Exercise 5

Domestic hot water, heating and cooling systems

In this exercise, you will model the domestic hot water (DHW) and the heating and cooling system of the apartment building by substituting the ideal system with a real one.

Step 1: Load the model starting point

It is always a good idea to periodically save your model with a new name with OpenStudio; if you named your file (for example) exercise_4.osm, save the model again as exercise_5.osm and work with the new file for this exercise.

Step 2: Load the design day file for your model

Until now, we have only used the EnergyPlus weather file (EPW), which contains 8,760 values for each meteorological parameter included in a typical meteorological year (TMY) dataset, which corresponds with the number of hours in a year. We used this file to run an annual energy simulation.
The design day file (DDY) is used for sizing (design day simulation) the equipment that is specified as 'auto size' in the project.

1) Navigate to the Site tab 

a. Click the Import From DDY button at the middle of the page, and select your downloaded weather file (in .ddy format).

Step 3: Setback setpoints schedule

Until now, we have used a constant setpoint; the temperature inside the apartments has been maintained at a constant temperature (e.g., 20°C for heating) at all times. However, this can be considered a waste of energy because the apartments are not always occupied. We can introduce setbacks by altering the setpoint values in the heating (and cooling) schedules to save energy. It is also possible to create a night setback schedule; this implies that the temperature can be lowered during the night, even if the space is occupied (e.g., bedroom).

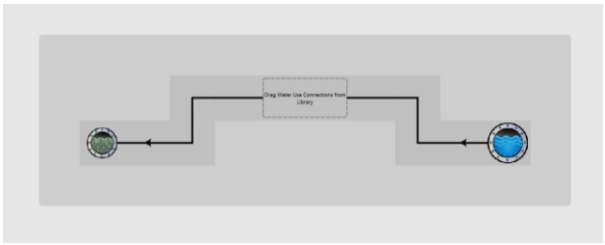
Following your occupancy schedule, implement a setback by modifying the heating (and cooling) setpoint schedule. (A good starting point for a setback temperature is 16°C. This prevents the heating system from working too hard when the space is occupied, and you want to warm up the apartment quickly. However, consider that now we are working with real systems: contrary to an ideal system, a real one will take time to heat and cool a space. This could potentially affect comfort).

Step 4: Domestic Hot Water (DHW) system

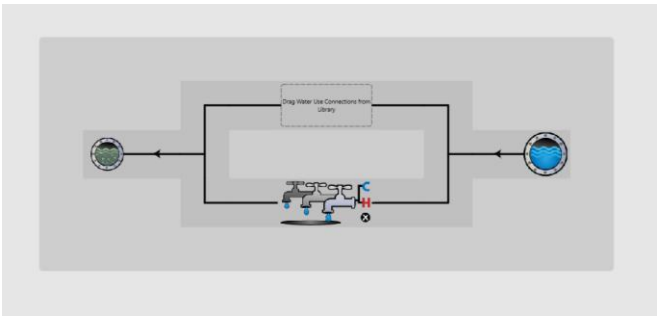
- **Domestic Hot Water (DHW)** [single apartment]

1) Navigate to the HVAC System tab 

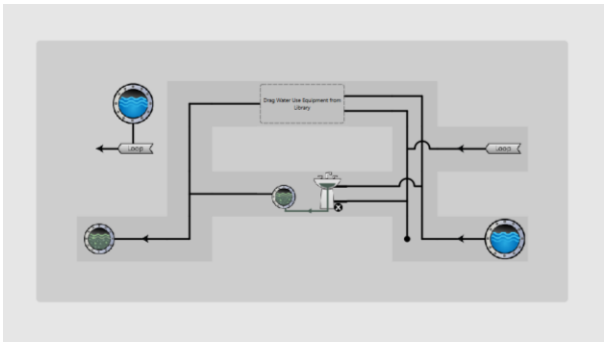
a. We need to create a domestic hot water system. You can see that we have a water system in place. It comes from the city water main, it continues to our building and then goes to the sewer.



b. We need to drag in a water use connection from the library. In the Library tab on the right-hand panel, under Water Uses find Water Use Connections. Expand the drop-down icon to find Water Use Connection, select it and drag and drop it in place (the water use connection represents one apartment).

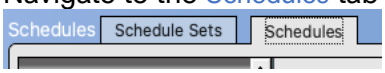


c. Click on the Water Use Connection and under Name type “Water use Apartment 1”. We need to drag in a water use equipment from the library. In the Library tab on the right-hand panel, under Water Uses find Water Use Equipment. Expand the drop-down icon to find Water Fixture, select it and drag and drop it in place (the water fixture represents only one equipment, for example, the sink. For simplicity you can consider only the shower as fixture for the hot water demand. However, if you want to be precise you can consider also the sink in the bathroom and kitchen. To combine them see the respective lecture).



d. Click on the Water Fixture. Under Name type “Shower 1 Apartment 1” and under Space Name select 0-A1.WC. You can notice that under Flow Rate Fraction Schedule Name there is no schedule select; we need to create one.

2) Navigate to the Schedules tab  and then to Schedules (not Schedule Sets).



a. On the bottom left of the page, click the + to create a new object.

