

# CAE 465/526 Building Energy Conservation Technologies

Fall 2022

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**November 09, 2022**

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

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**Dr. Mohammad Heidarinejad, Ph.D., P.E.**  
Civil, Architectural and Environmental Engineering  
Illinois Institute of Technology

[muh182@iit.edu](mailto:muh182@iit.edu)

**EXAM**

**PROJECT**

# **HOW TO EDIT OPENSTUDIO TEMPLATES**

# **OPENSTUDIO TIPS FOR PART 2 AND 3 SUBMISSIONS**

# Add OpenStudio Results

The screenshot displays the OpenStudio software interface. On the left, a vertical toolbar contains various icons, with the 'Add Measure' icon (a blue square with a white plus sign) highlighted by a red box. The main workspace is divided into three sections: 'OpenStudio Measures', 'EnergyPlus Measures', and 'Reporting Measures'. The 'Reporting Measures' section is highlighted with a red box and contains the 'OpenStudio Results' measure, which is also highlighted with a red dashed arrow pointing to the 'OpenStudio Results' measure in the main workspace. On the right, a 'Library' panel is visible, showing a list of measures categorized by type. The 'Reporting' category is expanded, and the 'OpenStudio Results' measure is highlighted with a red box. Below the screenshot, the text 'Add the OpenStudio Results Measure' is written in red.

Add the OpenStudio Results Measure

# External Lights

Facility Building Stories Shading Exterior Equipment

Drop Exterior Lights Exterior Lights Custom

Exterior Lights Name	All	Exterior Lights Definition	Schedule	Control Option	Multiplier	End Use Subcategory
	<input type="checkbox"/>	Apply to Selected	Apply to Selected	Apply to Selected	Apply to Selected	Apply to Selected
Exterior Lights 1	<input type="checkbox"/>	Exterior Lights Definitic	Always On Discrete	AstronomicalClock	1.000000	General

# External Lights

---

- How to find out more information about the inputs

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CHAPTER 1. INPUT-OUTPUT REFERENCE

## 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.



# System Availability

Thermal Zones

HVAC Systems		Cooling Sizing Parameters	Heating Sizing Parameters	Custom				
Name	All	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule	
Thermal Zone 1	<input type="checkbox"/>	<input type="checkbox"/>	VAV with Reheat	Duct VAV Reheat 11	Cooling Sch	Heating Sch		
Thermal Zone 10	<input type="checkbox"/>	<input type="checkbox"/>	VAV with Reheat	Duct VAV Reheat 22	Cooling Sch	Heating Sch		
Thermal Zone 11	<input type="checkbox"/>	<input type="checkbox"/>	VAV with Reheat	Duct VAV Reheat 9	Cooling Sch	Heating Sch		
Thermal Zone 12	<input type="checkbox"/>	<input type="checkbox"/>	VAV with Reheat	Duct VAV Reheat 6	Cooling Sch	Heating Sch		
Thermal Zone 13	<input type="checkbox"/>	<input type="checkbox"/>	VAV with Reheat	Duct VAV Reheat 14	Cooling Sch	Heating Sch		

My Model Library Edit

Maximum Flow Fraction During Reheat

Hard Sized Autocalculate

Autosized Autosize

Maximum Reheat Air Temperature

94.999999999999929

Control For Outdoor Air

No

**OS:Coil:Heating:Water**

Name

Coil Heating Water 23

Availability Schedule Name

Always On Discrete

~~U Factor Times Area Value~~

Hard Sized

Autosized Autosize

# System Availability



6

## Availability Schedule Name "Always On Discrete"



openstudio

availability-schedule



What exactly does the Availability Schedule Name **Always On Discrete** mean?



Can anyone illustrate with an example?



add a comment

asked 7 years ago

tajmann  
455 • 1 • 11

updated 7 years ago

Jamie Bull   
5032 • 6 • 24 <http://oc-carbon.com/>

1 Answer

Sort by » [oldest](#) [newest](#) [most voted](#)



5



This is just a [ScheduleConstant](#) object. It has a single value all the time. It is made at times through the API, but isn't something you can inspect or alter in the GUI. It is the same as if you made a Ruleset Schedule with only the default profile and set it to always equal 1.

Here is what the object looks like. It is typically used for availability schedules.

```
OS:Schedule:Constant,  
{966ffa9b-9939-4499-a950-d82bd2f10042}, !- Handle  
Always On Discrete, !- Name  
{07123e75-72aa-4cb6-b376-38f41b9624e3}, !- Schedule Type Limits Name  
1; !- Value
```

add a comment

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Seen: 968 times

Last updated: Aug 07 '15

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[How to get Maximum Flow Rate](#)

# Economizer or Demand Control Ventilation

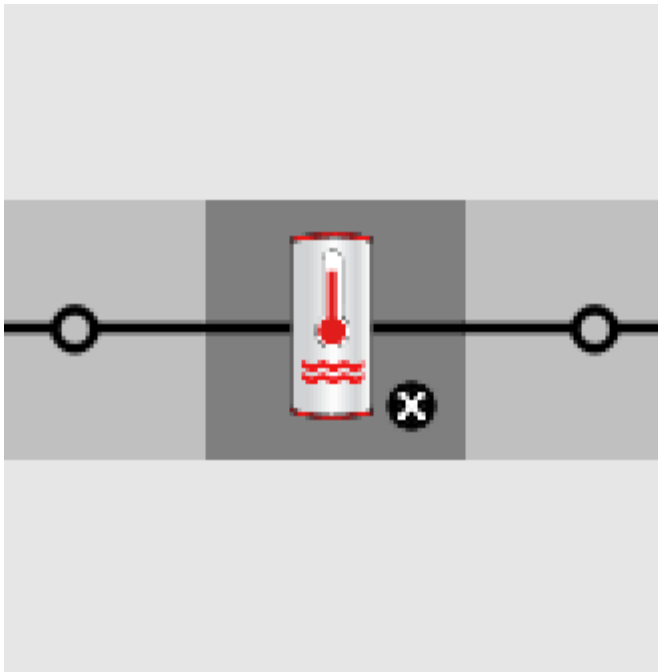
The screenshot displays the 'HVAC Systems' software interface for configuring a 'VAV with Reheat' system. The interface is organized into several sections, with key settings highlighted by red boxes:

- System Header:** The top bar shows 'HVAC Systems' and the selected system 'VAV with Reheat'. Navigation tabs for 'Layout', 'Control', and 'Grid' are visible, with 'Control' being the active tab.
- Basic Settings:** The 'Cooling Type' is set to 'Chilled Water' and the 'Heating Type' is set to 'Hot Water'.
- Time of Operation:** This section is titled 'Time of Operation' and 'HVAC Operation Schedule'. It features a dashed box containing a calendar icon and the text 'Always On Discrete'.
- Use Night Cycle:** A dropdown menu is set to 'Follow the HVAC Operation Schedule'.
- Supply Air Temperature:** This section is titled 'Supply Air Temperature' and includes the text 'Supply air temperature is controlled by a scheduled setpoint manager.' Below it, the 'Supply Air Temperature Schedule' is set to 'Deck\_Temperati'.
- Mechanical Ventilation:** This section is highlighted with a red box and contains:
  - 'Economizer' set to 'No Economizer' via a dropdown menu.
  - 'Demand Controlled Ventilation' set to 'off' via a toggle switch.
- Availability Managers:** The bottom section is titled 'Availability Managers' and includes the text 'Availability Managers from highest precedence to lowest'. A dashed box below it contains the text 'Drag From Library'.

