eQUEST: Modeling of Thermal Energy Storage System

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Contents

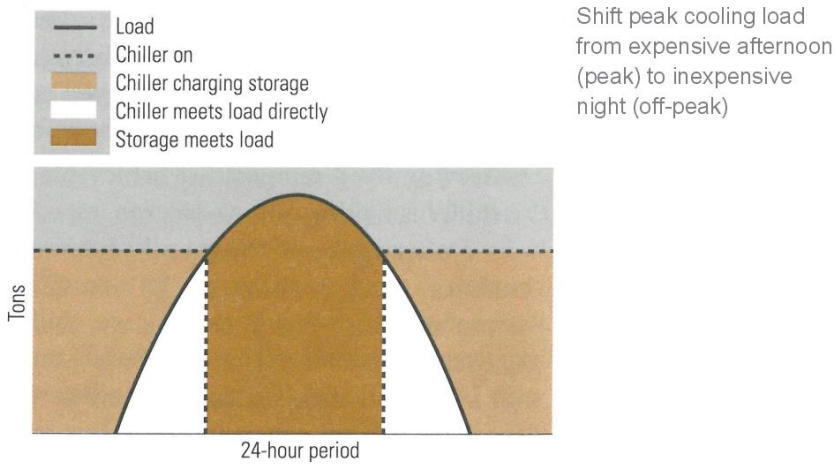
1. Objective

To learn how to model Thermal Energy Storage (TES) in eQUEST.

What is thermal energy storage?

Thermal energy storage includes a number of technologies that store thermal energy in energy storage tanks for later use. These applications include the production of ice, chilled water, or eutectic solution at night which is then used to cool the building during the day. The ice thermal storage (ITS) is one of thermal energy storage technology that is widely used in many countries to reduce electrical power or energy costs by moving the cost of cooling buildings from expensive "on-peak" periods to cheaper "off-peak" periods. The Thermal Energy Storage will be charged at night and the day cooling load will be met by discharging this thermal energy storage and running the chiller.

Typical Thermal Energy Storage load shifting is explained in the graph below:



Source: ASHRAE Design Guide for Cool Thermal Storage

2. The problem

In this tutorial we will create a building and add a thermal storage system to the building and add its controls. It the end we analyze the results to evaluate the performance of thermal energy storage.

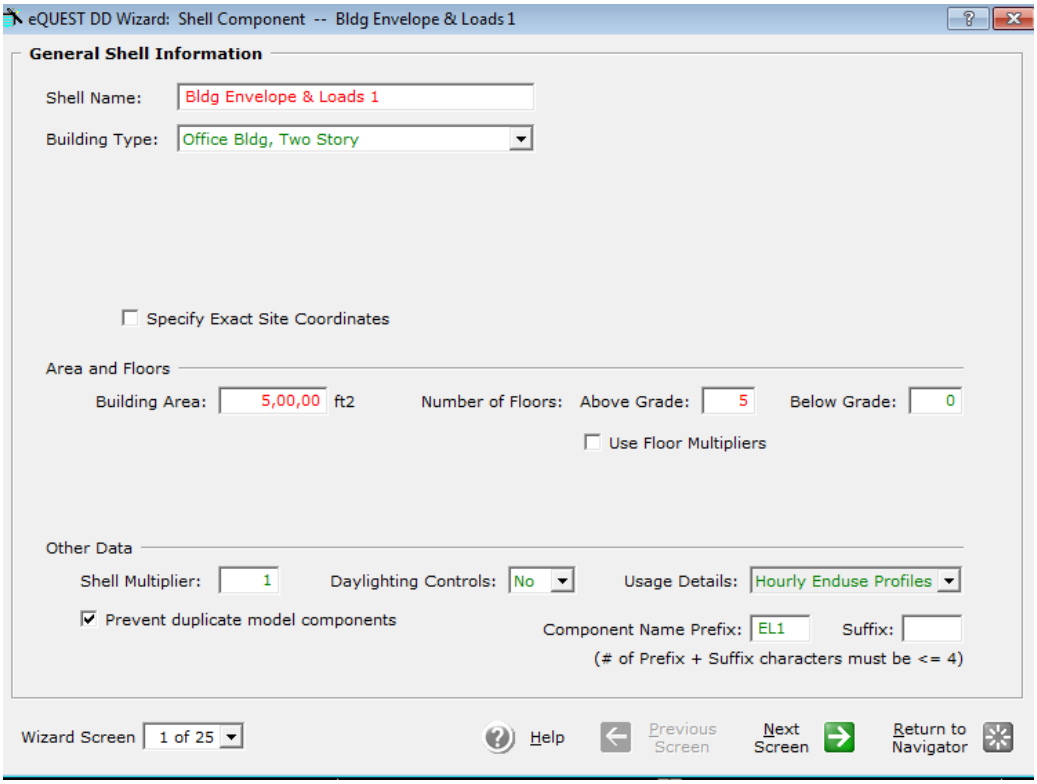
Specifications of the model:

- Built up Area = 50,000 Sqft
- Conditioned Area= 50,000 Sqft
- Number of floors = 5
- Occupancy type = Daytime (9 AM to 6 PM)
- Lighting power density = 1 W/sqft
- Equipment power density = 0.4 W/Sqft

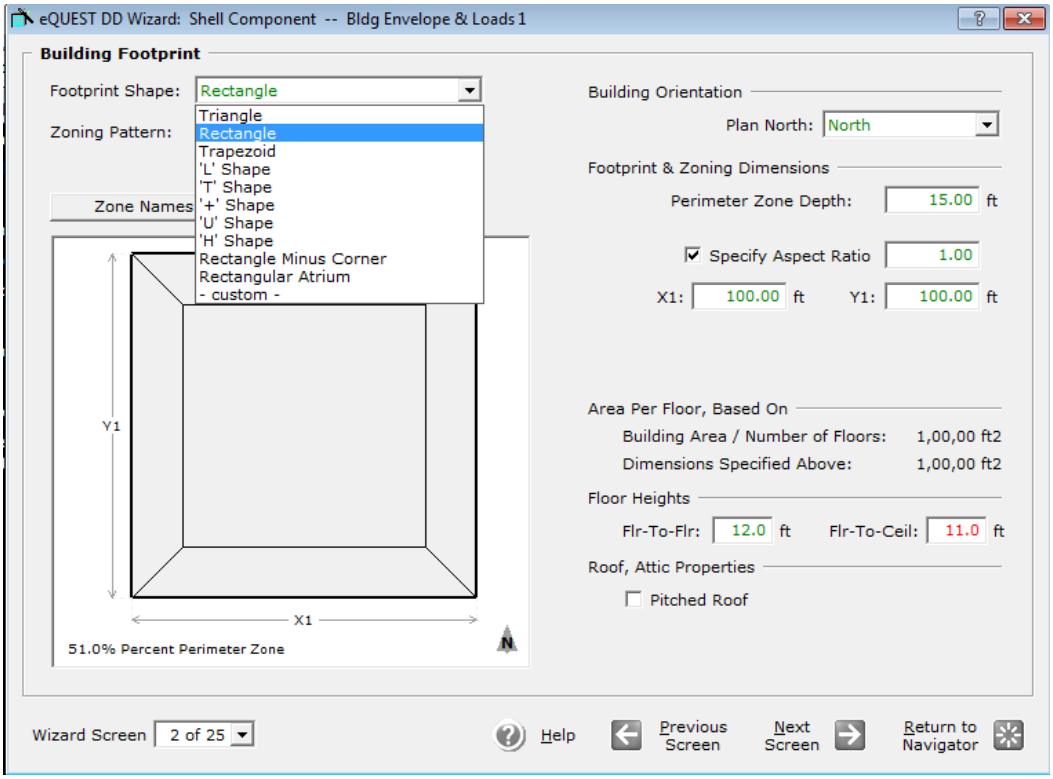
- Occupancy = 100 Sqft/person
- Fresh air = 15 cfm/person
- Number of Chillers: 2
- Chiller Type = Electric reciprocating Hermetic
- Chiller size = Auto

