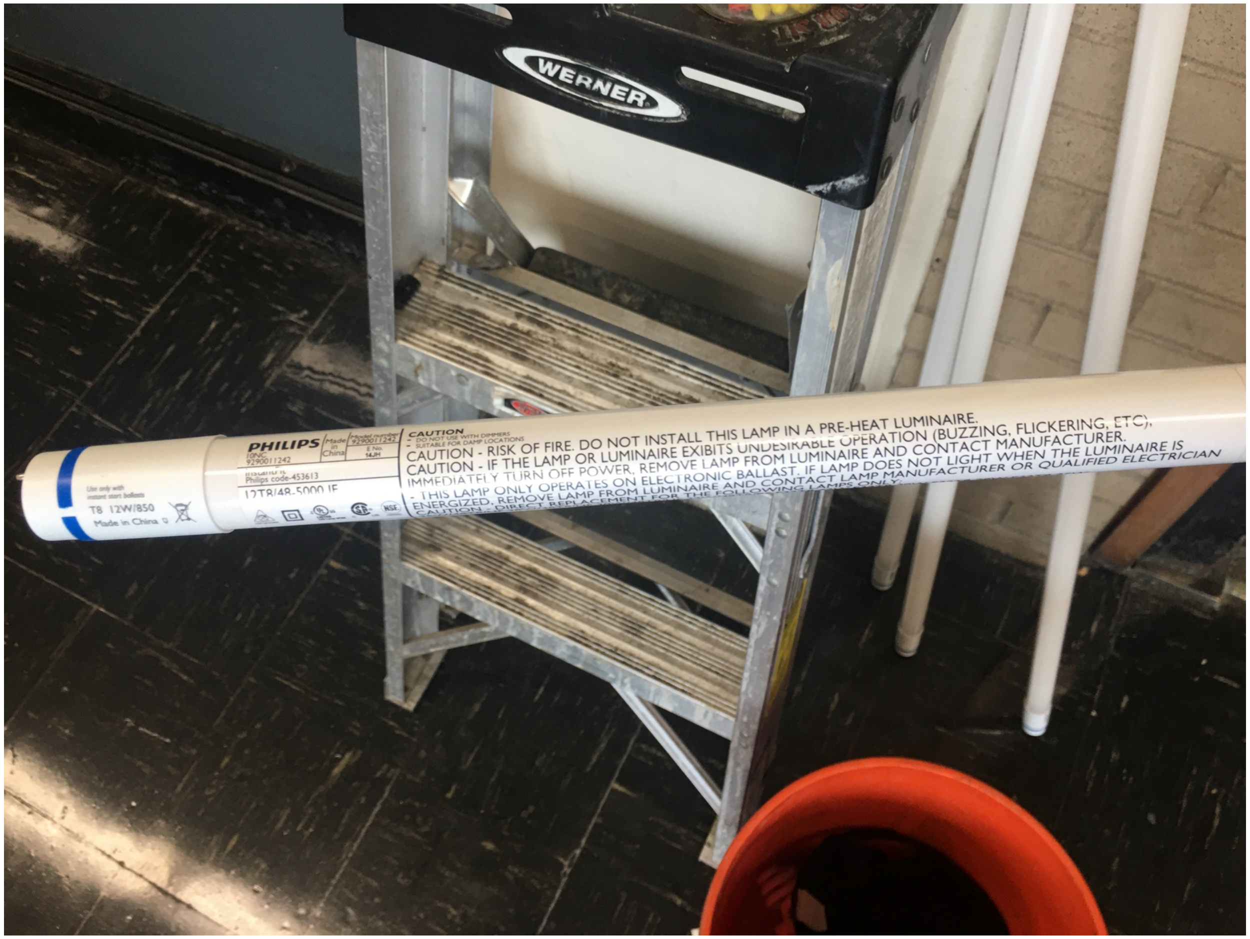
- Window replacement in AM Hall:

Building Retrofit EEM

- We looked at the new window installed on campus

Building Retrofit EEM

- We looked at lighting EEMs



http://www.assets.lighting.philips.com/is/content/PhilipsLighting/fp929001124204-pss-global

Building Retrofit EEM

- You can find the datasheet

LED InstantFit Lamps

12T8/48-5000 IF 10/1

Philips LED T8 InstantFit Lamps are an ideal energy saving choice for existing linear fluorescent fixtures.