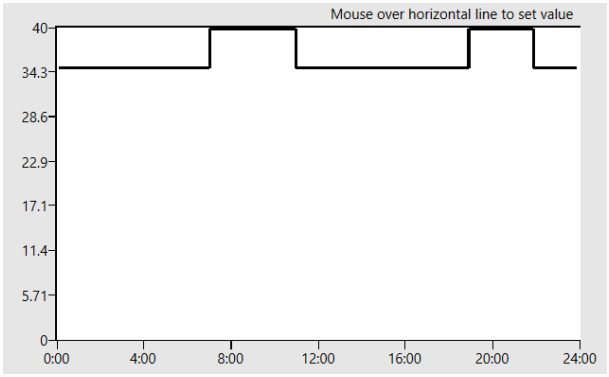
b. Under Schedule Type, select Fractional.
c. Rename the schedule “Schedule Flow Rate Fraction”.
d. This schedule will mimic the occupancy schedule. One should expect the peak domestic water flow for hours when the building is occupied and at reduced flow when the building is minimally occupied. You can create the schedule following the table below.

Hot water usage		
• For: weekdays	• For: weekends	• For: Holidays
— Until: 05:00, 0.02	— Until: 08:00, 0.02	— Until: 24:00, 0.02
— Until: 06:00, 0.07	— Until: 09:00, 0.07	
— Until: 09:00, 0.20	— Until: 11:00, 0.20	
— Until: 10:00, 0.07	— Until: 12:00, 0.07	
— Until: 17:00, 0.02	— Until: 16:00, 0.02	
— Until: 18:00, 0.07	— Until: 17:00, 0.07	
— Until: 21:00, 0.15	— Until: 20:00, 0.15	
— Until: 22:00, 0.07	— Until: 21:00, 0.07	
— Until: 24:00, 0.02	— Until: 24:00, 0.02	

e. Select WaterUse Schedule 120F.
f. Change the values of the schedule using the following the table below:

— Until: 07:00, 35°C
— Until: 11:00, 40°C
— Until: 19:00, 35°C
— Until: 22:00, 40°C
— Until: 24:00, 35°C

g. The final schedule for water use should resemble the image below



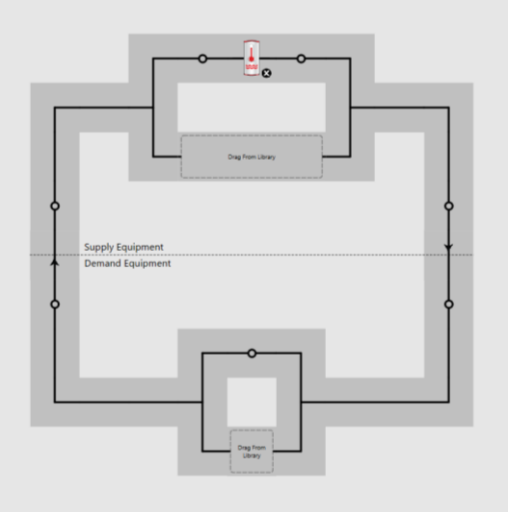
3) Navigate to the Loads tab  and under Water Use Equipment Definitions select Water Fixture Definition.

a. Under Peak Flow Rate type “0.000032” (this correspond ~114 l/h, which is the hot water demand for a shower).

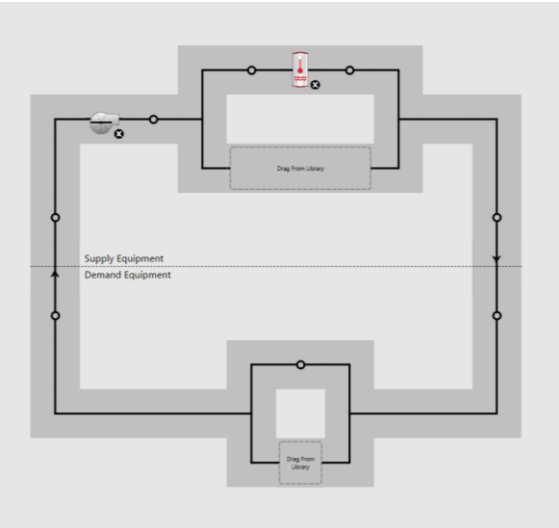
4) Navigate to the HVAC System tab 

a. Click on the Water Use Connection and then on the Water Fixture. Under Flow Rate Fraction Schedule Name select Schedule Flow Rate Fraction.
b. If in the same image we click on loop nothing happens; this is the case because we do not have any hot water system connected to this system. We will need to create a hot water loop. Go back to Water Mains Editor and on the top left of the page, click the + to create a new object.