3. Modeling System without Thermal storage

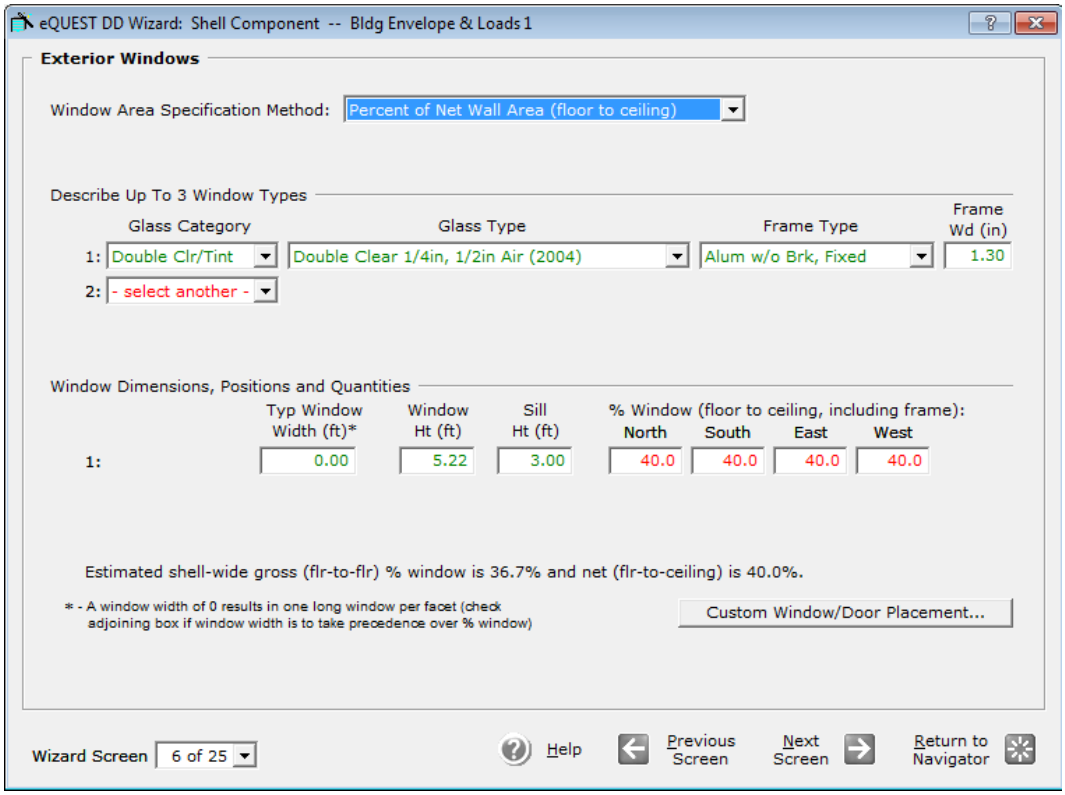
Open eQUEST and model default square with core perimeter having 50,000 Sqft area in 5 floors.



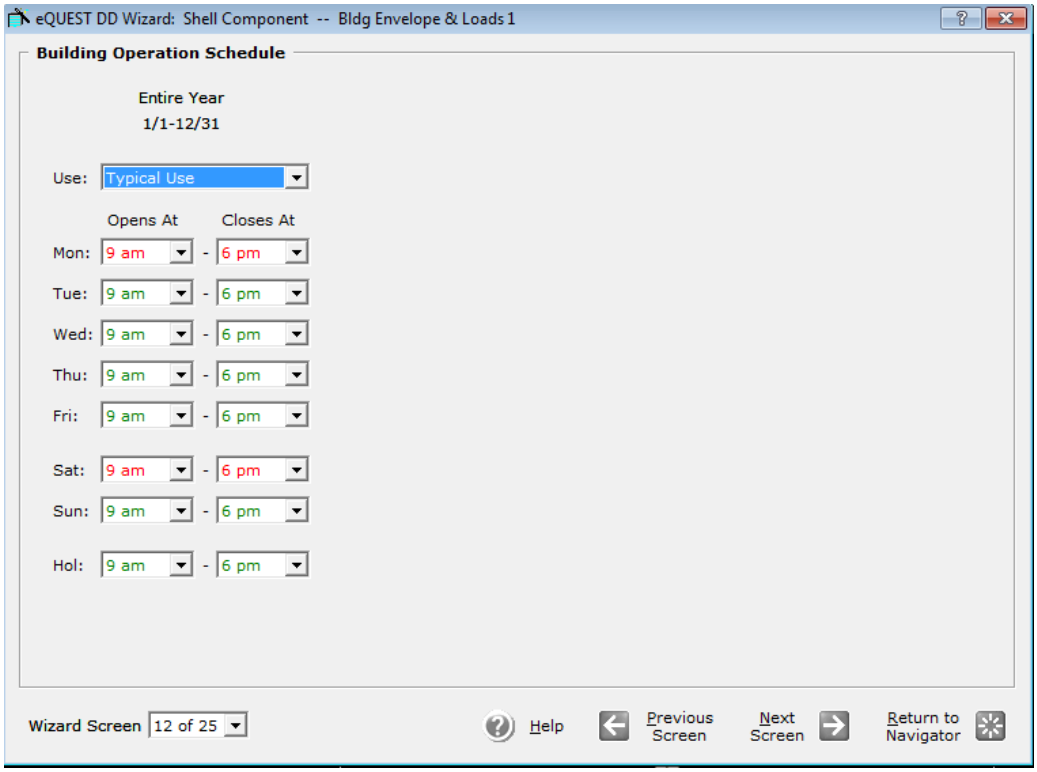
Choose a rectangular foot print and let the floor to ceiling height be 11ft



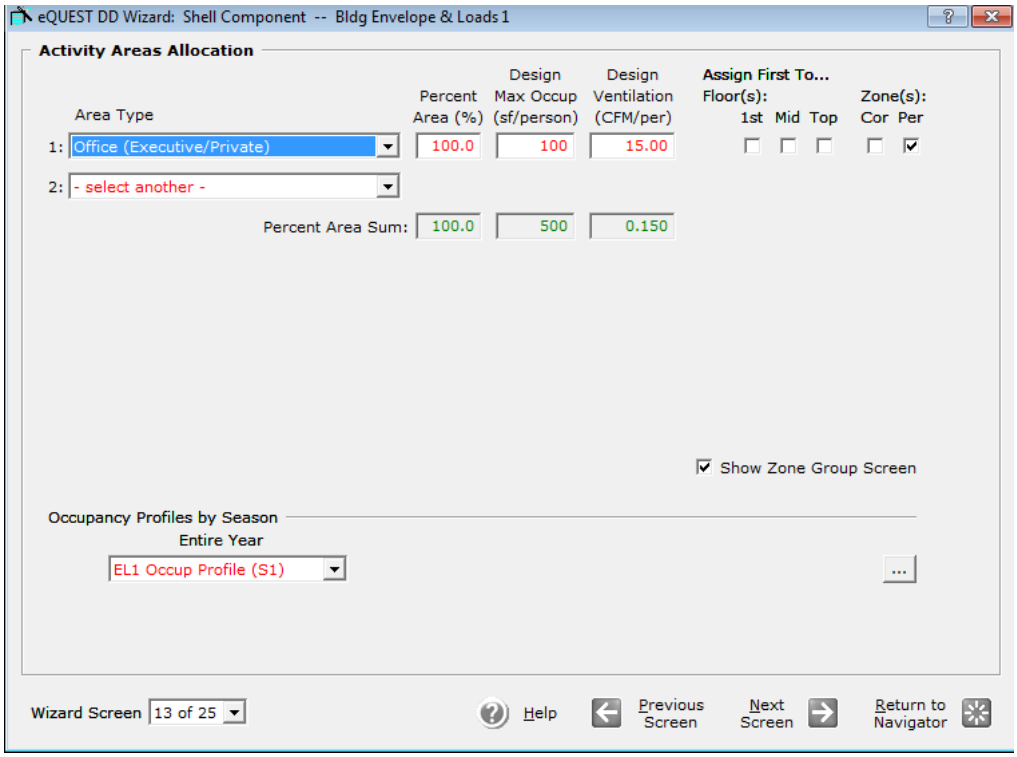
Change the window specification method to percent of net wall area (floor to ceiling) and specify only one window type with 40% window wall ratio on all four sides.