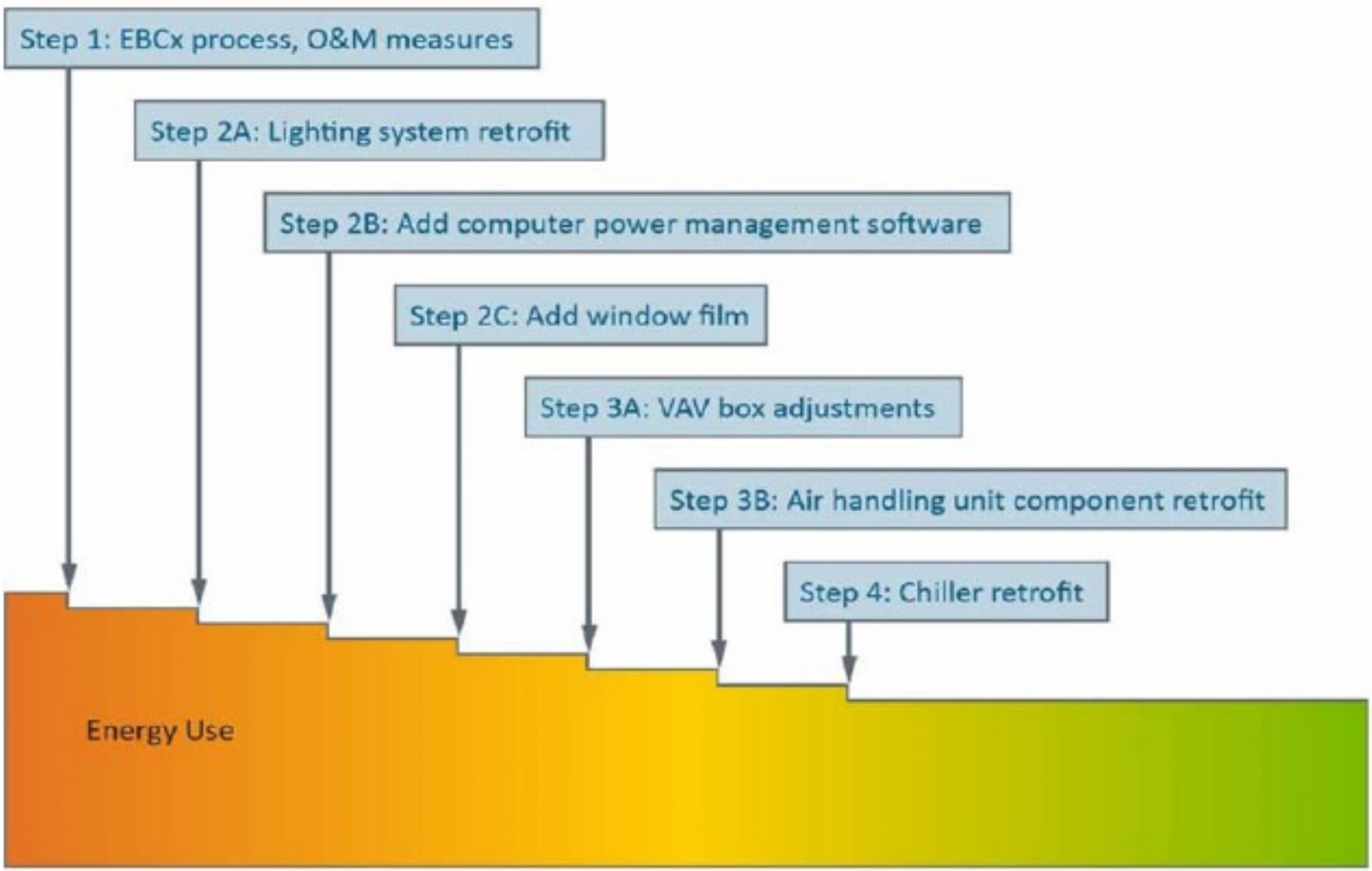
Product data

General Information	
Cap-Base	G13 [Medium Bi-Pin Fluorescent]
Main Application	Industrial
Nominal Lifetime (Nom)	50000 h
Switching Cycle	50000X
B50L70	50000 h
Light Technical	
Color Code	850 [CCT of 5000K]
Beam Angle (Nom)	160 °
Luminous Flux (Nom)	1650 lm
Luminous Flux (Rated) (Nom)	1650 lm
Rated Beam Angle	160 °
Correlated Color Temperature (Nom)	5000 K
Color Consistency	<5
Color Rendering Index (Nom)	82
LLMF At End Of Nominal Lifetime (Nom)	70 %
Operating and Electrical	
Input Frequency	50 to 60 Hz
Power (Rated) (Nom)	12 W
Lamp Current (Max)	150 mA
Lamp Current (Min)	60 mA
Starting Time (Nom)	0.5 s
Warm Up Time to 60% Light (Nom)	0.1 s

Power Factor (Nom)	0.9
Voltage (Nom)	120-277 V
Temperature	
T-Ambient (Max)	45 °C
T-Ambient (Min)	-20 °C
T-Storage (Max)	65 °C
T-Storage (Min)	-40 °C
T-Case Maximum (Nom)	40 °C
Controls and Dimming	
Dimmable	No
Mechanical and Housing	
Product Length	1200 mm
Approval and Application	
Energy Saving Product	Yes
Approval Marks	UL certificate RoHS compliance KEMA Keur certificate DLC compliance
Energy Consumption kWh/1000 h	14.5 kWh
Product Data	
Order product name	12T8/48-5000 IF 10/1
EAN/UPC - Product	046677453619

Building Retrofit EEM

- You need to develop your building retrofit path:



CLASS ACTIVITY

Class Activity

- Spend 30 to 40 minutes to propose a few EEMs
  - ❑ Enclosure
  - ❑ Window
  - ❑ Lighting
  - ❑ Plug load
  - ❑ HVAC

- Complete this table:
  - ❑ https://docs.google.com/spreadsheets/d/14sF09IPNmiycBBCkLjfJTHq9MfXONQ8RqfUBOE0EaSE/edit#gid=1145246215

ADVANCED ENERGY RETROFIT GUIDE

Advanced Energy Retrofit Guide

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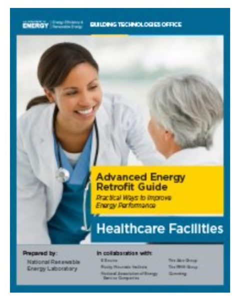
BUILDINGS

Advanced Energy Retrofit Guides

Buildings

Buildings » Commercial Buildings » Design & Decision Support Guides » Advanced Energy Retrofit Guides

The Advanced Energy Retrofit Guides (AERGs) were created to help decision makers plan, design, and implement energy improvement projects in their facilities. With energy managers in mind, they present practical guidance for kick-starting the process and maintaining momentum throughout the project life cycle. These guides are primarily reference documents, allowing energy managers to consult the particular sections that address the most pertinent topics. Useful resources are also cited throughout the guides for further information. Each AERG is tailored specifically to the needs of a specific building type, with an emphasis on the most effective retro-commissioning and retrofit measures identified by experts familiar with those unique opportunities and challenges. The guides present a broad range of proven practices that can help energy managers take specific actions at any stage of the retrofit process,



The Advanced Energy Retrofit Guides (AERGs) help building owners and managers as well as design and construction professionals plan, design, and implement energy-efficiency upgrades in commercial buildings.