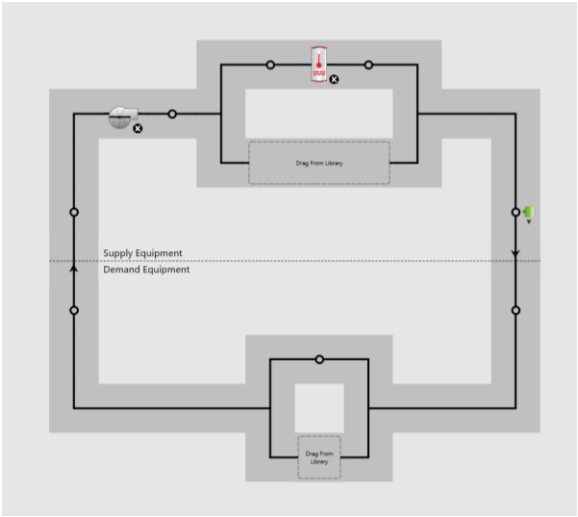

c. Scroll down to create an Empty Plant Loop and Click Add to Model. Click on the dashed line and under Name type “Boiler Apartment 1”.
d. First, we will add a water heater. In the Library tab on the right-hand panel, under Water heaters find Water Heater Mixed. Expand the drop-down icon to find Water Heater, select it and drag and drop it in place.



e. Next, we will need to add a pump. In the Library tab on the right-hand panel, under Pumps find Pump Constant Speed. Expand the drop-down icon to find Const Spd Pump, select it and drag and drop it in place.

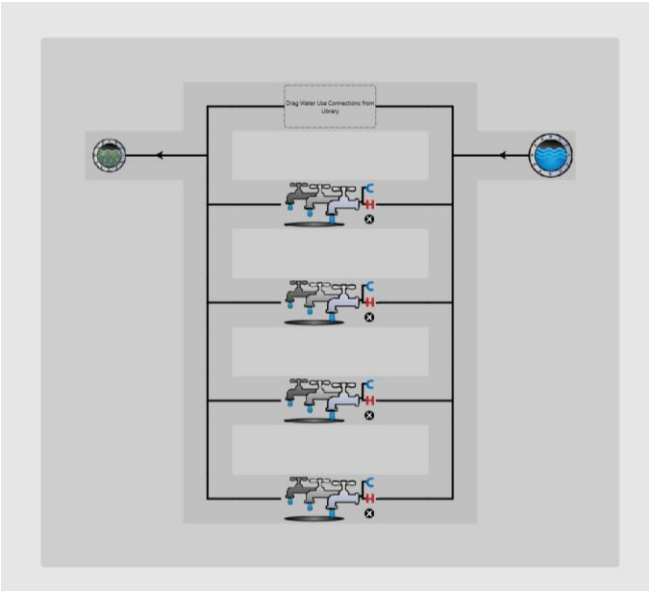


f. Then we need a setpoint manager to maintain the temperature of the loop. In the Library tab on the right-hand panel, under Setpoint Managers find Setpoint Manager Scheduled. Expand the drop-down icon to find Scheduled HW Temp, select it and drag and drop it in place. Click on it and under Schedule Name select Water Heater Setpoint Temperature.



g. Nest we will need to assign the water use equipment to this plant loop. In the My Model tab on the right-hand panel, under Water Uses find Water Use Connections. Expand the drop-down icon to find Water use Apartment 1, select it and drag and drop it in place.

The system is now finalised, and we have created a boiler for apartment 1. Now repeat the process for all the other apartments. Each apartment must have its water use connection, water use equipment, and boiler (See image below for an example).



Step 5: Heating and Cooling system

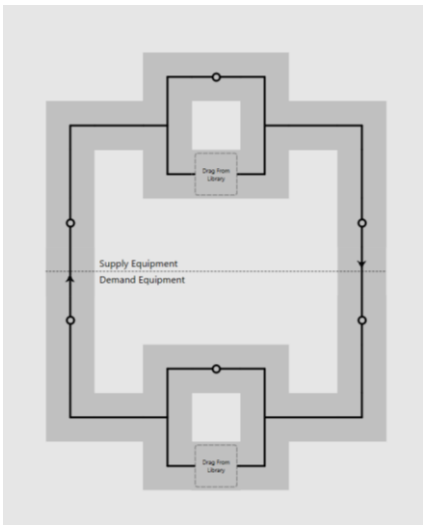
Below, different systems are presented to show different solutions.

- **Fan coil system** [heating and cooling, all building]

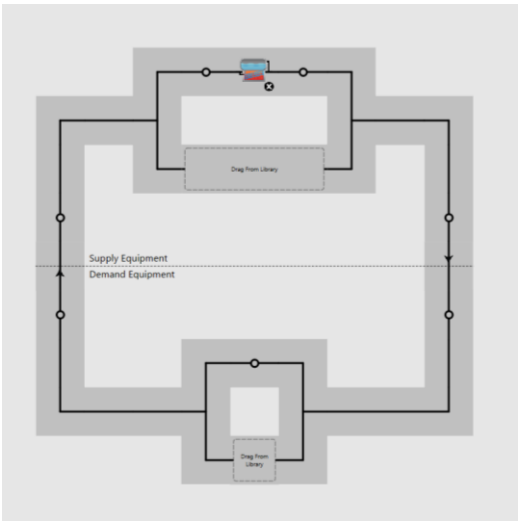
1) Navigate to the HVAC System tab 

a. We need to create a hot water plant. On the top left of the page, click the + to create a new object.