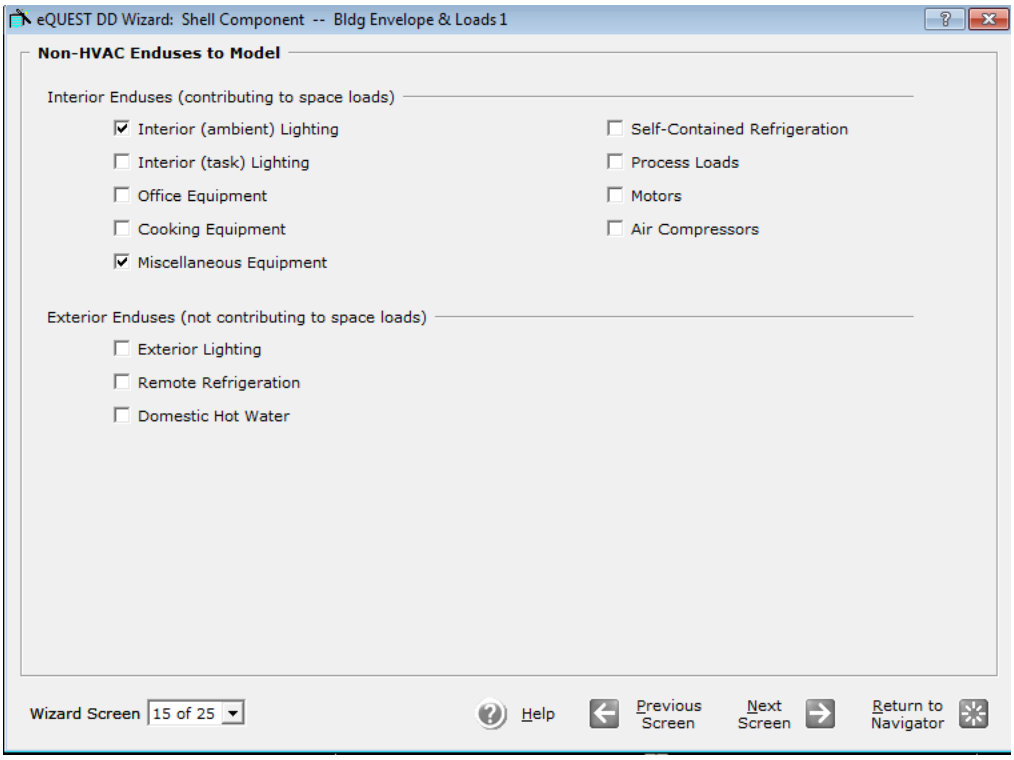
Define the schedule for the entire year as 9am to 6pm for all days of the year.



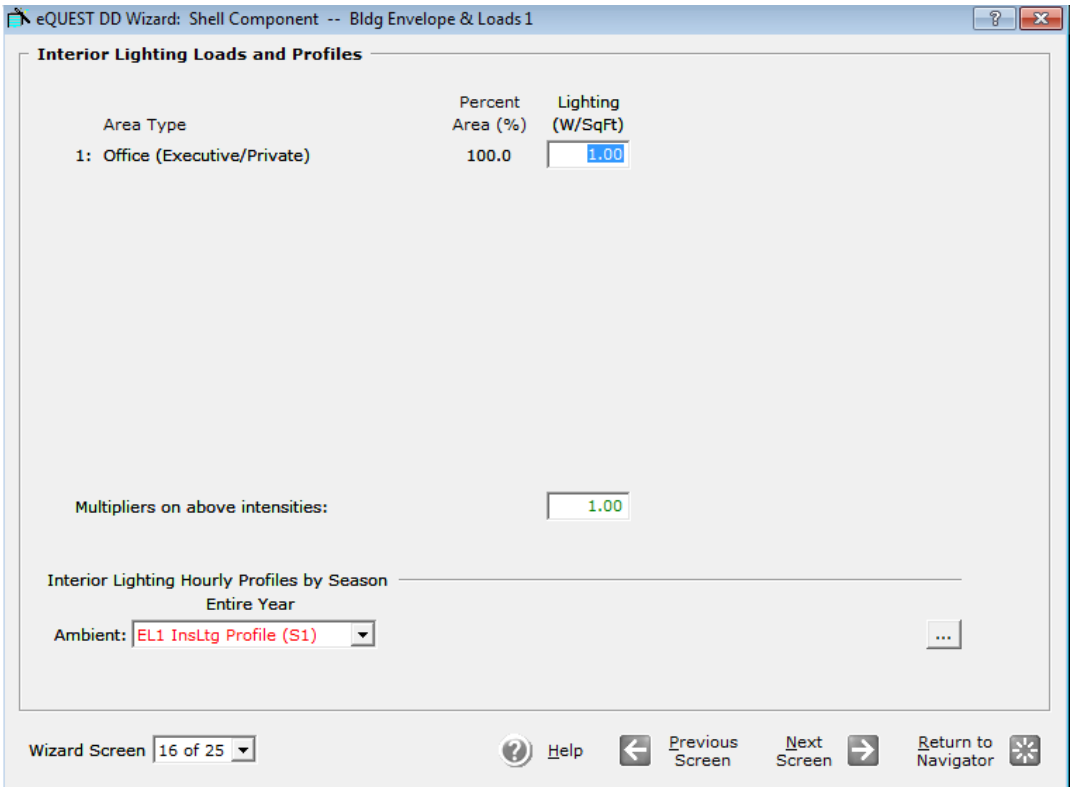
In Activity Area allocation screen, define the entire space as office area. For office area (Executive/private) changes the percent area to 100 and specify the design maximum occupancy to 100sf/person and the design ventilation to 15CFM/person. Change the rest of the area types to 'select another'.



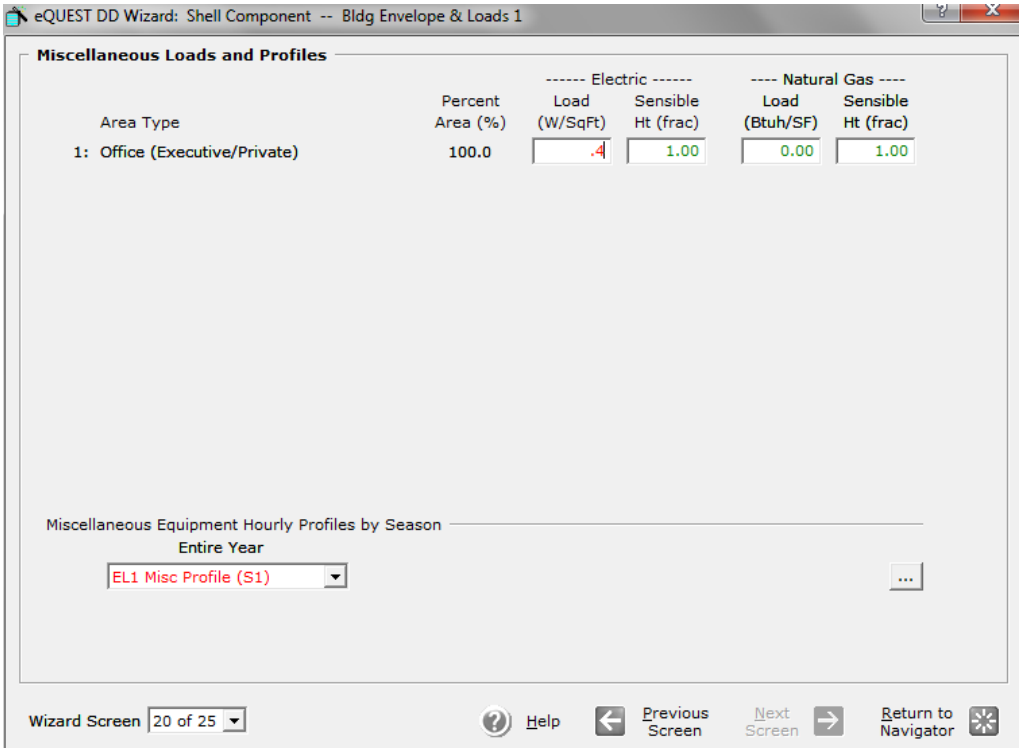
In non HVAC end uses, check the interior lighting and miscellaneous equipment and leave the rest of them unchecked.