https://www.energy.gov/eere/buildings/advanced-energy-retrofit-guides

Advanced Energy Retrofit Guide

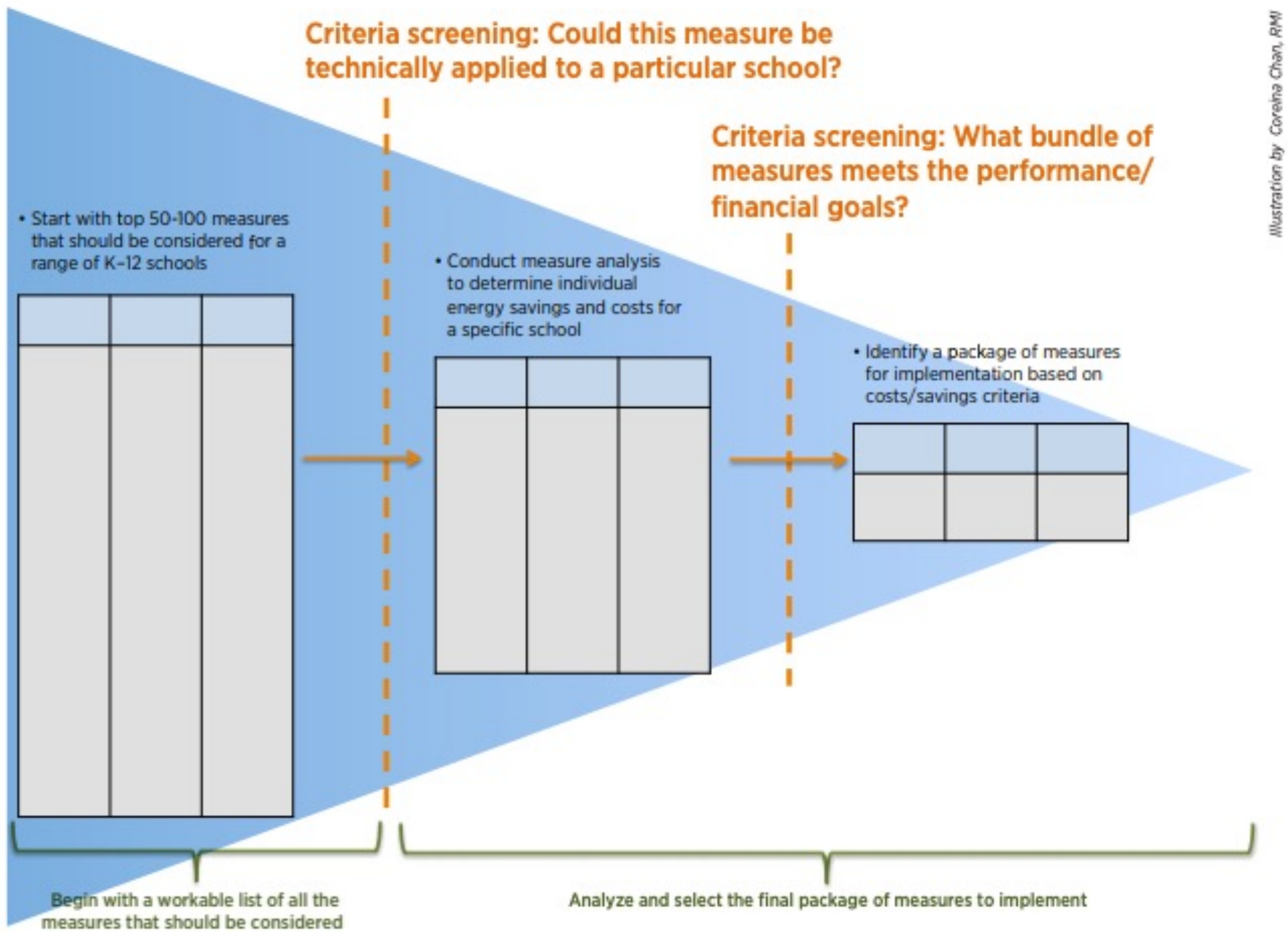
- For example, for K-12:

	Energy Manager	Custodial Staff	School Board or Financial Manager	Teachers and Students	Community and Parents	Utilities and Auditors
1 Introduction	●	●	●	●	●	●
2 Overview: Plan, Execute, Follow Up	●		●			
3 Existing Building Commissioning	●	●		●		●
4 Building Retrofits	●		●			●
5 Measurement and Verification	●	●				
6 Operations and Maintenance	●	●				
7 Conclusion	●	●	●	●	●	●

https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:



https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:

Case Study 1: Vigo County School Corporation

Quick Facts

- Facility Name: Vigo County School Corporation
- Facility Type: K-12 Schools
- Location: Terre Haute, Indiana
- Number of Buildings: 29

Photo from NAESCO

Project Description

The Vigo County School Corporation (VCSC) in Terre Haute, Indiana, and under the leadership of Superintendent Daniel Tanoos, partnered with Energy Systems Group to develop and implement comprehensive energy savings performance contracts. VCSC is made up of 3 high schools, 2 alternative schools, 6 middle schools, and 18 elementary schools.