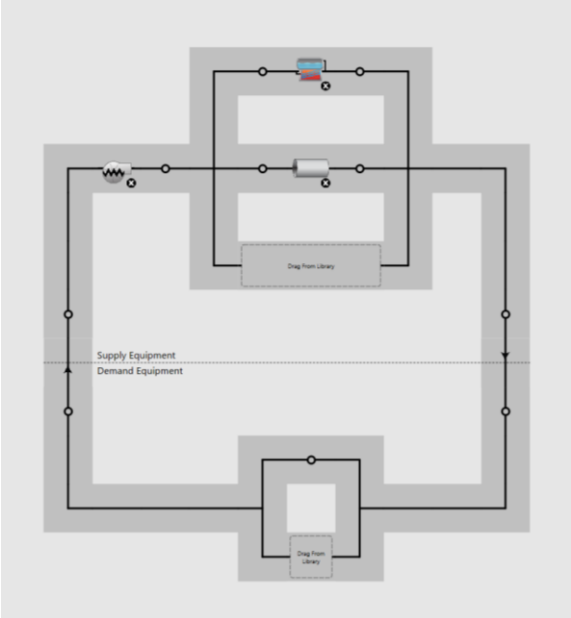

b. Scroll down to create an Empty Plant Loop and Click Add to Model. Click on the dashed line and rename it “HW Plant”.



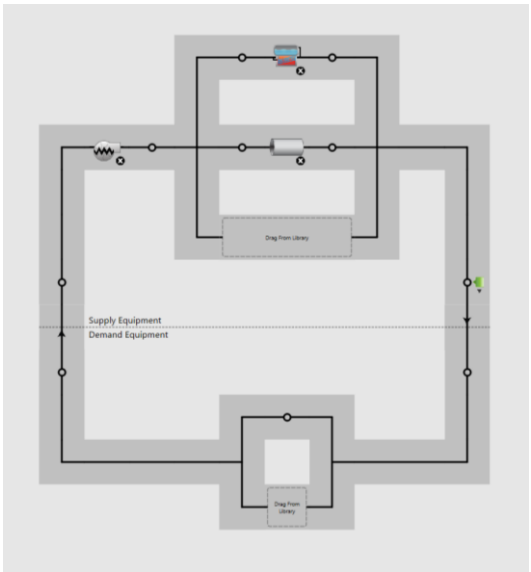
c. First, we will add a boiler. In the Library tab on the right-hand panel, under Boilers find Boiler Hot Water. Expand the drop-down icon to find HW Boiler, select it and drag and drop it in place.



d. Next, we will need to add a pump. In the Library tab on the right-hand panel, under Pumps find Pump Variable Speed. Expand the drop-down icon to find Var Spd Pump, select it and drag and drop it in place. We will also add a bypass pipe to the boiler. In the Library tab on the right-hand panel, under Pipes find Pipe - Adiabatic. Expand the drop-down icon to find Adiabatic Pipe, select it and drag and drop it in place.

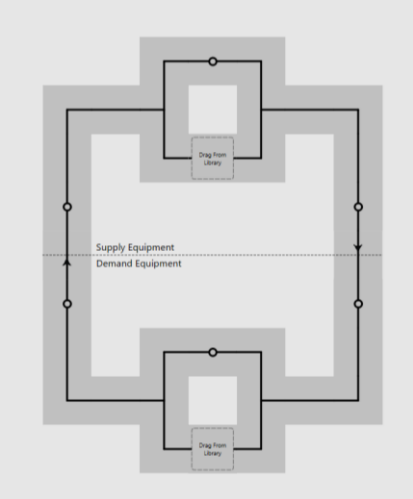


e. Then we need a setpoint manager to maintain the temperature of the loop. In the Library tab on the right-hand panel, under Setpoint Managers find Setpoint Manager Scheduled. Expand the drop-down icon to find Scheduled HW Temp, select it and drag and drop it in place. (more info: https://bigladdersoftware.com/epx/docs/25-2/input-output-reference/group-setpoint-managers.html#setpointmanagerscheduled)

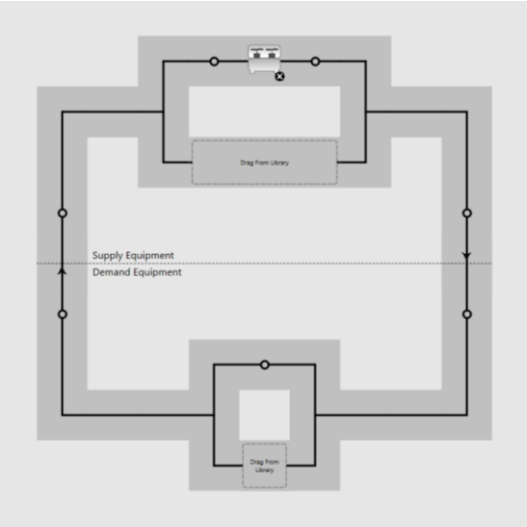


f. We need to create a chill water plant. On the top left of the page, click the + to create a new object.