# **SERVICE HOT WATER**

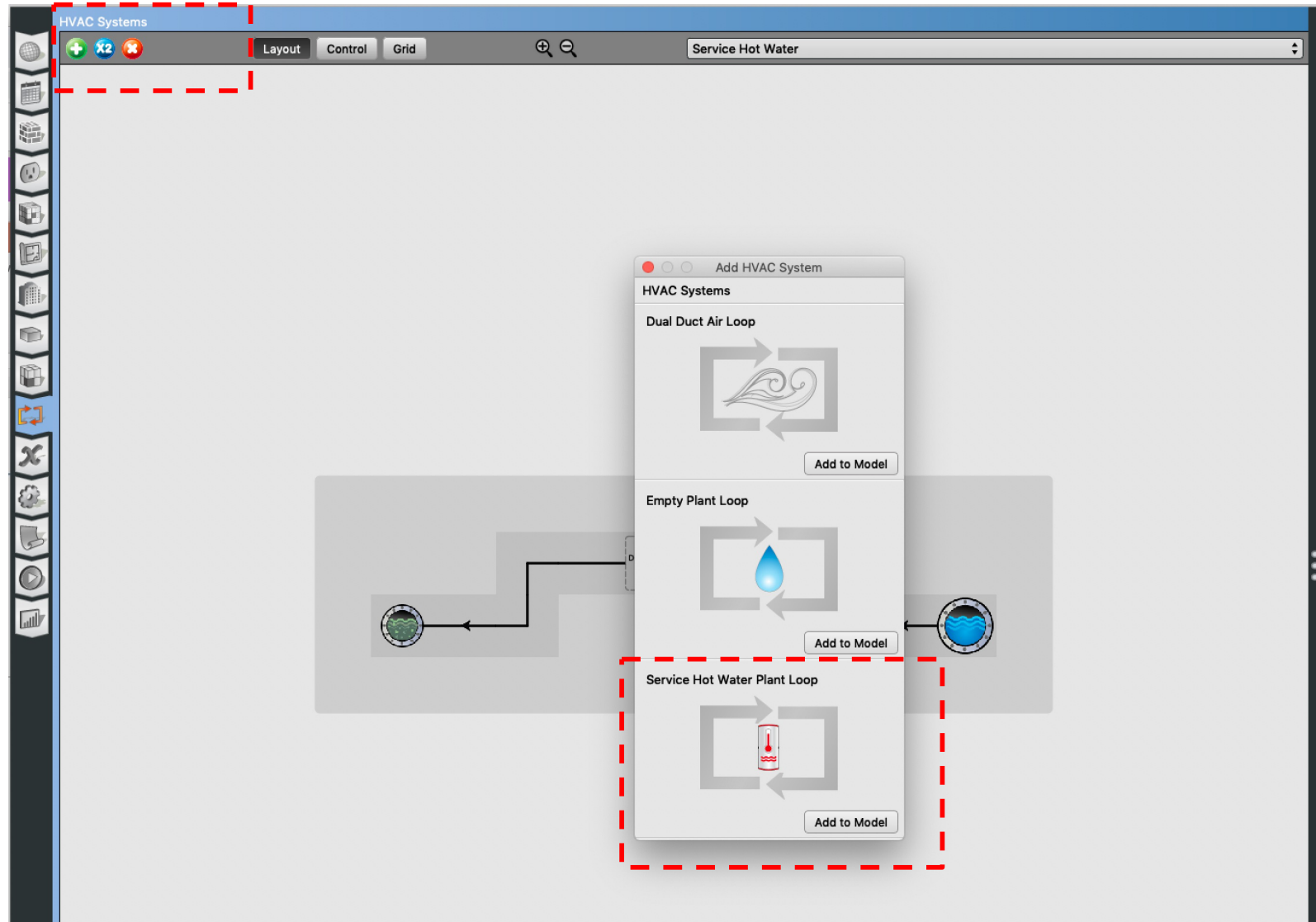
# Service Hot Water

---



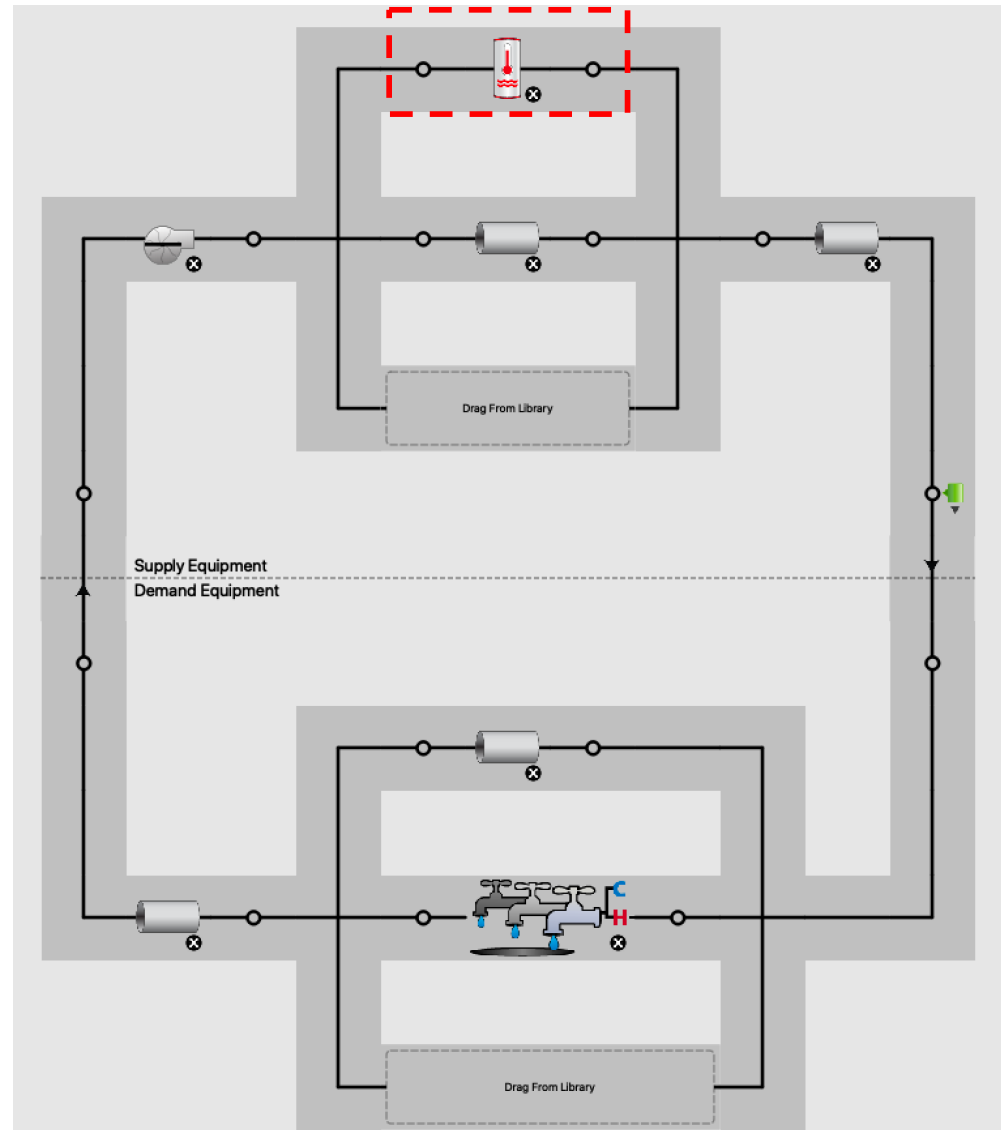
# Service Hot Water

- 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

Drag Water Use Equipment from Library

Loop

Loop

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

The image displays two screenshots of a software interface for designing HVAC systems, specifically focusing on Service Hot Water (SHW) systems. The top screenshot shows a basic loop configuration with a central equipment box labeled "Drag Water Use Equipment from Library" and two loops connected to it. The bottom screenshot shows a more detailed connection diagram with a box labeled "Drag Water Use Connections from Library" and a more complex piping arrangement. A red dashed arrow points from the top diagram to the bottom one, indicating a transition or comparison between the two designs.

The top screenshot shows a window titled "Test.osm\*" with a menu bar (File, Preferences, Components & Measures, Help) and a toolbar on the left. The main area displays a schematic diagram of a Service Hot Water system. The diagram includes a central box labeled "Drag Water Use Equipment from Library" and two loops connected to it. The left loop is labeled "Loop" and the right loop is also labeled "Loop". The bottom right loop is connected to a circular component with a blue water icon. The bottom window shows a similar schematic diagram, but with a more detailed connection diagram labeled "Drag Water Use Connections from Library". A red dashed arrow points from the bottom right loop of the top diagram to the bottom right loop of the bottom diagram.

The bottom screenshot shows a window titled "Test.osm\*" with a menu bar (File, Preferences, Components & Measures, Help) and a toolbar on the left. The main area displays a schematic diagram of a Service Hot Water system. The diagram includes a central box labeled "Drag Water Use Connections from Library" and two loops connected to it. The left loop is labeled "Loop" and the right loop is also labeled "Loop". The bottom right loop is connected to a circular component with a blue water icon. The bottom window shows a similar schematic diagram, but with a more detailed connection diagram labeled "Drag Water Use Connections from Library". A red dashed arrow points from the bottom right loop of the top diagram to the bottom right loop of the bottom diagram.