In 1999, VCSC decided to take control over rising operating costs with an assessment of its utility costs, which at the time averaged $\$0.845/\text{ft}^2$. This was compared to other Indiana school facilities that had installed energy retrofits resulting in energy costs as low as $\$0.65/\text{ft}^2$. Of the 19 VCSC schools surveyed, 9 were operating at more than $\$0.90/\text{ft}^2$.

In 2000, VCSC and Energy Systems Group entered into an initial agreement to provide energy-related upgrades at 20 of its facilities. This initial project resulted in a guaranteed cost reduction of more than $1 million per year over the term of the agreement. To date, Energy Systems Group has met its savings guarantee.

VCSC has implemented more than $29 million in comprehensive energy improvements and renovation projects in six phases which are estimated to save close to $35 million over the terms of the contracts.

Environmental Benefits

1. *Removes emissions equivalent to more than 5,200 passenger vehicles per year.*
2. *Creates enough electricity to provide power for more than 3,800 homes per year.*
3. *Planting more than 6,500 acres of forests annually.*

https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:

Key EEMs:
• Comprehensive HVAC improvements and replacements • Lighting systems redesigns and retrofits • First school in Indiana to be 100% retrofitted with light-emitting diodes (LEDs) • Electrical system upgrades • District-wide EMS • Window replacements • Hot water pump replacements • 1.5-kW wind turbine with curriculum for science students • High school pool improvements.

Installation Costs	M&V Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$29,922,466	$75,477	$29,977,943	$60,000	$29,862,466

Energy $ Savings	O&M $ Savings	Capital Cost Avoidance	Total Annual $ Savings
$592,321/year	$1,395,838/year	$1,206,457/year	$3,194,616

Energy Cost Intensity Pre-Retrofit	Energy Cost Intensity Post-Retrofit	Energy Cost Intensity ASHRAE 90.1-2004	Simple Payback (years) (Excluding Incentives)
$\$0.84/\text{ft}^2$	$\$0.70/\text{ft}^2$	$\$1.40/\text{ft}^2$	9.3 (9.4)

https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:

System	EEM Description	Applicable to: Hot-Humid	Hot Dry	Marine	Cold	Very Cold
Lighting	Replace incandescent lamps in exit signs with LEDs	✓	✓	✓	✓	✓
	Replace T12 fluorescent lamps and magnetic ballasts with high- efficiency T8 lamps and instant-start electronic ballasts	✓	✓	✓	✓	✓
	Replace incandescent lamps with compact fluorescent lamps (CFLs)	✓	✓	✓	✓	✓
	Install wireless motion sensors for lighting in rooms that are used intermittently	✓	✓	✓	✓	✓
	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient	✓	✓	✓	✓	✓
	Replace high intensity discharge (HID) lights with T5 high- output (HO) fluorescents in gymnasiums	✓	✓	✓	✓	✓
	Install more efficient exterior lighting for façades and parking lot	✓	✓	✓	✓	✓
Plug and process loads	Replace cafeteria appliances with ENERGY STAR models	✓	✓	✓	✓	✓
	Install VSD demand control for kitchen hood exhaust fans	✓	✓	✓	✓	✓

https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:

System	EEM Description	Applicable to:				
		Hot-Humid	Hot Dry	Marine	Cold	Very Cold
Envelope	Add reflective roof covering	✓	✓		✓	
Service water heating	Install low-flow showerheads in locker rooms	✓	✓	✓	✓	✓
HVAC Heating and cooling	Add evaporative precooling of condenser supply air		✓			
	Add a small condensing boiler to handle the base load and summer load, with current inefficient boiler operating when heating loads are highest	✓	✓	✓	✓	✓
	Install VSDs on chilled-water and hot water pumps	✓	✓	✓	✓	✓
	Replace standard furnace with a high-efficiency condensing furnace	✓	✓	✓	✓	✓
	Install an EMS and replace pneumatic controls with direct digital controls (DDCs)	✓	✓	✓	✓	✓
	Replace oversized, inefficient fans and motors with rightsized National Electric Manufacturers Association (NEMA) premium efficiency models	✓	✓	✓	✓	✓
	Convert CV or dual-duct air handling system to variable air volume (VAV) (add dampers, VSD fan motors)	✓	✓	✓	✓	✓
	Install VSDs on cooling tower fans	✓	✓	✓	✓	✓
HVAC Ventilation	Install a dry-bulb airside economizer	✓	✓	✓	✓	✓
	Upgrade to DCV to reduce OA flow during partial occupancy	✓	✓	✓	✓	✓
	Add heat/energy recovery to the ventilation system	✓	✓	✓	✓	✓

https://buildingdata.energy.gov/cbrd/resource/17

Advanced Energy Retrofit Guide

- For example, for K-12:

Table E-2 Recommended Temperature Setbacks and Setups for U.S. Climate Zones

Climate Zone	Massive Building		Metal Building	
	Heating Setback (°F)	Cooling Setup (°F)	Heating Setback (°F)	Cooling Setup (°F)
1A	4.3	10.4	4.1	7.7
2A	9.4	13.9	10.1	11.2
3A	9.4	13.1	13.3	12.9
4A	19.4	16.4	20.7	15.3
5A	18	10.8	22.1	13.5
6A	20.5	10.4	23.9	12.7
2B	9.7	20.5	8.6	15.5
3B	7.9	14.2	12.1	13.5
4B	20.7	16.5	21.9	15.8
5B	19.4	10.6	22.1	12.1
6B	19.4	10.3	22.3	12.1
7	20.7	8.8	6.3	11.5
8	22.3	5	23	7.9

https://buildingdata.energy.gov/cbrd/resource/17

PAYBACK PERIOD EXAMPLES

Payback Period Examples

- An example of short payback period in Dayton Ohio:

	AR No.	Description	Payback (yrs)
Lighting	1	Replace Metal Halide Lamps with T-8 Flourescent Fixtures	2.3
	2	Install Photosensor Controls to Utilize Daylight	0.6
Space Conditioning	3	Install Programable Thermostat in the Office	0.2
	4	Adjust the Year Round Thermostat Set Points in the Office	0.2
Compressed Air	5	Reduce Overall Pressure in Compressed Air System	0.2
	6	Reduce Leaks in Compressed Air System	1.1
	7	Eliminate use of Air Motors on Pipe Turners	1.0

	AR No.	Description	Cost-Benefit Analysis Results	Simple Payback (yrs)
Lighting	1	Replace 8' T-12 Bulbs with 8' T-8 Bulbs	1.085	3.6
	2	Install Photo Sensor Controls	0.525	2.0
Comp Air	3	Lower Air Compressor Discharge Pressure	0.093	0.3
Space Conditioning	4	Install Programmable Thermostats	0.128	0.4
	5	Increase Air Conditioning Thermostat Set Points	0.012	0.0
Other Rec.		Replace 4' T-12 Lamps with 4' T-8 Lamps	1.881	4.9

Economic analysis of energy retrofit of buildings, 2011

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ 85-year-old
  - ❑ 114,000 ft^2
- Three energy efficiency measures are:
  - ❑ Steam boiler replaced with vertical fire tube boilers
  - ❑ Replace interior and exterior with LEDs
  - ❑ Building control upgrade

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ LEDs consume 60% less energy
  - ❑ Add controls to dim or turn off the lights
  - ❑ LED lights fail in a different way, so control may be an important factor in the light selection

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ Total cost: $870,000
  - ❑ Annual utility cost savings $99,000
  - ❑ Payback period:

$$Payback = \frac{870{,}000}{99{,}000} = 8.8\ years$$

  - ❑ The project has received $70,000 in utility rebates, making the economic case more practical

$$Payback = \frac{(870{,}000 - 70{,}000)}{99{,}000} = 7.8\ years$$

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Long payback period for building envelopes:
  - ❑ It is hard to do a building envelope retrofit since owners only 60% of the commercial floorspaces
  - ❑ They do not have a good payback period
  - ❑ Usually there are different motivations to conduct a building envelope retrofit

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

EEM	Cost / Unit	Cost	Source
Occupancy Sensors	$1.06/ft^2	$ 44,991	RSMeans, "5 fixtures per 1000 S.F., including occupancy and time switching"
Condensing Boiler	$20,706 + $13.82/MBH	$ 31,401	RSMeans, commercial gas boilers
Light Power Density Reduction	$4.78/ft^2	$ 202,886	RSMeans, "Fluorescent high-bay 4 lamp fixture, 1W/sf,59FC, 4 fixtures per 1000 S.F."
Condensing Unit Replacement	$7,909 + $766/ton	$ 132,687	RSMeans, packaged air-cooled refrigerant compressor and condensor
Window Film	$18.93/ft^2 glazing	$ 182,311	RSMeans, "Solar Films on Glass" average of min/max value
Wall Insulation	$4.78/ft^2 wall area	$ 927,930	RSMeans, "4 in. EPS insulation, Commercial renovation Exterior Insulation and Finish System",