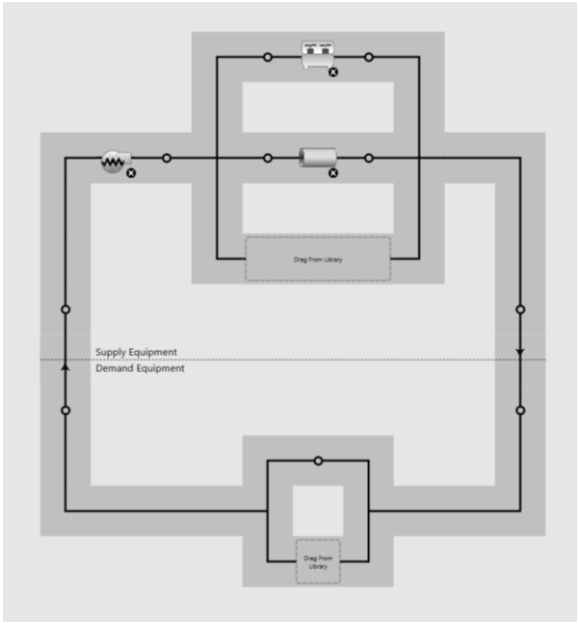
g. Scroll down to create an Empty Plant Loop and Click Add to Model. Click on the dashed line and rename it “CHW Loop”. In Loop Type we have to select Cooling, in Design Loop Exit Temperature type “6”, and in Loop Design Temperature Difference type “6”.



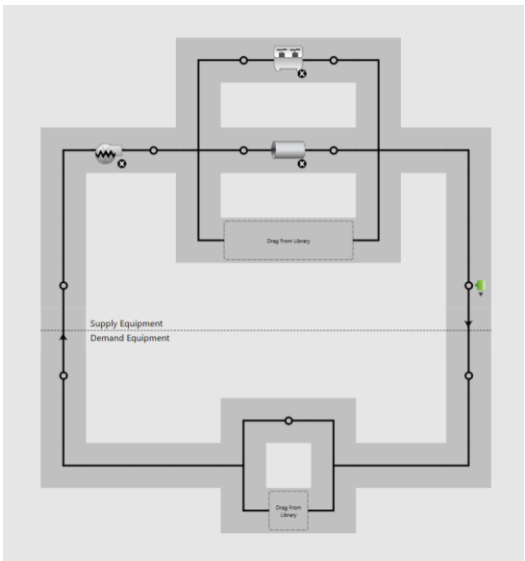
h. First, we will add a chiller. In the Library tab on the right-hand panel, under Chillers find Chiller - Electric EIR. Expand the drop-down icon to find Chiller - Air Cooled, select it and drag and drop it in place.



i. Next, we will need to add a pump. In the Library tab on the right-hand panel, under Pumps find Pump Variable Speed. Expand the drop-down icon to find Var Spd Pump, select it and drag and drop it in place. We will also add a bypass pipe to the boiler. In the Library tab on the right-hand panel, under Pipes find Pipe - Adiabatic. Expand the drop-down icon to find Adiabatic Pipe, select it and drag and drop it in place.

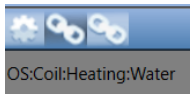


j. Then we need a setpoint manager to maintain the temperature of the loop. In the Library tab on the right-hand panel, under Setpoint Managers find Setpoint Manager Scheduled. Expand the drop-down icon to find Scheduled CHW Temp, select it and drag and drop it in place.

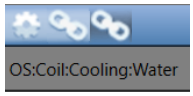


2) Navigate to the Thermal Zones tab 

a. In the Library tab on the right-hand panel, under Zone HVAC find Four Pipe Fan Coil. Expand the drop-down icon to find Fain Coil with Cycling Fan, select it and drag this to the box labelled Zone equipment corresponding to the row for TZ_0-A1.B.

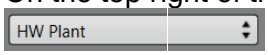
b. Click on the box Fan Coil with Cycling Fan and in the Edit tab on the right-hand panel, click on the chain symbol on the left 

and select HW Plant. Now the fan coil is connected to the hot water plant.

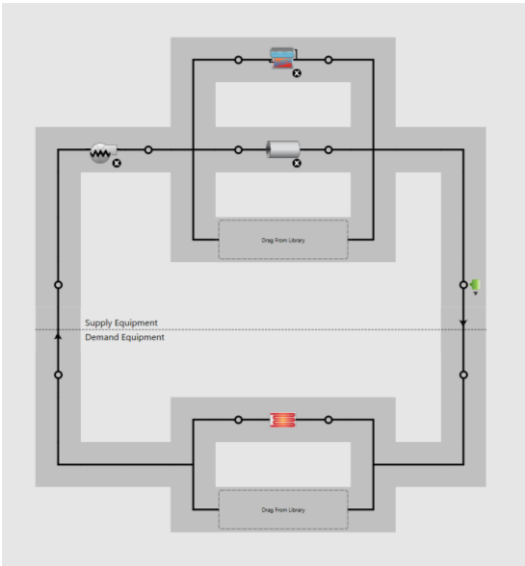
c. Click on the box Fan Coil with Cycling Fan and in the Edit tab on the right-hand panel, click on the chain symbol on the right 

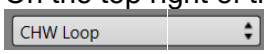
and select CHW Loop. Now the fan coil is connected to the chiller loop.

3) Navigate to the HVAC System tab 

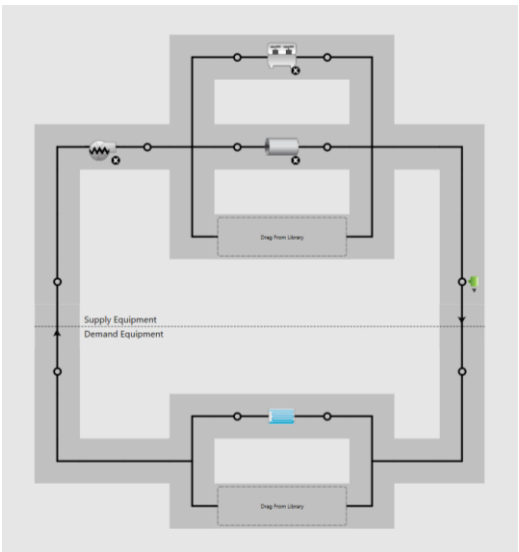
a. On the top right of the page, scroll down to select HW Plant.