# 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 has a tabbed interface with "My Model", "Library", and "Edit" tabs. On the left, a vertical toolbar contains various icons for different load types. The main area is divided into a list of load categories on the left and a detailed configuration panel on the right. The "Water Use Equipment Definitions" category is selected, and the "Water Fixture Definition" item is highlighted with a red dashed border. The configuration panel for "Water Fixture Definition" includes 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

At the bottom of the interface, there are icons for adding (+), deleting (X2), and other actions.

# 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)

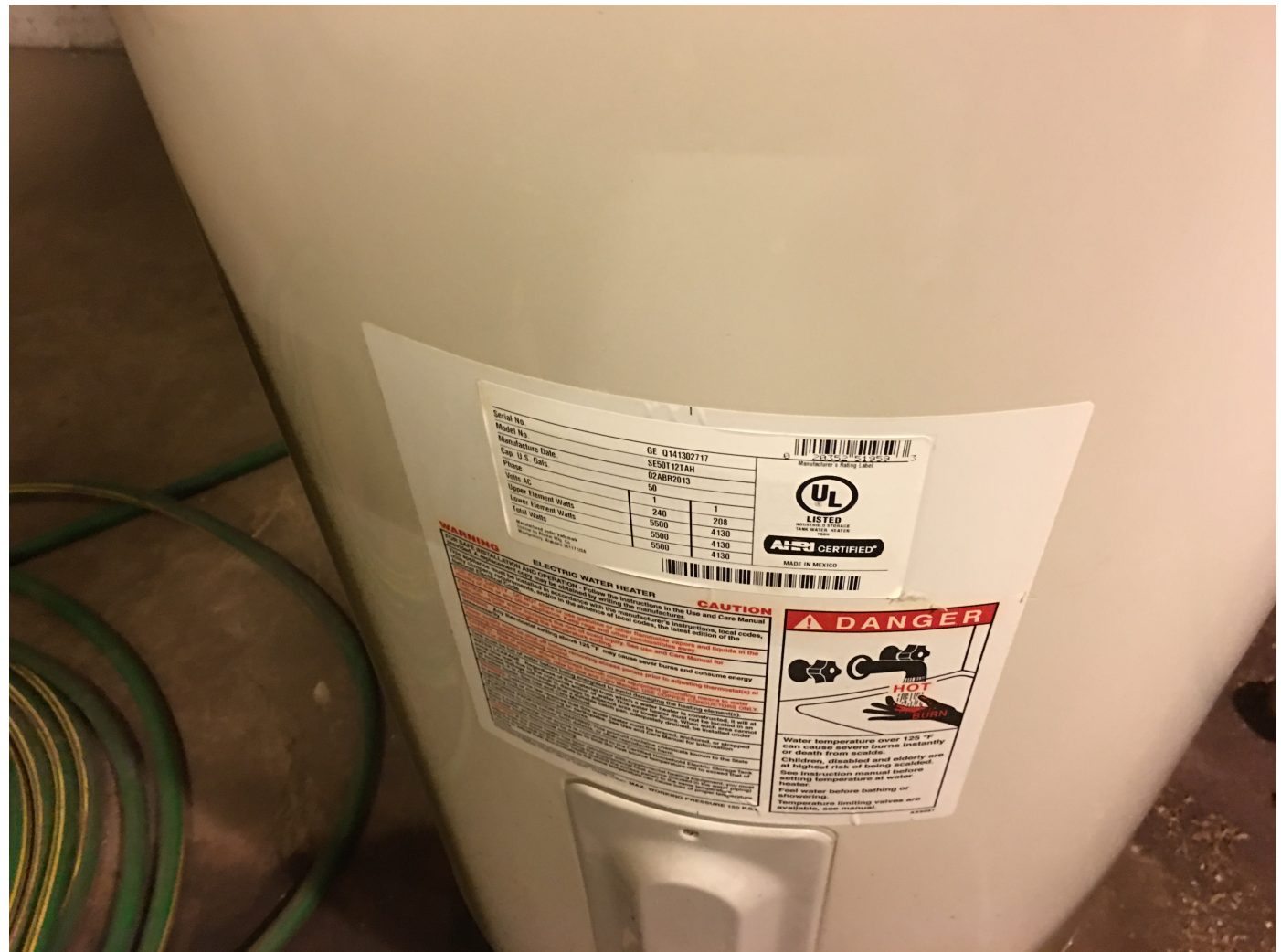
# Service Hot Water

---

- 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

- 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:

The screenshot shows the OpenStudio Online BCL interface. The left sidebar displays a tree view of categories, with 'Service Water Heating' expanded and 'Water Heating' selected. The main panel shows a list of measures under the heading 'Service Water Heating'. The measures are:

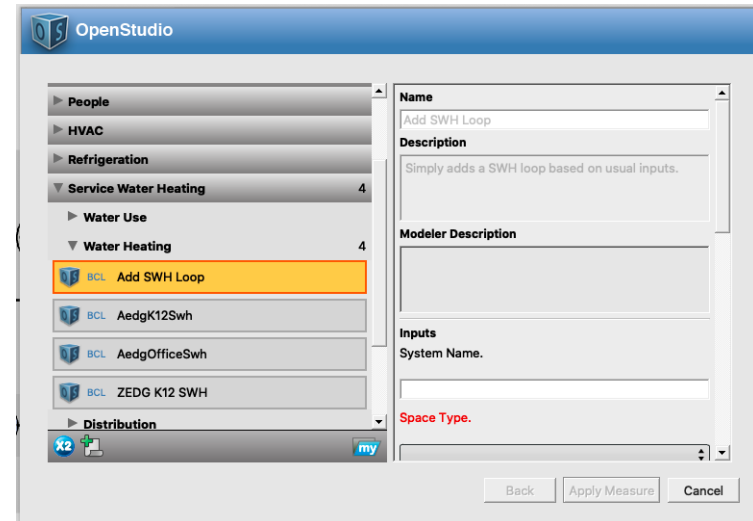
Name	Measure Type	Checked
Set Water Heater Efficiency, Heat Loss, and Peak Water Flow Rate	ModelMeasure	<input type="checkbox"/>
Set Site Water Mains Temperature	ModelMeasure	<input type="checkbox"/>
AedgK12SwH	ModelMeasure	<input checked="" type="checkbox"/>
AedgOfficeSwH	ModelMeasure	<input checked="" type="checkbox"/>
ZEDG K12 SWH	ModelMeasure	<input checked="" type="checkbox"/>
Add SWH Loop	ModelMeasure	<input checked="" type="checkbox"/>
Water Heater Mixed Multiplier	ModelMeasure	<input type="checkbox"/>
Water Heater Mixed Percent Change	ModelMeasure	<input type="checkbox"/>



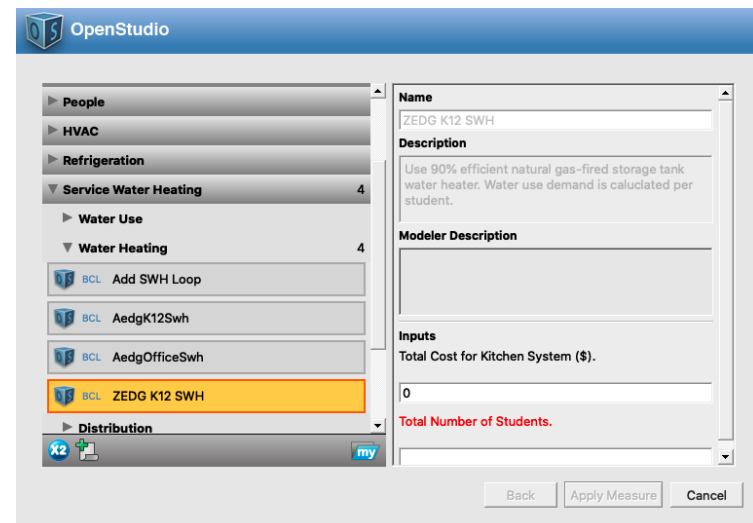
# Service Hot Water

- You can use the OpenStudio measures:

- First, use “Add SHW Loop”



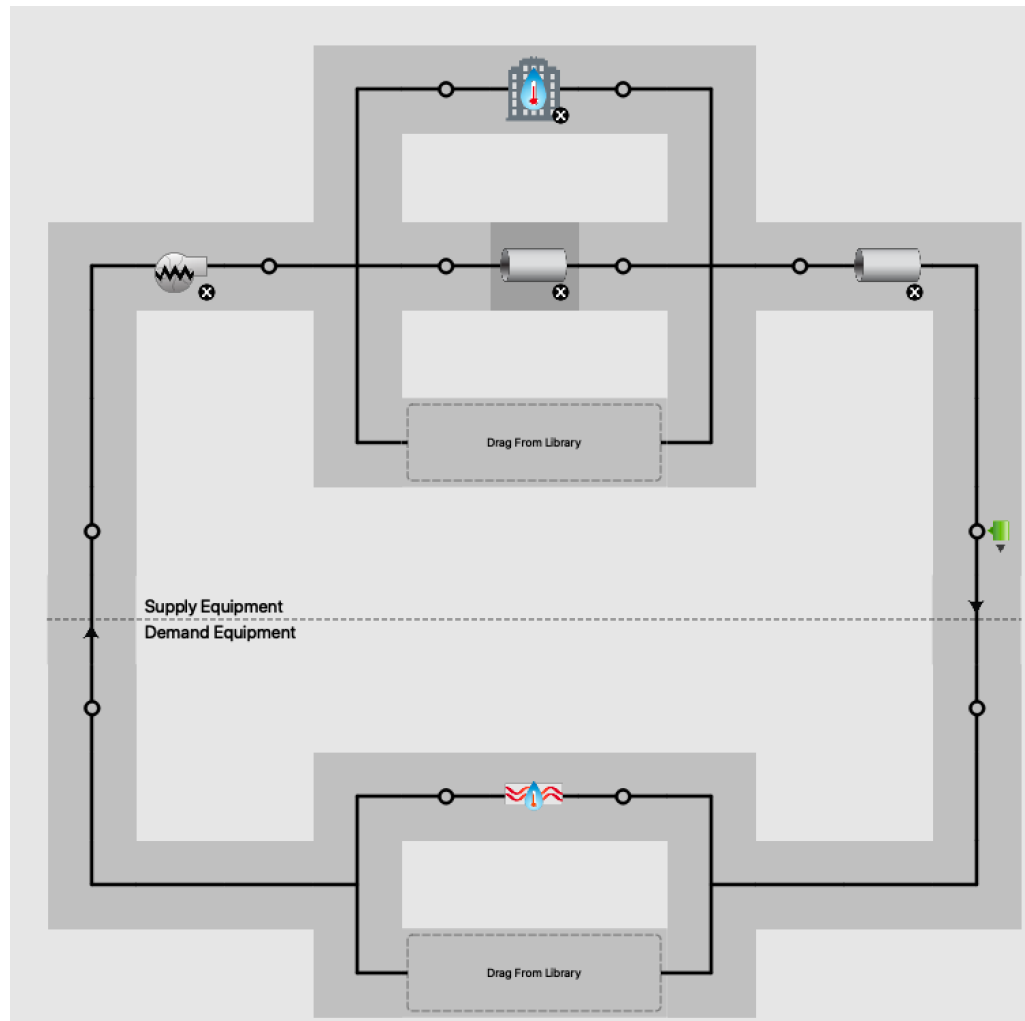
- Second, use “ZEDG K12 SHW”



**BASEBOARD**

# Baseboard

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



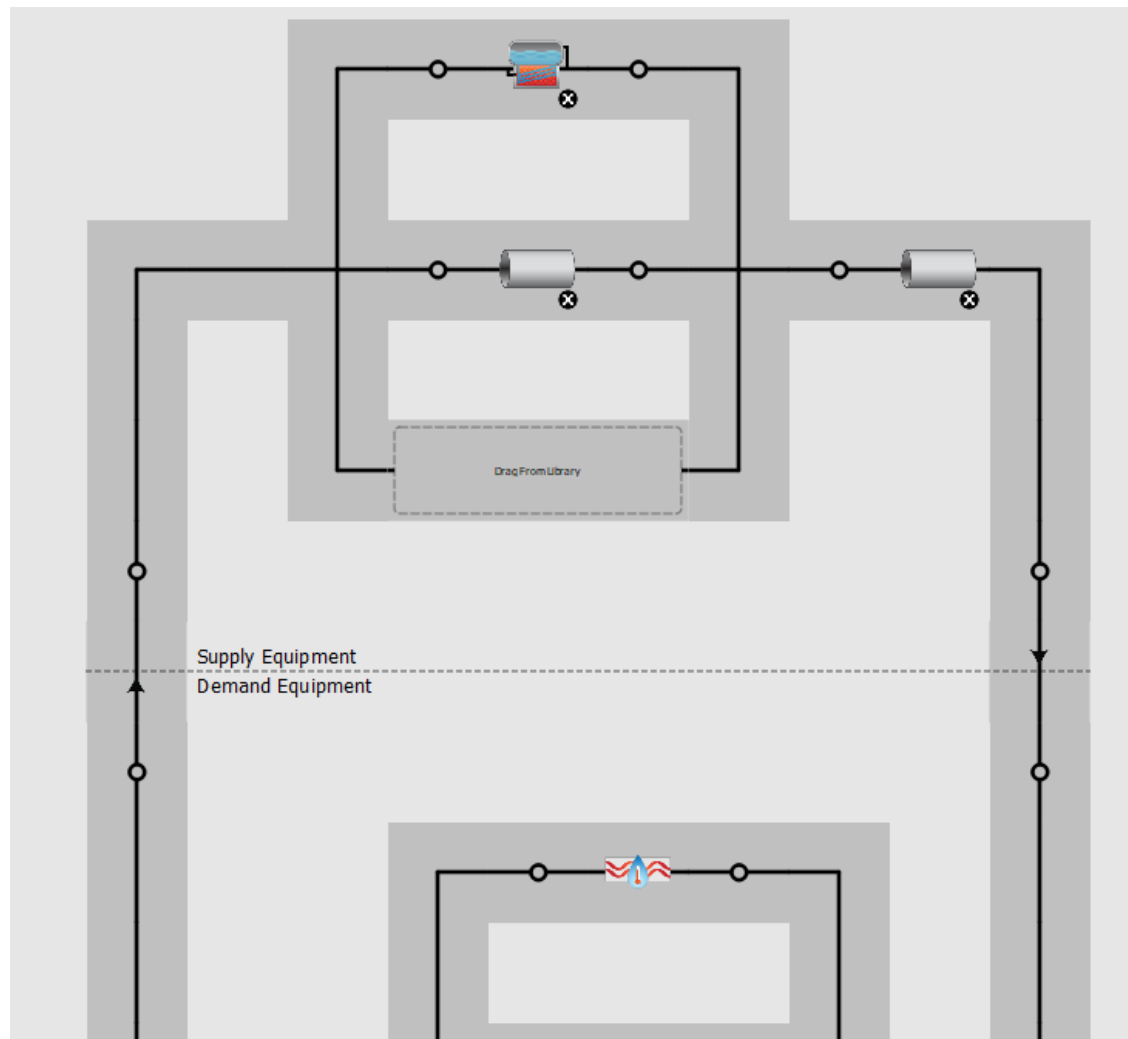
# Baseboard

- Add the convector and assign it to a loop

<div style="display: flex; justify-content: space-between; border-bottom: 1px solid black; padding-bottom: 5px;"> <span>HVAC Systems</span> <span>Cooling Sizing Parameters</span> <span>Heating Sizing Parameters</span> <span>Custom</span> </div>								
Name	All	Rendering Color	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule
	<input type="checkbox"/>		<input type="checkbox"/>					
			Apply to Selected		Apply to Selected	Apply to Selected	Apply to Selected	Apply to Selected
Thermal Zone 1	<input type="checkbox"/>	<span style="color: blue;">■</span>	<input type="checkbox"/>		HW Baseboard <span style="border: 1px dashed gray; display: inline-block; width: 50px; height: 15px;"></span>	<span style="border: 1px dashed gray; padding: 2px;">LargeHotel ClgSetp</span>	<span style="border: 1px dashed gray; padding: 2px;">LargeHotel Corridor Htg</span>	<span style="border: 1px dashed gray; display: inline-block; width: 50px; height: 15px;"></span>

# 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?

The image displays a software interface for HVAC system design. The main window shows a schematic diagram of a VAV system with PFP boxes and reheat. The diagram includes a supply equipment section (top left) and a demand equipment section (bottom). A dashed line separates the two. The system includes a fan, a reheat coil, and a VAV box. A red dashed box highlights the 'Maximum Flow Rate' section in the properties panel, which is set to 'Autosized'.