Payback Period Examples

Energy Efficiency Measures	Simple Payback
Condensing Boiler	9.4
Occupancy Sensors	10.4
Light Power Density Reduction	32.4
Condensing Unit Replacement	41.2
Window Film	70.7
Wall Insulation	247.0

Dahlhausen, M. PSU 2014

CLASS ACTIVITY

Class Activity

- Spend 30 to 40 minutes to propose different retrofit paths:
  - ❑ Staging
  - ❑ EBCx
  - ❑ Lowest cost
  - ❑ Lowest energy
  - ❑ IAQ
  - ❑ Decarbonization

- Complete this table:
  - ❑ https://docs.google.com/spreadsheets/d/14sF09IPNmiycBBCkLjfJTHq9MfXONQ8RqfUBOE0EaSE/edit#gid=199962998

OPENSTUDIO MEASURES

OpenStudio Measures

- Creating a Project
- Loading a Baseline Model
- Organize and Edit Measures for Project
- Select Measures and Create Design Alternatives
- Run Simulations
- Create and View Reports
- Running on the Cloud
- Viewing Results
- Publications

Back to OpenStudio®

Parametric Analysis Tool (PAT) Interface Guide

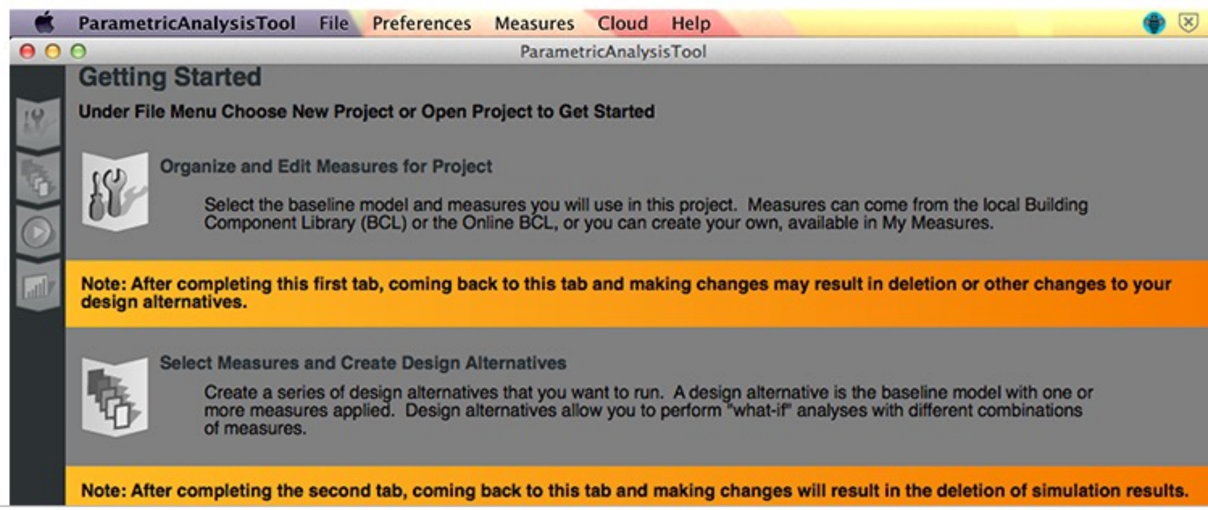
PAT removes the need to hand edit each model to try out different architectures, energy efficiency measures, and mechanical systems. PAT applies scripts to your baseline model and lets you quickly compare many alternatives. OpenStudio has developed a workflow that allows energy modelers to create and run a customized parametric analysis using commercially available cloud computing services. This workflow will enable anyone to perform powerful parametric studies in a reasonable time for a relatively low cost.

Creating a Project

The Parametric Analysis Tool Quick Start Guide (PDF) provides an introduction to the interface and workflow for creating multiple design alternatives from a seed model.