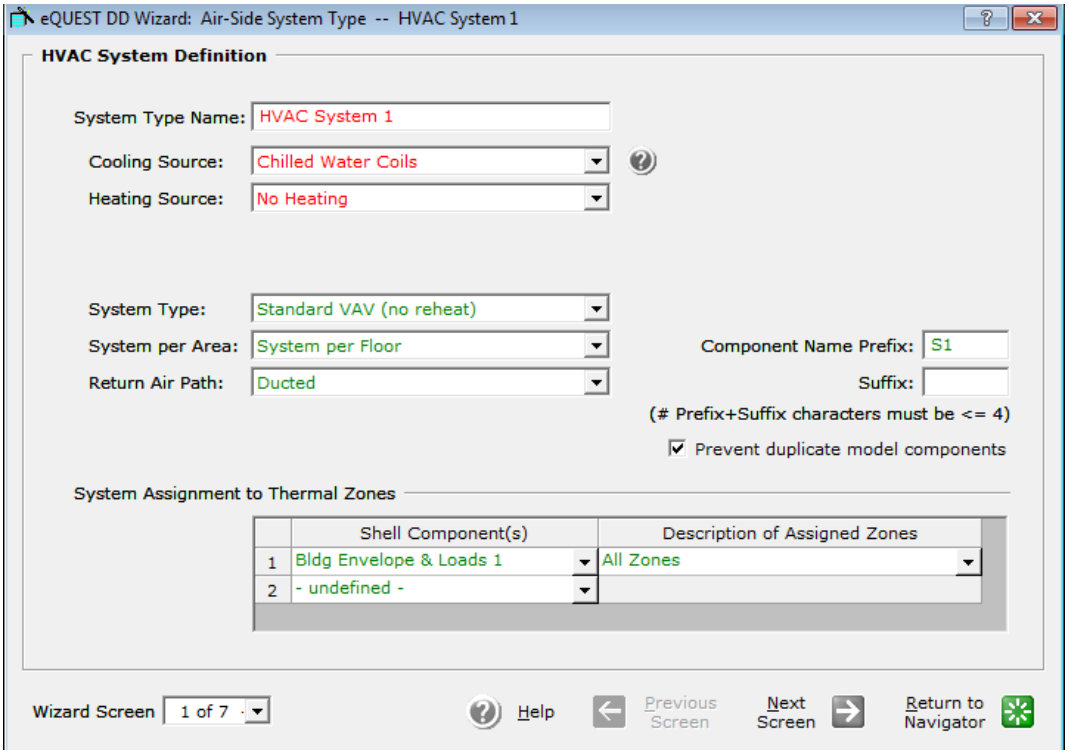
Define the LPD for the office area as 1 W/SqFt.



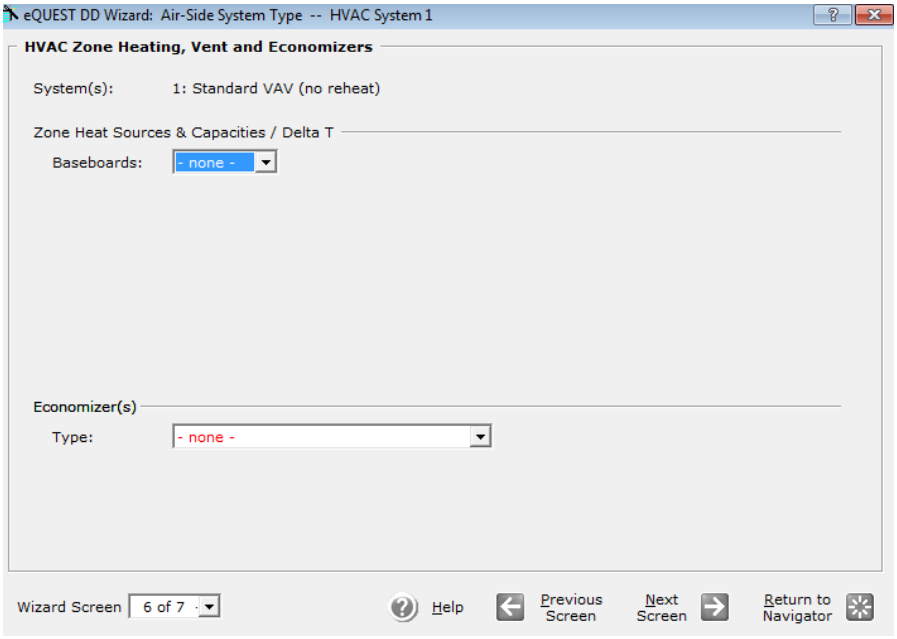
Define the EPD for the office area as 0.4 W/SqFt.



Change the Cooling Source to 'Chilled Water Coils' and Heating Source as 'No Heating'.