**OS:Fan:VariableVolume**

Name	Fan Variable Volume 1
Availability Schedule Name	Always On Discrete
Fan Total Efficiency	0.6045
Pressure Rise	500
Maximum Flow Rate	<input type="radio"/> Hard Sized <input checked="" type="radio"/> Autosized <span>Autosize</span>
Fan Power Minimum Flow Rate Input Method	FixedFlowRate
Fan Power Minimum Flow Fraction	0
Fan Power Minimum Air Flow Rate	

# HVAC Sizing

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- You can find the autosize fields in advance:

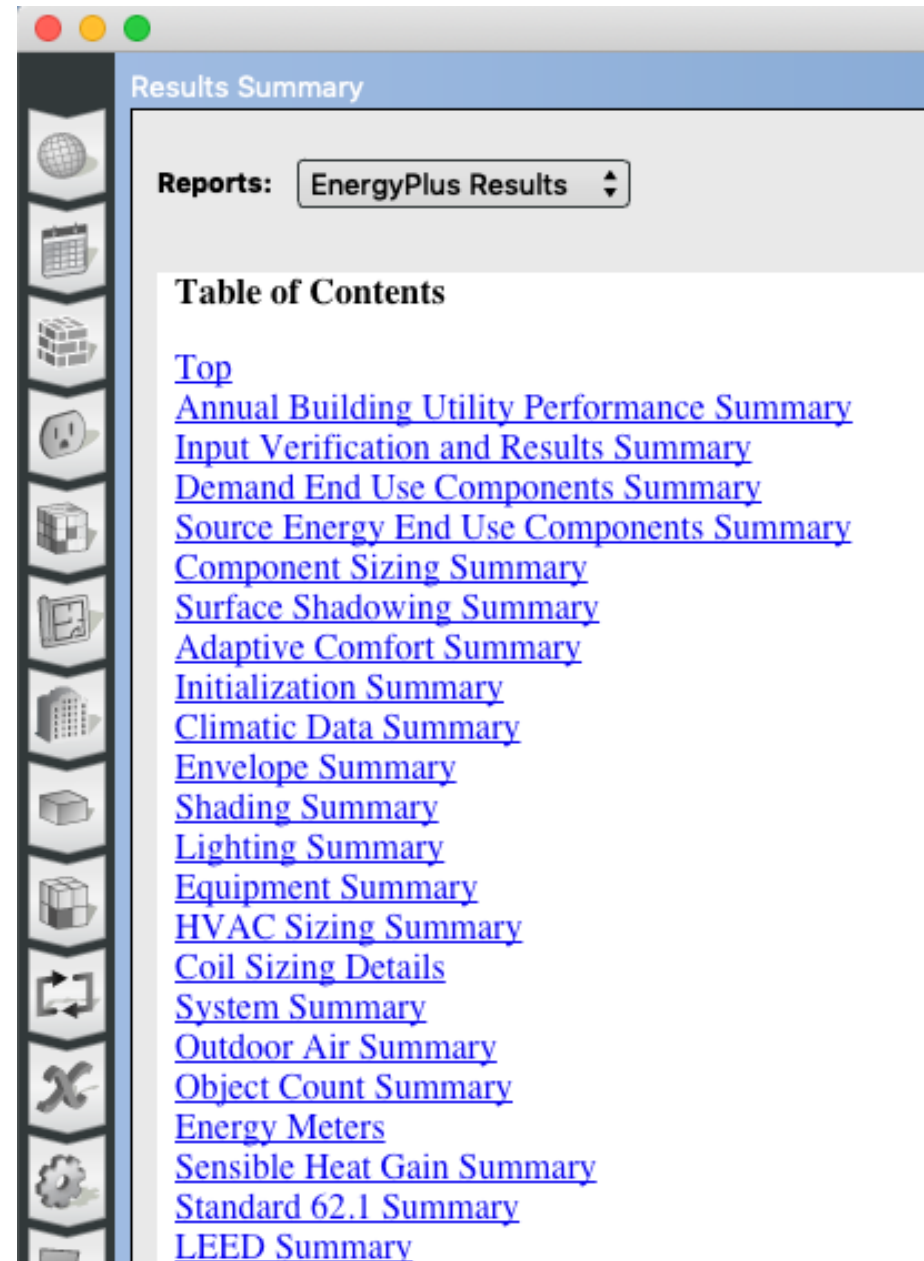
```
Fan:VariableVolume,
  Supply Fan 1,           !- Name
  FanAvailSched,         !- Availability Schedule Name
  0.7,                   !- Fan Efficiency
  600.0,                 !- Pressure Rise {Pa}
  autosize,              !- Maximum Flow Rate {m3/s}
  autosize,              !- Minimum Flow Rate {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
```



# HVAC Sizing

- Approach 1:
  - ❑ Find from EnergyPlus results



The screenshot shows a software window titled "Results Summary". On the left is a vertical toolbar with various icons. The main content area has a "Reports:" dropdown menu set to "EnergyPlus Results". Below this is a "Table of Contents" section with a list of blue hyperlinks. The link for "HVAC Sizing Summary" is highlighted.

Results Summary

Reports:























**Table of Contents**

- [Top](#)
- [Annual Building Utility Performance Summary](#)
- [Input Verification and Results Summary](#)
- [Demand End Use Components Summary](#)
- [Source Energy End Use Components Summary](#)
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- [Object Count Summary](#)
- [Energy Meters](#)
- [Sensible Heat Gain Summary](#)
- [Standard 62.1 Summary](#)
- [LEED Summary](#)

# HVAC Sizing

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- Approach 2:
  - Open the EIO extension file

Today	Today
 files	 data_point_out.json
 measures	 data_point.zip
 out.osw	 eplusout.audit
 reports	 eplusout.bnd
 run	 <b>eplusout.eio</b>
 stderr	 eplusout.end
 stdout	 eplusout.err
 workflow.osw	 eplusout.eso
	 eplusout.mdd
	 eplusout.mtd
	 eplusout.rdd
	 eplusout.shd
	 eplusout.sql
	 eplussz.csv