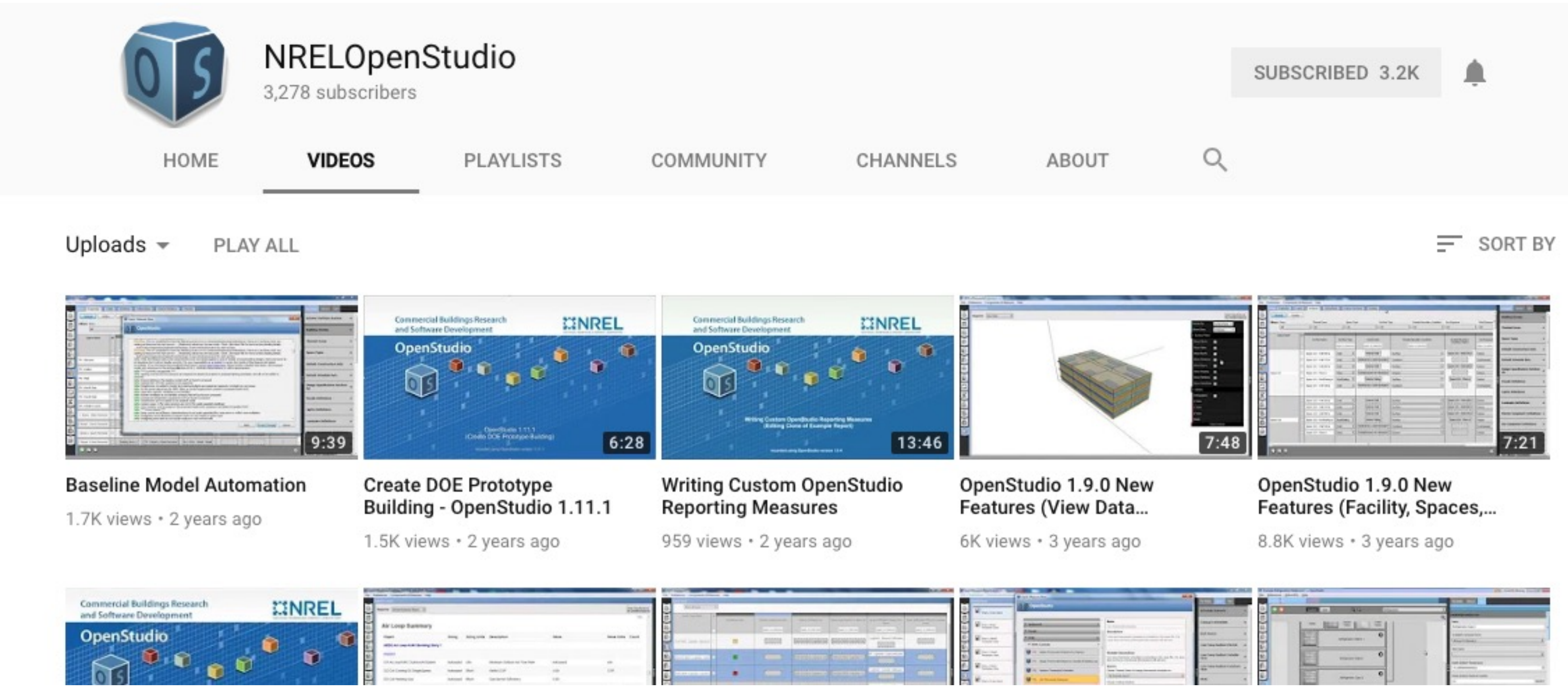
When you first open PAT you will see the screen below. It shows the workflow:

1. Organize and edit measures for project
2. Select measures and create design alternatives
3. Run simulations
4. Create and view reports



http://nrel.github.io/OpenStudio-user-documentation/reference/parametric_studies/

OpenStudio Measures



How many of you have watched any videos related to OpenStudio?

https://www.youtube.com/user/NRELOpenStudio/videos

OpenStudio Measures

- Useful links:
  - ❑ https://www.youtube.com/watch?v=3rmEIK_OB28
  - ❑ https://www.youtube.com/watch?v=4g5nJzDoh58
  - ❑ https://www.youtube.com/watch?v=9WgUhiJ785I
  - ❑ https://www.youtube.com/watch?v=0IlNfGNe5x0

http://nrel.github.io/OpenStudio-user-documentation/reference/parametric_studies/

OpenStudio Measures

- You can also use the OpenStudio App