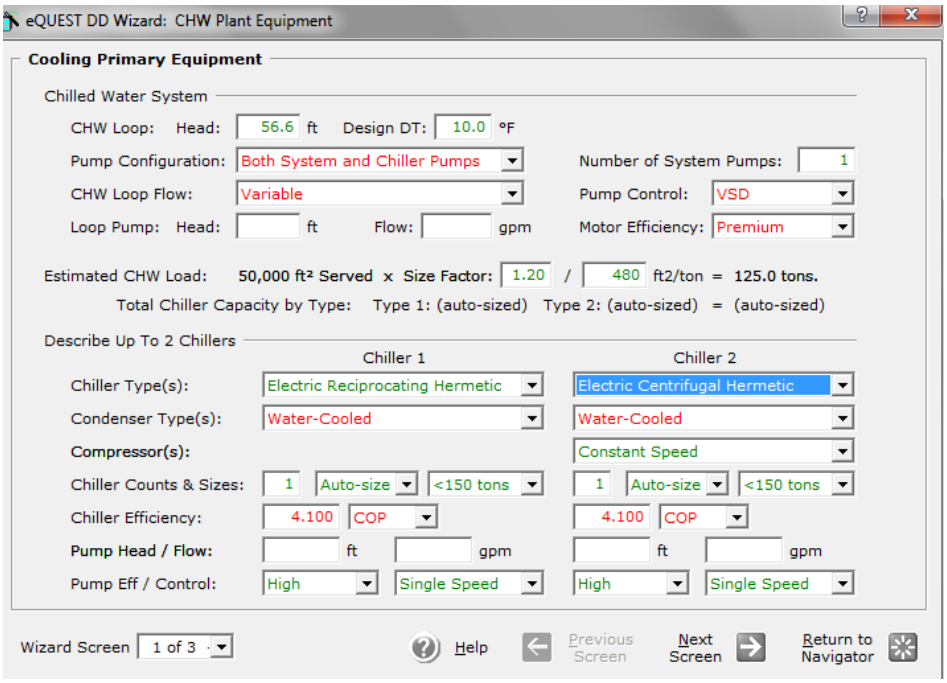


Mark the baseboard and economiser as ‘none’ in screen 6 of 7

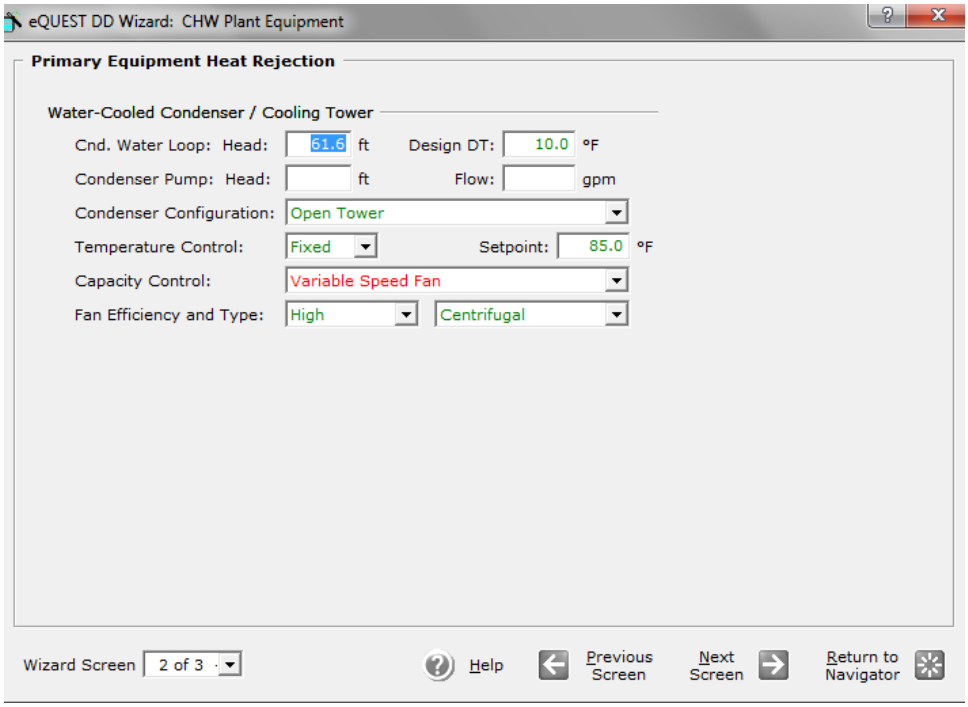


From the navigator select the CHW Plant Equipment and change the pump configuration to ‘both system and chiller pumps’ and CHW loop flow to Variable. Mark the pump control as ‘VSD’, motor efficiency to ‘premium’.

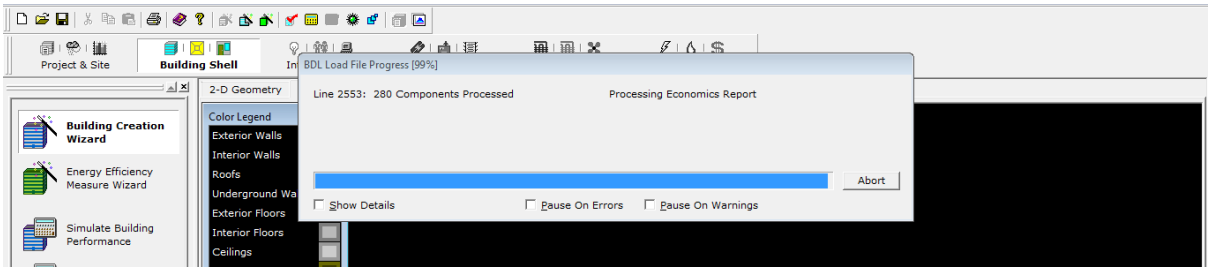
Create two identical chillers and change both the chiller types to ‘Electric reciprocating Hermetic’. Change the condenser type to ‘Water cooled’ and chiller Efficiency as 4.1 (COP) for both the chillers.



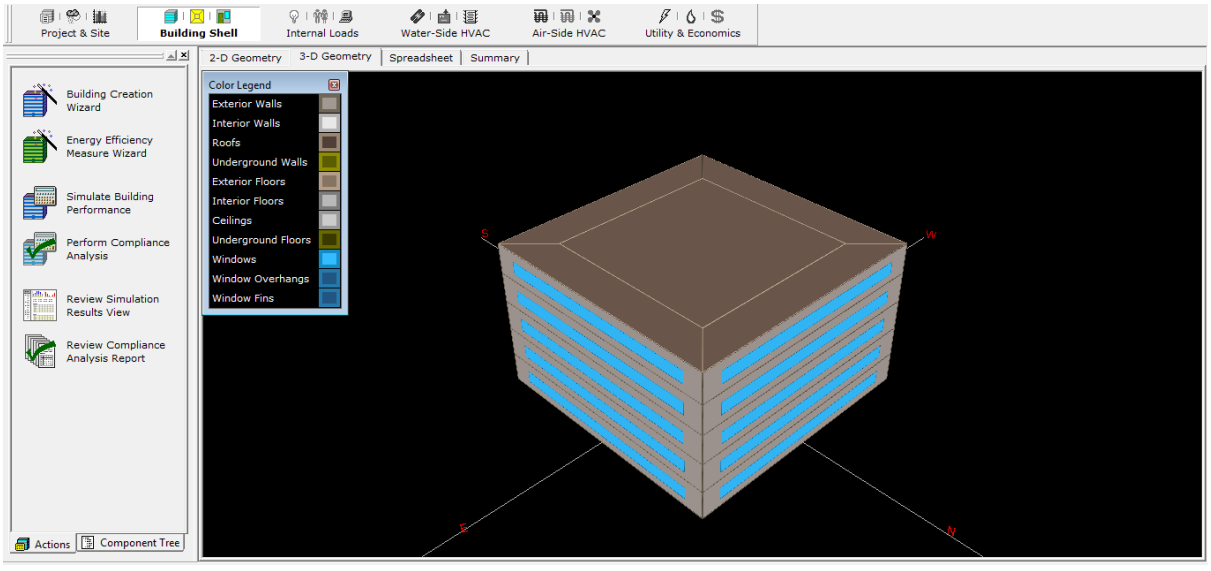
In the following screen change the capacity control to ‘Variable Speed Fan’.



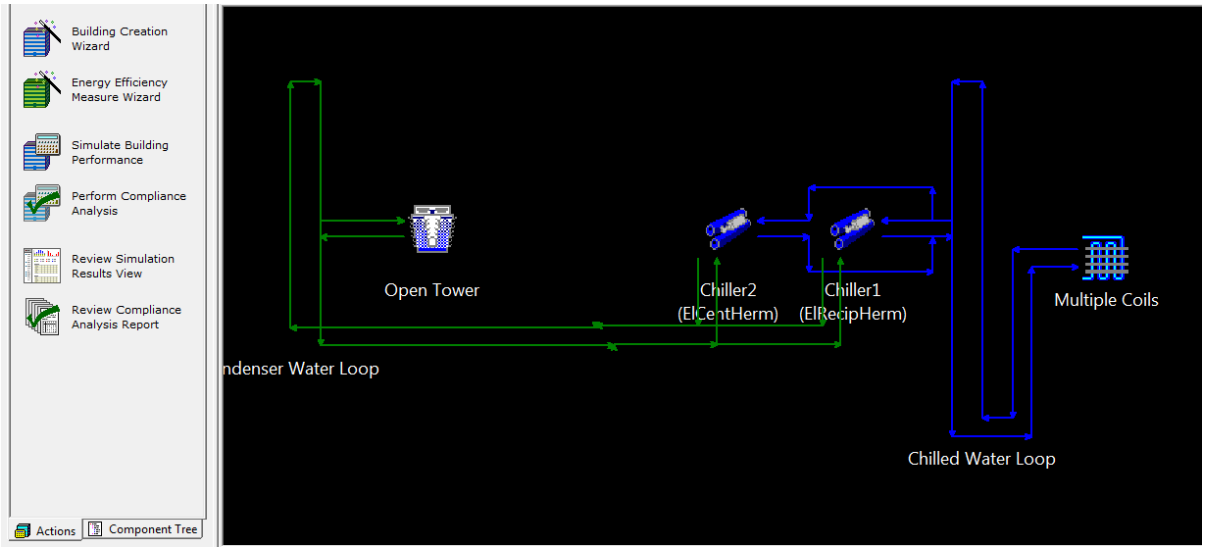
Once the above information is added, click finish and complete the project.



A 3D image of the building will be displayed. We can run the simulation.



Clicking on the Water-Side HVAC tab will give you a layout of the system before adding a thermal storage.