You will notice an icon that represent the heating coil.



b. On the top right of the page, scroll down to select CHW Loop.


You will notice an icon that represent the cooling coil.



4) Navigate to the Thermal Zones tab 

a. To apply the Fain Coil with Cycling Fan to all thermal zone that required heating and cooling, select the check mark next to thermal zones name. Then select Fain Coil with Cycling Fan in the box you just dragged it to. Immediately above that, click Apply to Selected.

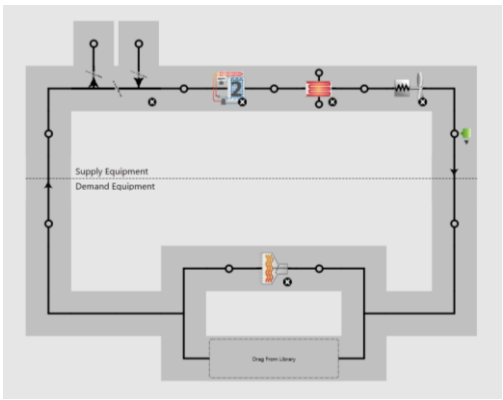
The system is now finalised, and you can run the model. However, before running the model, ensure that in the Thermal Zones tab, there is a schedule for heating and cooling setpoint in the box under Heating Thermostat Schedule and Cooling Thermostat Schedule for all the thermal zones that have the fan coils. If the schedule is absent, the simulation will fail.

- **Convective/radiative heaters** [only heating, all building]

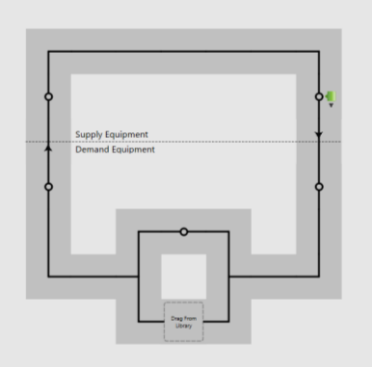
1) Navigate to the HVAC System tab 

a. On the top left of the page, click the + to create a new object.


b. Scroll down to create a Packaged Rooftop VAV with Reheat and Click Add to Model. This will automatically add a Hot Water Loop to our model so that we do not have to do all the work to create it from scratch.

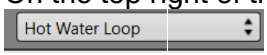


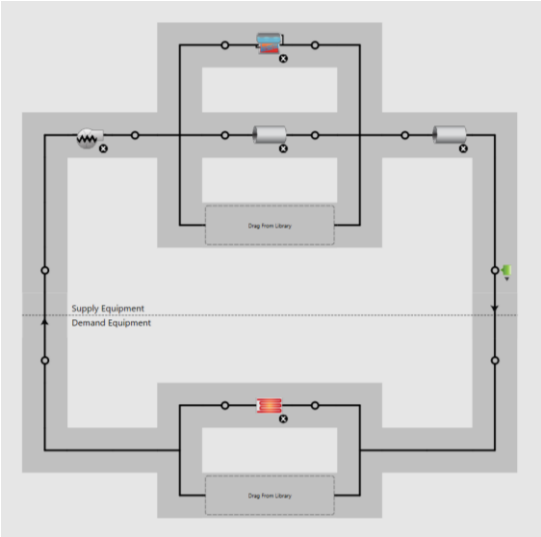
c. Our interest is only in the Hot Water Loop, so we can eliminate the Packaged Rooftop VAV with Reheat. However, we will first eliminate all the elements in this loop. To do so click on the x next to the items  .



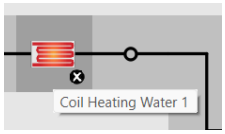
d. On the top left of the page, click the x to eliminate the loop.

e. On the top right of the page, scroll down to select Hot Water Loop.

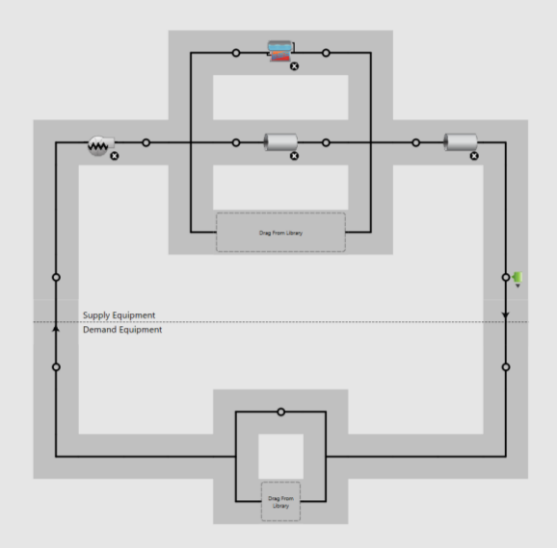




f. In the Hot Water Loop, eliminate the Coil Heating Water by clicking on the x next to it



g. We are now left with an empty hydronic hot water loop, since there is no demand equipment attached to it.