# HVAC Sizing

- Approach 2:
  - Find the autosize values

```
875 | <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
876 | 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 08:00:00
877 | 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
878 | <Component Sizing Information>, Component Type, Component Name, Input Field Description, Value
879 | Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Air Flow
Rate [m3/s], 0.36239
880 | Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Constant Minimum
Air Flow Fraction, 8.33684E-002
881 | Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, User-Specified Constant
Minimum Air Flow Fraction, 0.30000
882 | Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Minimum Air Flow
Rate [m3/s], 0.10872
883 | 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
884 | Component Sizing Information, AirTerminal:SingleDuct:VAV:Reheat, AIR TERMINAL SINGLE DUCT VAV REHEAT 2, Design Size Maximum Flow
Fraction during Reheat [], 0.30000
885 | 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

The screenshot displays a software interface for HVAC system design. The main window shows a schematic diagram of an air loop system. The diagram is divided into two sections: "Supply Equipment" (top) and "Demand Equipment" (bottom). The supply equipment section includes a fan, a coil, and a valve. The demand equipment section includes three zones, each with its own coil and valve. A red dashed box highlights the supply equipment section. The properties panel on the right shows the configuration for the "OS:AirLoopHVAC:OutdoorAirSystem" and "OS:Controller:OutdoorAir". The "Minimum Outdoor Air Flow Rate" is set to "Hard Sized" with a value of 0 cfm. The "Maximum Outdoor Air Flow Rate" is set to "Autosized". The "Economizer Control Type" is set to "NoEconomizer" and the "Economizer Control Action Type" is set to "ModulateFlow".

Layout Control Grid VAV with Reheat

OS:AirLoopHVAC:OutdoorAirSystem

Name  
Air Loop HVAC Outdoor Air System 1

OS:Controller:OutdoorAir

Name  
Controller Outdoor Air 1

Minimum Outdoor Air Flow Rate

Hard Sized 0 cfm

Autosized Autosize

Maximum Outdoor Air Flow Rate

Hard Sized cfm

Autosized Autosize

Economizer Control Type

NoEconomizer

Economizer Control Action Type

ModulateFlow

Economizer Maximum Limit Dry-Bulb Temperature  
82.39999999999935 F

Economizer Maximum Limit Enthalpy  
27.515047291487534 Btu/lb<sub>m</sub>

Economizer Maximum Limit Dewpoint Temperature  
F

Economizer Minimum Limit Dry-Bulb Temperature  
-148.0000000000006 F

# HVAC Sizing

- Hard size all components

The screenshot displays a software interface for HVAC system design. The main window shows a schematic diagram of a VAV with Reheat system. The diagram includes a supply air duct, a reheat coil, and three zones. A red dashed box highlights the air terminal in the top zone. The properties panel on the right is titled "OS:AirTerminal:SingleDuct:VAV:Reheat" and contains the following settings:

- Name: Air Terminal Single Duct VAV Reheat 30
- Availability Schedule Name: Always On Discrete
- Air Inlet Node Name: {0be6dd1a-bb4a-475b-bd4e-add0db656cfa}
- Maximum Air Flow Rate:  Hard Sized  Autosized
- Zone Minimum Air Flow Input Method: Constant
- Constant Minimum Air Flow Fraction:  Hard Sized (0.2999999999999999)  Autosized
- Fixed Minimum Air Flow Rate:  Hard Sized (0)  Autosized
- Minimum Air Flow Fraction Schedule Name: [Empty]
- Reheat Coil Name: Coil Heating Water 32
- Maximum Hot Water or Steam Flow Rate:  Hard Sized  Autosized

# HVAC Sizing

- Hard size all components

The screenshot displays the HVAC Systems software interface. The main window shows a schematic of a "Chilled Water Loop" with various components like pumps, valves, and chillers. A red dashed box highlights a specific chiller component in the diagram. On the right side, the properties panel for "OS:Chiller:Electric:EIR" is visible. The panel includes fields for Name, Reference Capacity, Reference COP, Reference Leaving Chilled Water Temperature, Reference Entering Condenser Fluid Temperature, Reference Chilled Water Flow Rate, Reference Condenser Fluid Flow Rate, and Cooling Capacity Function of Temperature Curve Name. A red dashed box highlights the Reference Entering Condenser Fluid Temperature field, which is set to 84.5199999999988 F.

OS:Chiller:Electric:EIR

Name  