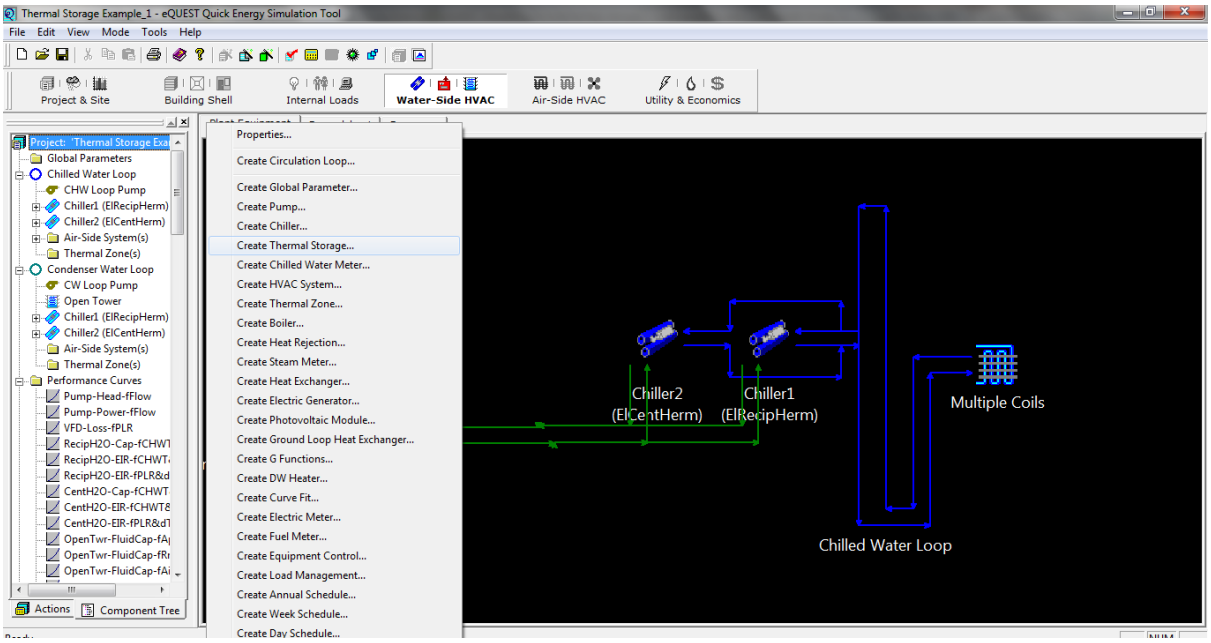
Save the Project with desired name, e.g Tut_no_thermal_storage.

4. System with Thermal storage

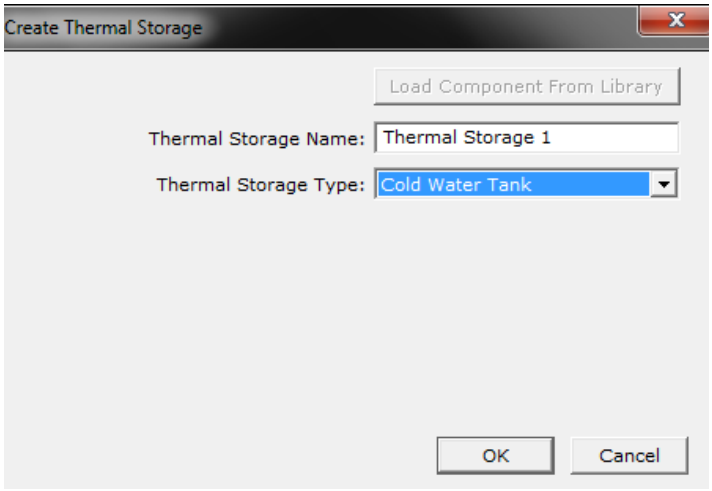
Open the previous model and save it as a different file with a different file name, e.g. Tut_thermal_storage.

Now that we have modelled the building with two identical chillers, the next task is to model the thermal storage.

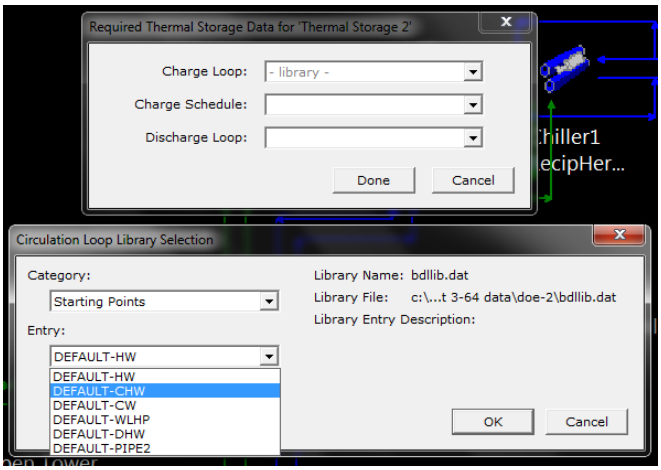
To add a thermal storage system, go to Water-Side HVAC and right click on the project and 'Create Thermal Storage'



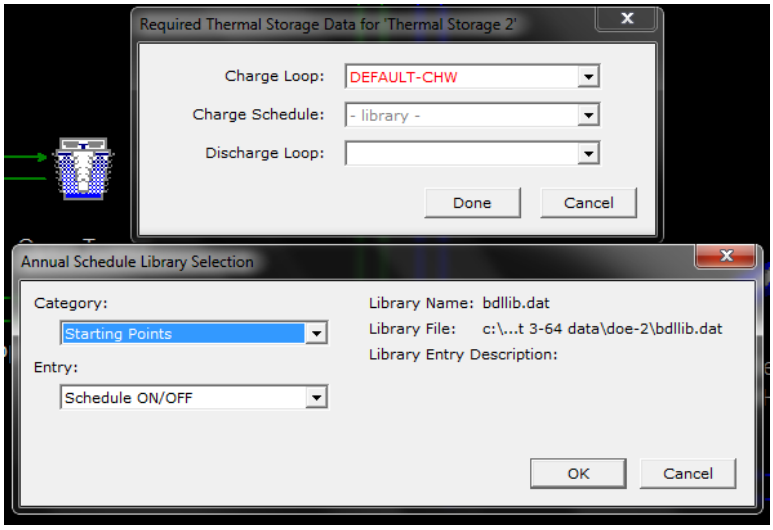
Name your thermal storage system and define the type as Cold Water Tank



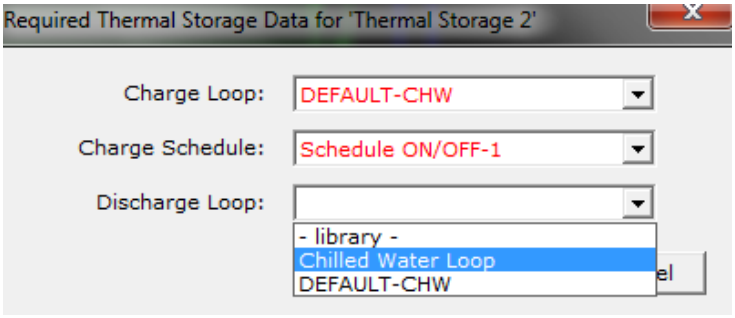
In the next window, select Charge loop from the library which opens in a new window. We have to now select the entry as "Default-CHW" and click OK.