5) Navigate to the Thermal Zones tab 

a. In the Library tab on the right-hand panel, under Zone HVAC find Baseboard Radiant Convective Water. Expand the drop-down icon to find Zone HVAC Baseboard Rad Conv Water, select it and drag this to the box labelled Zone equipment corresponding to the row for TZ_0-A1.B. (More info on here: https://bigladdersoftware.com/epx/docs/25-2/engineering-reference/baseboard-heaters.html)

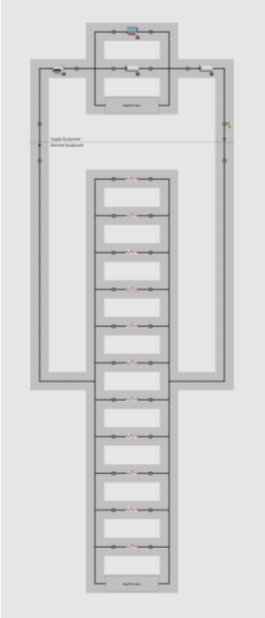
b. Click on the box Zone HVAC Baseboard Rad Conv Water and in the Edit tab on the right-hand panel, click on the chain symbol  and select Hot water Loop.

c. To apply the Zone HVAC Baseboard Rad Conv Water to all thermal zone that required heating, select the check mark next to thermal zones name. Then select Zone HVAC Baseboard Rad Conv Water in the box you just dragged it to. Immediately above that, click Apply to Selected.

6) Navigate to the HVAC System tab 

a. On the top right of the page, scroll down to select Hot Water Loop.

b. Now you can see that all of those radiator/convectors have been added to the loop.



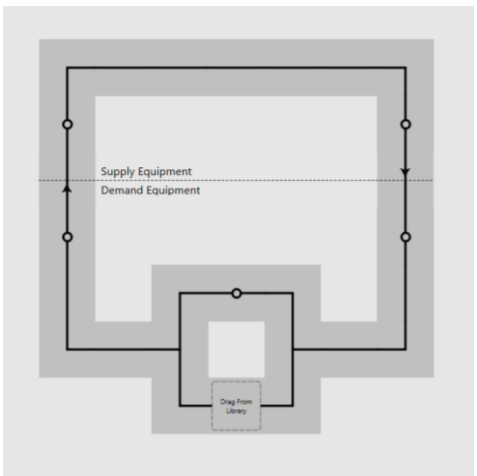
The system is now finalised, and you can run the model. However, before running the model, ensure that in the Thermal Zones tab, there is a schedule for heating setpoint in the box under Heating Thermostat Schedule for all the thermal zones that have the radiators. If the schedule is absent, the simulation will fail.

- **Split unit air conditioner** [only cooling, single zone in a single apartment]

1) Navigate to the HVAC System tab 

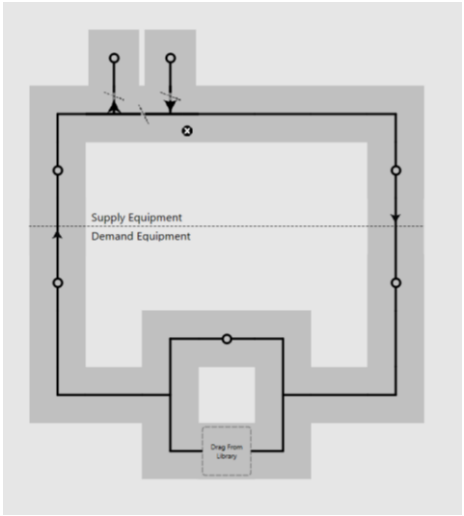
a. On the top left of the page, click the + to create a new object.


b. Scroll down to create an Empty Air Loop and Click Add to Model.

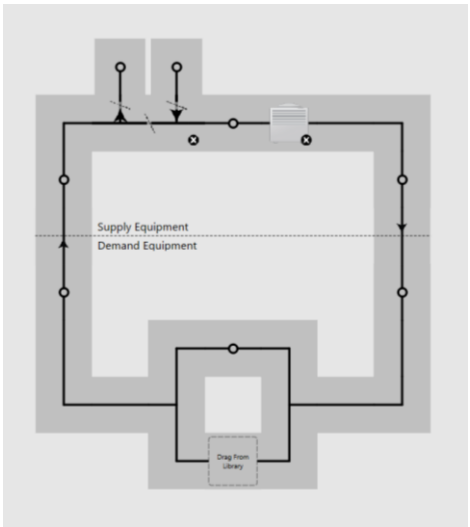


c. First, we will add an outdoor unit (also called a condenser unit) with a condenser and a compressor. In the Library tab on the right-hand panel, under

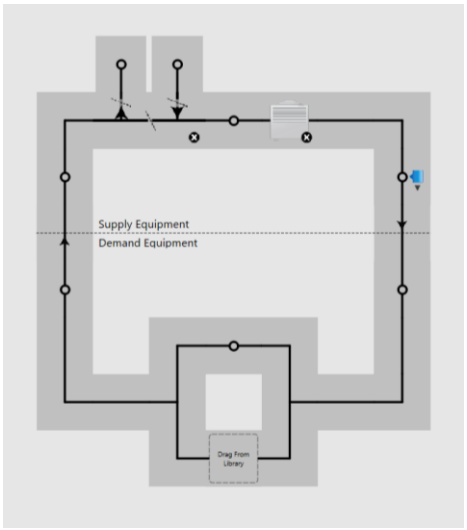
Air Loop HVAC find AirLoopHVAC Outdoor Air System. Expand the drop-down icon to find OA System, select it and drag and drop it in place.