Chiller Electric EIR 1

Reference Capacity  
 Hard Sized 2038062.0634066698 Btu/h  
 Autosized Autosize

Reference COP  
5.5

Reference Leaving Chilled Water Temperature  
44.005999999999965 F

Reference Entering Condenser Fluid Temperature  
84.5199999999988 F

Reference Chilled Water Flow Rate  
 Hard Sized gal/min  
 Autosized Autosize

Reference Condenser Fluid Flow Rate  
 Hard Sized gal/min  
 Autosized Autosize

Cooling Capacity Function of Temperature Curve Name  
Curve Biquadratic 1

Electric Input to Cooling Output Ratio Function of Temperature Curve Name  
Curve Biquadratic 2

Electric Input to Cooling Output Ratio Function of Part Load Ratio Curve Name  
Curve Quadratic 1

# HVAC Sizing

- Hard size all components

The screenshot displays the HVAC Systems software interface. The main window shows a schematic of a "Condenser Water Loop 1". The schematic includes a pump, a cooling tower, and various piping and valves. A red dashed box highlights the cooling tower component in the schematic. The right-hand panel shows the properties for the selected component, "OS: Cooling Tower: Single Speed". The properties are as follows:

Property	Value
Name	Cooling Tower Single Speed 2
Design Water Flow Rate	Autosized
Design Air Flow Rate	Autosized
Fan Power at Design Air Flow Rate	Autosized
U-Factor Times Area Value at Design Air Flow Rate	Autosized
Air Flow Rate in Free Convection Regime	Autosized
U-Factor Times Area Value at Free Convection Air Flow Rate	Autosized
Performance Input Method	UFactorTimesAreaAndDesignWaterFlowRate
Nominal Capacity	

# HVAC Sizing

- Hard size all components

The screenshot displays a software interface for HVAC sizing, divided into a main table and a detailed view on the right.

**Thermal Zones Table:**

Name	All	Rendering Color	Turn On Ideal Air Loads	Air Loop Name	Zone Equipment	Cooling Thermostat Schedule	Heating Thermostat Schedule	Humidifying Setpoint Schedule	Dehumidify Schedule
Thermal Zone 1	<input type="checkbox"/>		<input type="checkbox"/>	VAV with Reheat 1	HW Baseboard Single Duct VAV Reheat 60	Medium Office ClgSetp	Medium Office HtgSetp		
Thermal Zone 10	<input type="checkbox"/>		<input type="checkbox"/>	VAV with Reheat 1	HW Baseboard 67 Single Duct VAV Reheat 61	Medium Office ClgSetp	Medium Office HtgSetp		
Thermal Zone 11	<input type="checkbox"/>		<input type="checkbox"/>	VAV with Reheat 1	HW Baseboard 54 Single Duct VAV Reheat 62	Medium Office ClgSetp	Medium Office HtgSetp		
Thermal Zone 12	<input type="checkbox"/>		<input type="checkbox"/>	VAV with Reheat 1	HW Baseboard 57 Single Duct VAV Reheat 63	Medium Office ClgSetp	Medium Office HtgSetp		
Thermal Zone 13	<input type="checkbox"/>		<input type="checkbox"/>	VAV with Reheat 1	HW Baseboard 63 Single Duct VAV Reheat 64	Medium Office ClgSetp	Medium Office HtgSetp		

**OS: AirTerminal: SingleDuct: VAV: Reheat 60 Properties:**

- Name: Air Terminal Single Duct VAV Reheat 60
- Availability Schedule Name: Always On Discrete
- Air Inlet Node Name: {1ca7d805-4099-4d6b-877c-ced44a01dba}
- Maximum Air Flow Rate:
  - Hard Sized
  - Autosized (Autosize)
- Zone Minimum Air Flow Input Method: Constant
- Constant Minimum Air Flow Fraction:
  - Hard Sized (0.2999999999999999)
  - Autosized (Autosize)
- Fixed Minimum Air Flow Rate:
  - Hard Sized (0)
  - Autosized (Autosize)
- Minimum Air Flow Fraction Schedule Name:
- Reheat Coil Name: Coil Heating Water 62
- Maximum Hot Water or Steam Flow Rate:
  - Hard Sized (0)



# **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

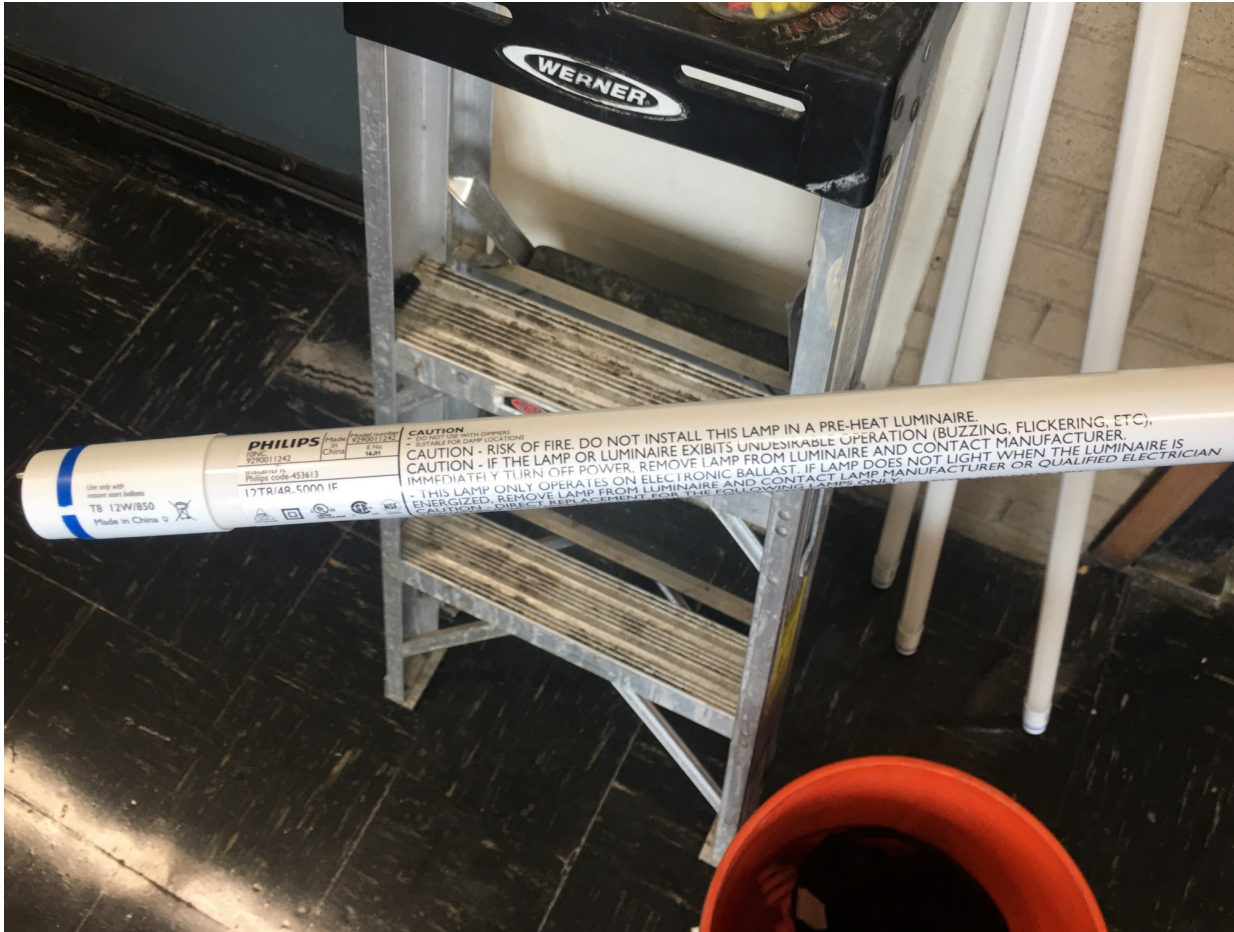
---

- We looked at the new window installed on campus



# Building Retrofit EEM

- We looked at lighting EEMs



# Building Retrofit EEM

- You can find the datasheet

## LED InstantFit Lamps

### 12T8/48-5000 IF 10/1

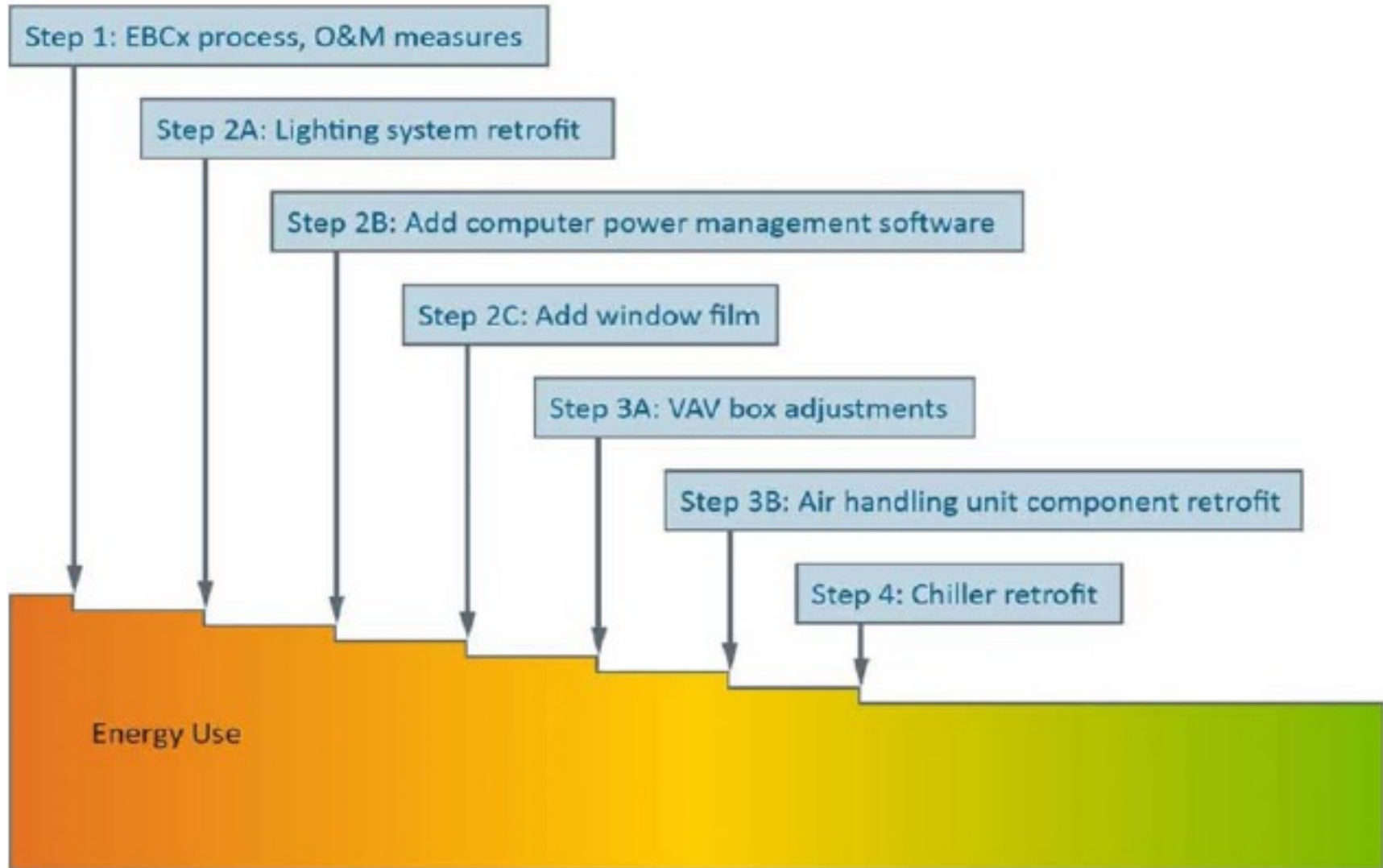
Philips LED T8 InstantFit Lamps are an ideal energy saving choice for existing linear fluorescent fixtures.

#### Product data

General Information		Power Factor (Nom)		0.9	
Cap-Base	G13 [ Medium Bi-Pin Fluorescent]	Voltage (Nom)	120-277 V		
Main Application	Industrial	<b>Temperature</b>			
Nominal Lifetime (Nom)	50000 h	T-Ambient (Max)	45 °C		
Switching Cycle	50000X	T-Ambient (Min)	-20 °C		
B50L70	50000 h	T-Storage (Max)	65 °C		
<b>Light Technical</b>		T-Storage (Min)	-40 °C		
Color Code	850 [ CCT of 5000K]	T-Case Maximum (Nom)	40 °C		