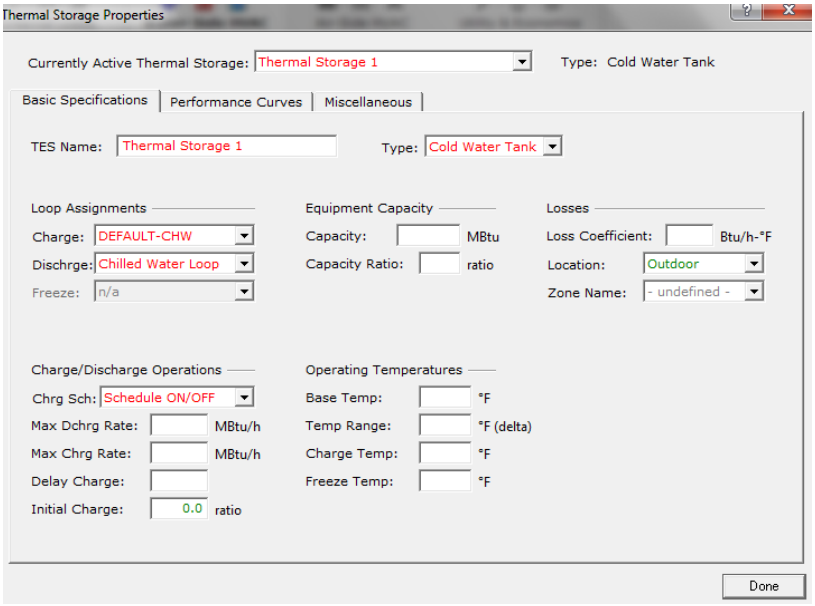
For Charge Schedule, select the library and enter the schedule as "Schedule ON/OFF"



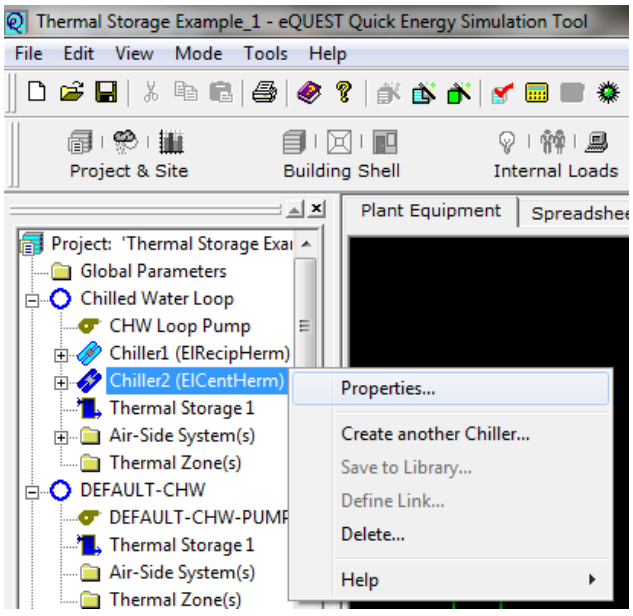
Now select the discharge loop as ‘Chilled Water Loop’



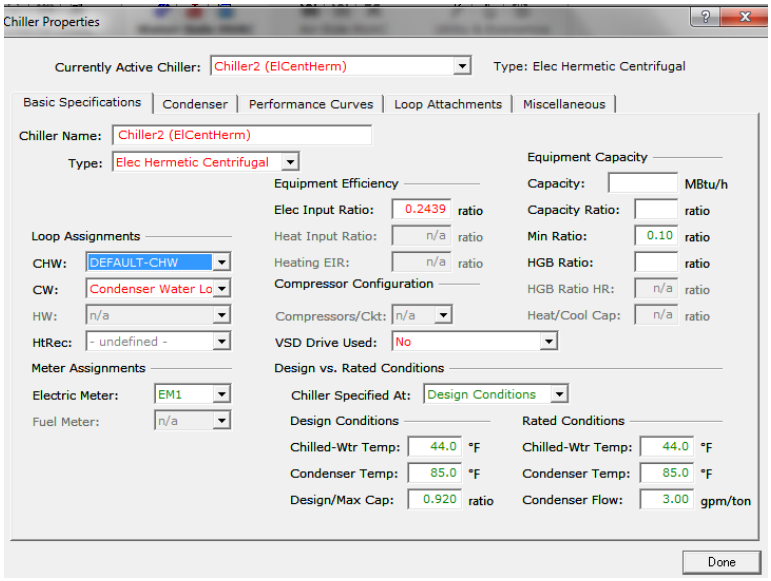
Once the required data is entered we get the thermal properties of the Thermal Storage.



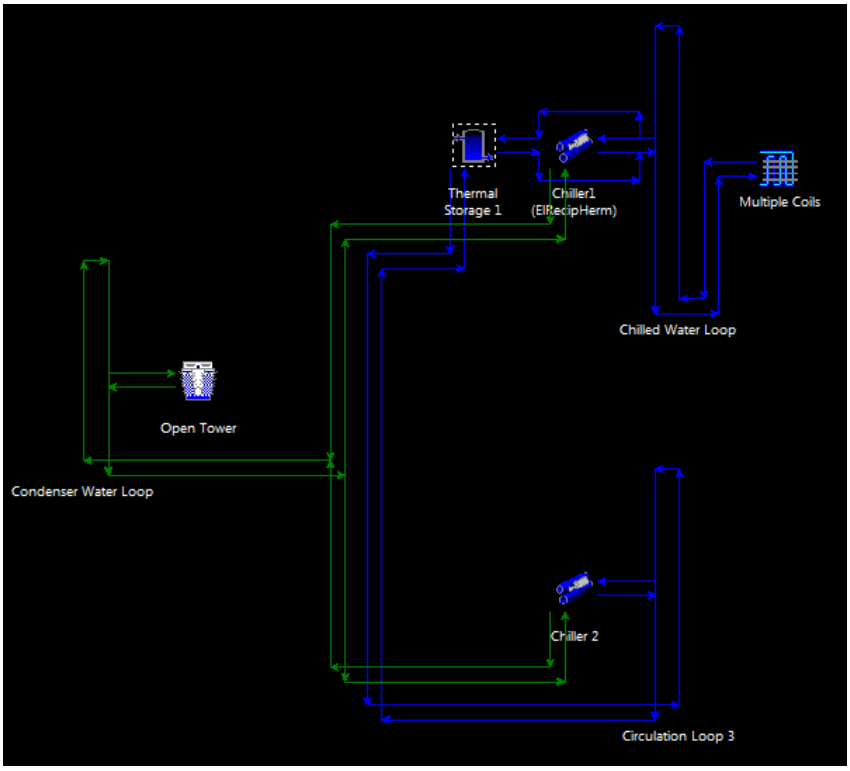
Now right click on Chiller 2 from the component tree and select properties



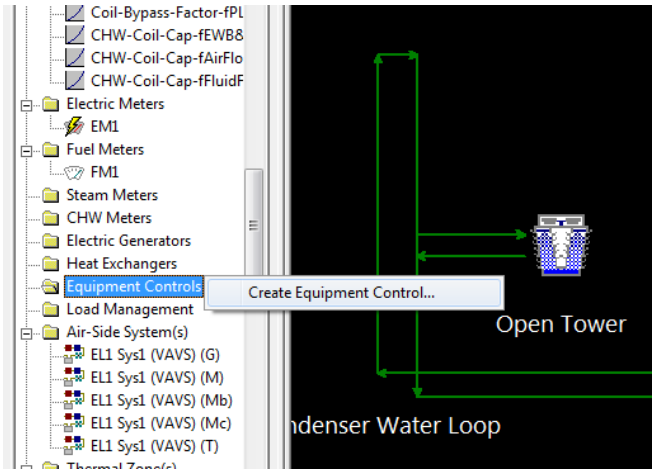
Now in Loop assignments, assign the “Default-CHW” for CHW.



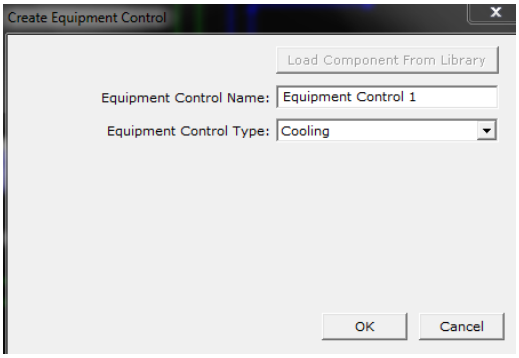
The Water-Side HVAC Module will now show the Thermal Storage and the two chillers.