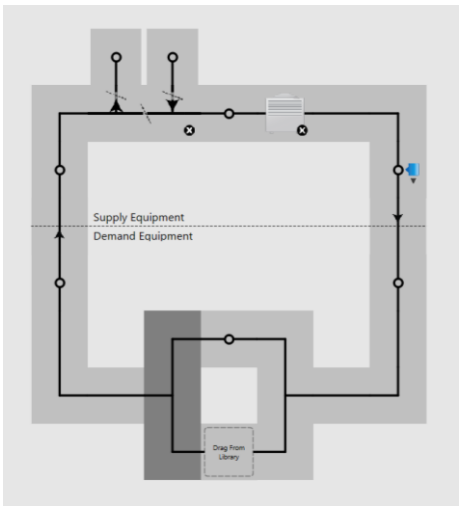
d. Next, we will need to ad indoor unit with the evaporator and a fan (air-handler). In the Library tab on the right-hand panel, under Air Loop HVAC find AirLoopHVAC Unitary System. Expand the drop-down icon to find Unitary - Single Speed DX cooling - Cycling - Elec reheat, select it and drag and drop it in place. (for more info https://bigladdersoftware.com/epx/docs/25-2/input-output-reference/group-heating-and-cooling-coils.html#coilcoolingdxsinglespeed)

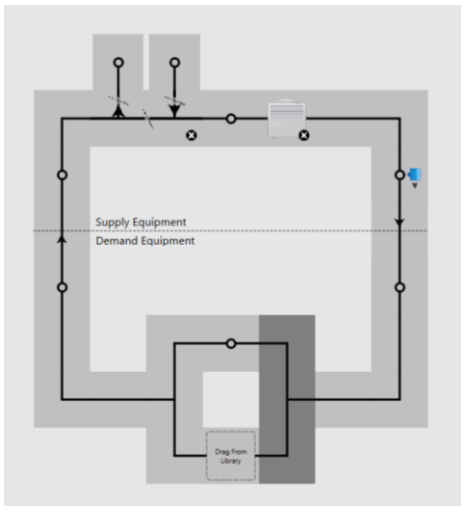


e. Then we need a setpoint manager to maintain the temperature of the loop. In the Library tab on the right-hand panel, under Setpoint Managers find Setpoint Manager Single Zone Cooling. Expand the drop-down icon to find Setpoint Manager Single Zone Cooling, select it and drag and drop it in place.

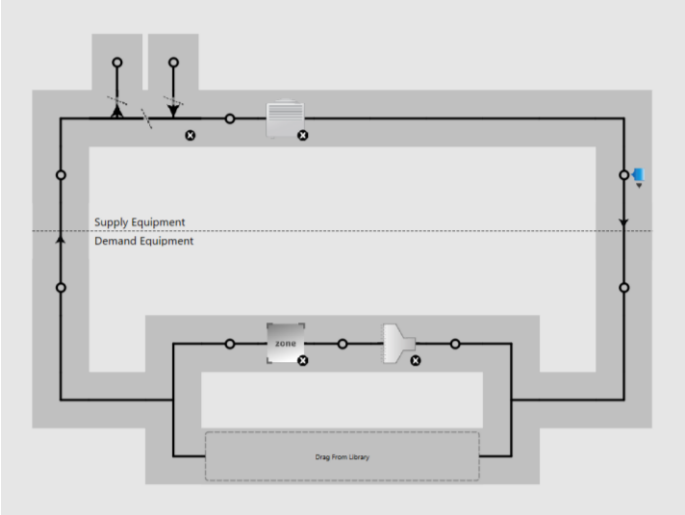


f. Then we need a attached the thermal zone. Click on the ZoneMixer (see left image below) or ZoneSplitter (see right image below) and select the thermal zone TZ_0-A1.B (since we are modelling a single zone split, we need to select only one thermal zone).





g. We also need to select the air terminal. In the Library tab on the right-hand panel, under Air Terminals find AirTerminal Single Duct Constant Volume No Reheat. Expand the drop-down icon to find Diffuser, select it and drag and drop it in place.



h. Finally, we need to make sure that the control zone is equal to the thermal zone that we selected. Click on the Unitary - Single Speed DX cooling - Cycling - Elec reheat, and in the Edit tab on the right-hand panel, under Controlling Zone or Thermostat Location select TZ_0-A1.B. Click on the Setpoint Manager Single Zone Cooling, and in the Edit tab on the right-hand panel, under Control Zone Name is make sure TZ_0-A1.B is selected.

The system is now finalised, and you can run the model. However, before running the model, ensure that in the Thermal Zones tab, there is a schedule for cooling setpoint in the box under Cooling Thermostat Schedule for the thermal zone TZ_0-A1.B. If the schedule is absent, the simulation will fail.