Beam Angle (Nom)	160 °	<b>Controls and Dimming</b>			
Luminous Flux (Nom)	1650 lm	Dimmable	No		
Luminous Flux (Rated) (Nom)	1650 lm	<b>Mechanical and Housing</b>			
Rated Beam Angle	160 °	Product Length	1200 mm		
Correlated Color Temperature (Nom)	5000 K	<b>Approval and Application</b>			
Color Consistency	<5	Energy Saving Product	Yes		
Color Rendering Index (Nom)	82	Approval Marks	UL certificate RoHS compliance KEMA Keur certificate DLC compliance		
LLMF At End Of Nominal Lifetime (Nom)	70 %	Energy Consumption kWh/1000 h	14.5 kWh		
<b>Operating and Electrical</b>		<b>Product Data</b>			
Input Frequency	50 to 60 Hz	Order product name	12T8/48-5000 IF 10/1		
Power (Rated) (Nom)	12 W	EAN/UPC - Product	046677453619		
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				

# 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

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.

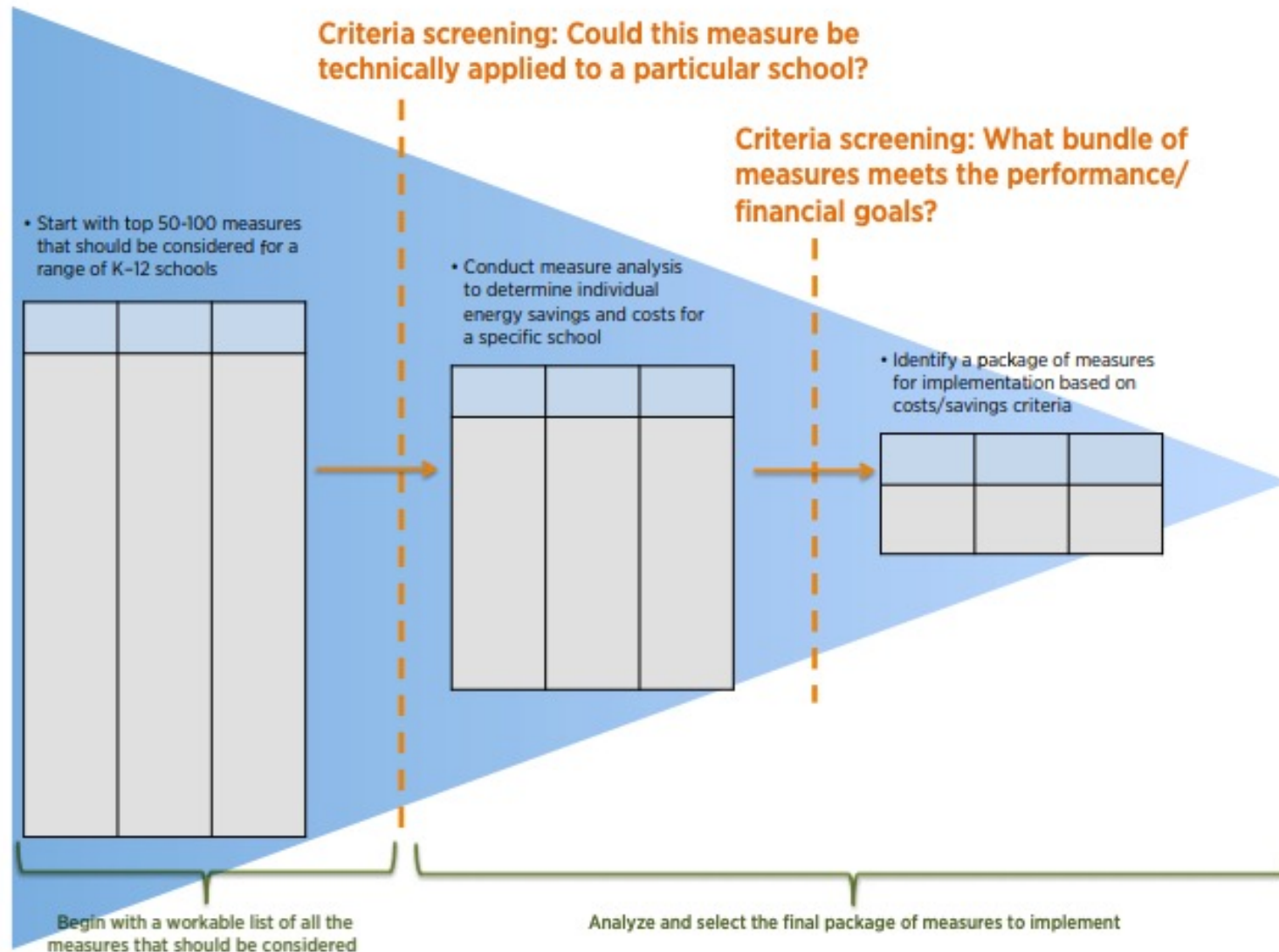
# Advanced Energy Retrofit Guide

- 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	●	●	●	●	●	●

# Advanced Energy Retrofit Guide

- For example, for K-12:



# 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

### 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/ft<sup>2</sup>. This was compared to other Indiana school facilities that had installed energy retrofits resulting in energy costs as low as \$0.65/ft<sup>2</sup>. Of the 19 VCSC schools surveyed, 9 were operating at more than \$0.90/ft<sup>2</sup>.

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.*

# Advanced Energy Retrofit Guide

- For example, for K-12:

Key EEMs:				
<ul style="list-style-type: none"> <li>• Comprehensive HVAC improvements and replacements</li> <li>• Lighting systems redesigns and retrofits</li> <li>• First school in Indiana to be 100% retrofitted with light-emitting diodes (LEDs)</li> <li>• Electrical system upgrades</li> <li>• District-wide EMS</li> </ul>		<ul style="list-style-type: none"> <li>• Window replacements</li> <li>• Hot water pump replacements</li> <li>• 1.5-kW wind turbine with curriculum for science students</li> <li>• High school pool improvements.</li> </ul>		
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/ft <sup>2</sup>	\$0.70/ft <sup>2</sup>	\$1.40/ft <sup>2</sup>	9.3 (9.4)	



# 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	✓	✓	✓	✓	✓

# 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	✓	✓	✓	✓	✓

# 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

# **PAYBACK PERIOD EXAMPLES**

# Payback Period Examples

- An example of short payback period in Dayton Ohio:

	<i>AR No.</i>	<i>Description</i>	<i>Payback (yrs)</i>
<i>Lighting</i>	1	Replace Metal Halide Lamps with T-8 Fluorescent Fixtures	2.3
	2	Install Photosensor Controls to Utilize Daylight	0.6
<i>Space Conditioning</i>	3	Install Programmable Thermostat in the Office	0.2
	4	Adjust the Year Round Thermostat Set Points in the Office	0.2
<i>Compressed Air</i>	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

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

# Payback Period Examples

---

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



# 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

# Payback Period Examples

---

- Building: Liberty Tower (Dayton, Ohio)

- Total cost: \$870,000

- Annual utility cost savings \$99,000

- Payback period:

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

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

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



# 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

# Payback Period Examples

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

# Payback Period Examples

---

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

---

# **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

## 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

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

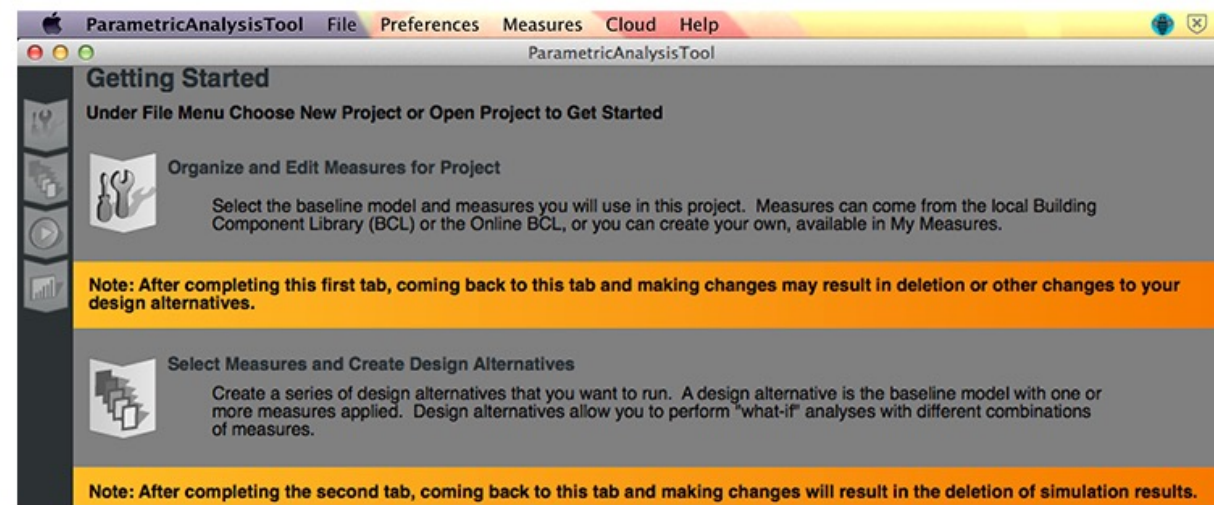
[Back to OpenStudio®](#)

### 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



# OpenStudio Measures

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# OpenStudio Measures

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- Useful links:
  - ❑ [https://www.youtube.com/watch?v=3rmEIK\\_OB28](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=0IINfGNe5x0>

# OpenStudio Measures

- You can also use the OpenStudio App