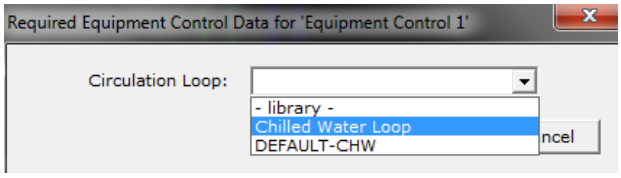


We have created the thermal storage system and now we need to add controls to it. For that we need to come down to Equipment control in the component tree, right click and 'Create Equipment Control'

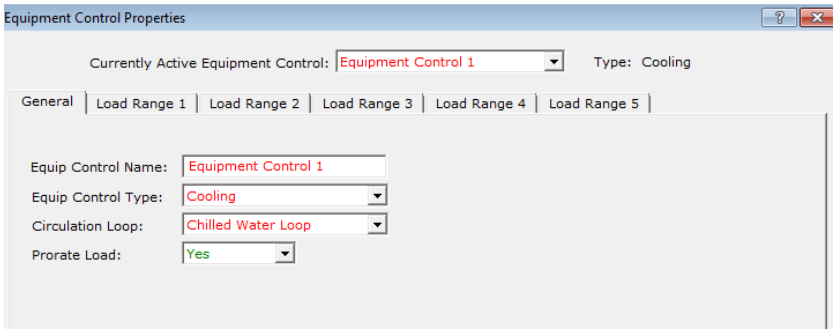


Define the Equipment Control Name and the Control Type as 'Cooling'. In the next screen select the circulation loop as 'Chilled Water Loop'

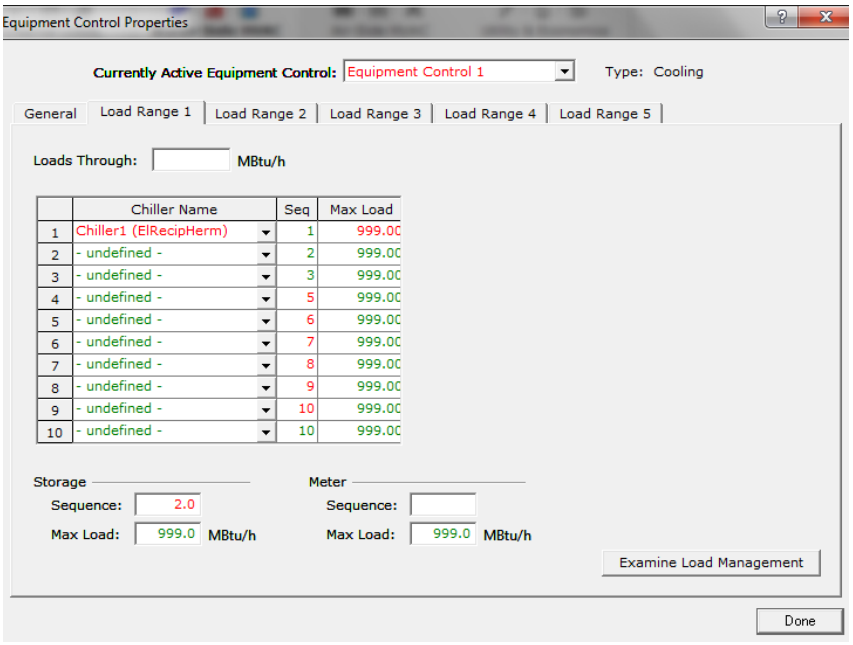




The Equipment Control Properties will now be displayed as below.



Under load range tab add Chiller1 and Sequence as 1 and define the Storage sequence as 2, which implies that the load is shifted to thermal storage when the maximum load on the Chiller1 is 999 MBtu/hr.



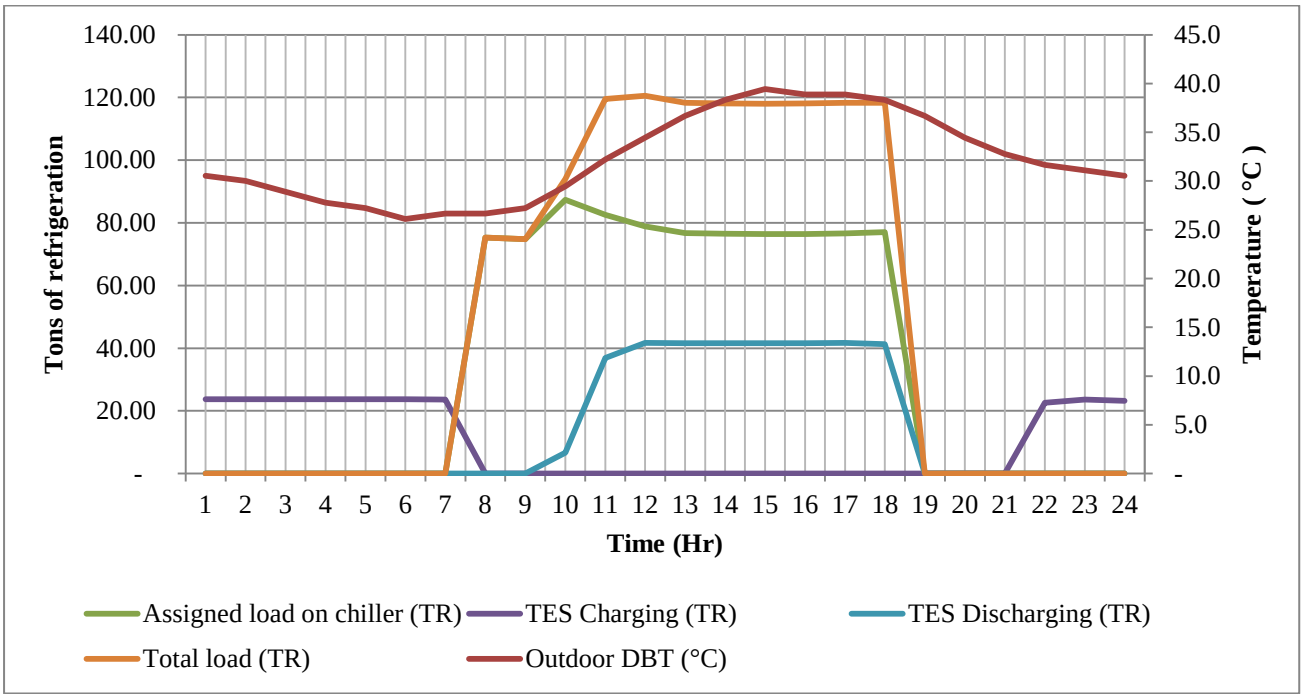
5. Comparison

For the comparison purpose and to identify the potential saving by using the Thermal Energy Storage, simulate both the models, with and without thermal storage. You will get results similar to the table given below.

The charging and discharging load of thermal energy storage, the total load and the assigned load on chiller after using the Thermal Energy Storage are all described in the table for every hour in the day with the corresponding Outdoor Dry Bulb Temperature.

Time	Outdoor DBT (°C)	Assigned load on chiller (TR)	TES Charging (TR)	TES Discharging (TR)	Total load (TR)
1	30.6	-	23.74	-	-
2	30.0	-	23.74	-	-
3	28.9	-	23.74	-	-
4	27.8	-	23.72	-	-
5	27.2	-	23.72	-	-
6	26.1	-	23.71	-	-
7	26.7	-	23.65	-	-
8	26.7	75.34	-	-	75.34
9	27.2	74.78	-	-	74.78
10	29.4	87.33	-	6.69	94.02
11	32.2	82.58	-	36.91	119.49
12	34.4	78.85	-	41.67	120.52

13	36.7	76.71	-	41.63	118.34
14	38.3	76.50	-	41.63	118.14
15	39.4	76.39	-	41.64	118.03
16	38.9	76.47	-	41.64	118.11
17	38.9	76.64	-	41.64	118.28
18	38.3	77.00	-	41.29	118.29
19	36.7	-	-	-	-
20	34.4	-	-	-	-
21	32.8	-	-	-	-
22	31.7	-	22.60	-	-
23	31.1	-	23.58	-	-
24	30.6	-	23.25	-	-



This graph represents how the Thermal Energy Storage is getting charged (purple line) during the night (from 9pm to 7am) and is getting discharged (blue line) in the morning (from 9am to 7pm). The orange line indicates the total load and the Green one indicates the assigned load on chiller when used in combination with Thermal Energy Storage. We can see how the peak load is being shedded by the Thermal Energy Storage.