Installation instructions

1. Install Openstudio application version 1.5.

2. Copy the measure folder containing code for the ETS model into the measures directory of the Openstudio application (ex. C:\Users\Steffes\OpenStudio\Measures).

3. In the Openstudio application add the ETS to an existing heating loop:

    1. Access the components & measures tab
    2. Apply measure now
    3. Browse to HVAC>Heating measures
    4. Choose the “Add central electric thermal storage” measure
    5. Define inputs
    6. Apply measure and accept changes

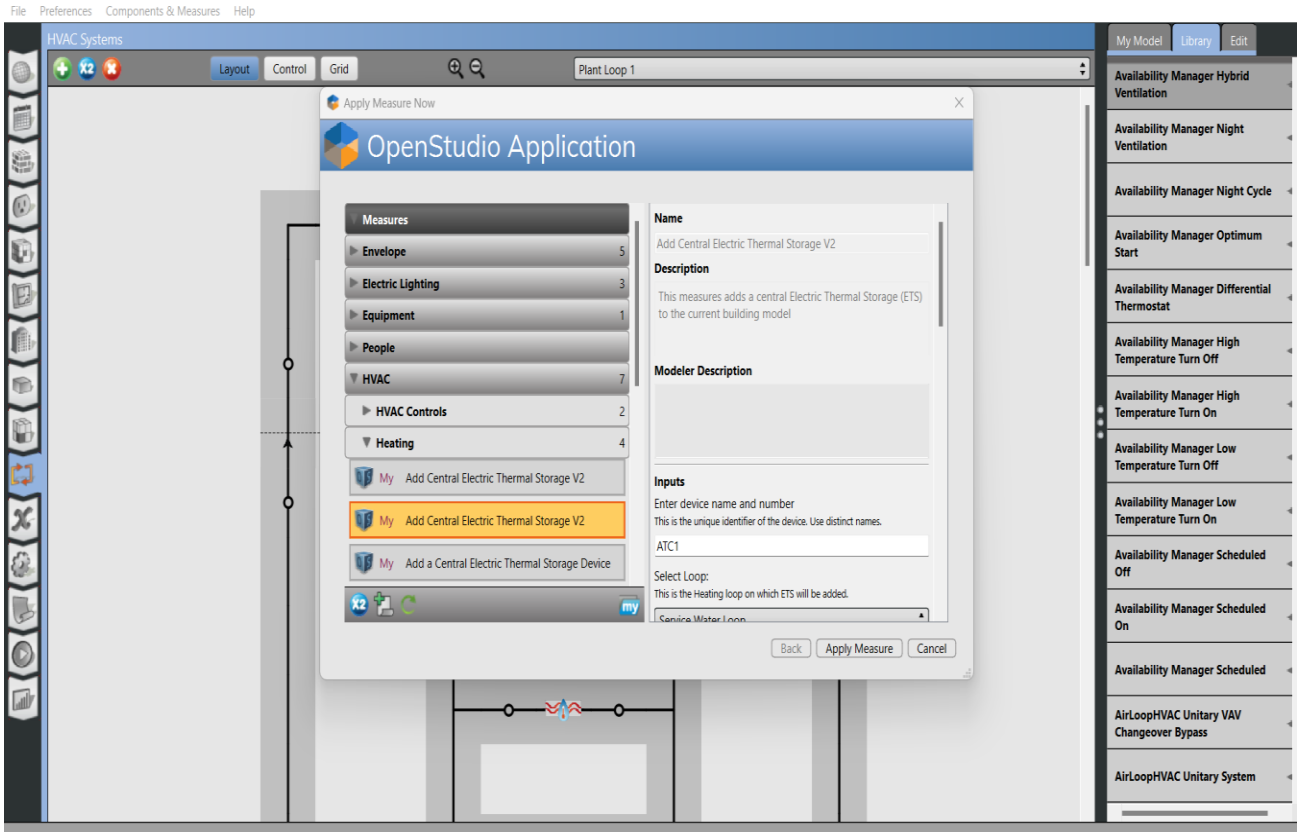

Figure 1 - Openstudio Application Interface

Input fields:

Input	Description	Remarks
1. Name and number	Unique identifier for the ETS being added	The default name is ETS1. Use distinct names each time an ETS is added. Avoid special characters
2. Loop	This is the hot water loop where ETS will be added	Create the hot water loop before adding ETS.
3. Boiler	If there is a boiler already in the loop, it can be operated alongside the ETS	The default priority is: Electric boilers>ETS>fossil fuel fired boilers. Default load distribution scheme: UniformLoad. If simulating ETS with boilers, boilers need to be created before adding ETS.
4. Location	Position of the ETS device relative to the selected boiler (upstream, downstream or parallel)	The default option is parallel. Upstream or downstream options need to have setpoint managers defined by user for each equipment to override the default priorities defined in the PlantEquipmentOperationHeatingLoad object.
5. Charging schedule	Charge authorization values of either 0 or 1	Schedule needs to be defined before adding ETS. One schedule can be used for multiple ETS.
6. Discharging schedule	Discharge authorization values of either 0 or 1	Schedule needs to be defined before adding ETS. One schedule can be used for multiple ETS.
7. Peak power schedule	Building peak demand schedules in Watts	Schedule needs to be defined before adding ETS. One schedule can be used for multiple ETS.
8. Initial brick temperature	Initial brick temperature after WarmUp period complete.	Default is 760°C (maximum core temperature).

9. Maximum brick target temperature	Maximum temperature that will be targeted by controls when outdoor temperature is below a minimal threshold.	Default is 760°C.
10. Minimum outdoor temperature	Threshold for the maximum brick target temperature.	Default is -15°C.
11. Minimum brick target temperature	Minimum temperature that will be targeted by controls when outdoor temperature is above a maximum threshold.	Default is 100°C.
12. Maximum outdoor temperature	Threshold for the minimum brick target temperature.	Default is -15°C.
13. Mass flow rate	Maximum mass flow rate that can be requested by ETS.	Default is 1.86 kg/s. the value chosen should maintain the mass flow rate balance. A first simulation with another equipment can help determine the overall mass flow rate in the loop.
14. Ambient zone	Zone where ETS will be added.	This can be a mechanical room. The heat losses from the ETS will be counted as internal gains to the selected zone.
15. Reporting frequency	Options for displaying output variables. Timestep, hourly, daily etc.	The default is Timestep i.e the timestep chosen for the simulation e.g 5 minutes.
16. Level of output reporting	Defines the level of detail for calculations of outputs variables in the EDD file.	Default is None. If debugging, verbose option can be used but otherwise should be avoided as it creates extremely large EDD text files.

Model outputs:

Output variables (timeseries) related to the ETS can be viewed after the simulation by opening the ESO file from the results folder. Eso viewer for energyplus such as DesignBuilder Results Viewer 3.1 can be used. Outputs include:

Thermal power and energy delivered by ETS.

Electric power and energy consumed by ETS.

Heat losses from the ETS.

Average brick temperature.

ETS outlet temperature.

Controls

1. **Peak shifting strategy**
   Under this strategy, the ETS will have a **charging schedule** defined such that authorization values are equal to 1 in off-peak periods and 0 during peak hours.

2. **Load leveling strategy.**
   Under this strategy, the ETS will have a **peak power schedule** containing building demand limit values in Watts. These limits are used to calculate the available power in the building that can be used to charge the ETS.

Note: **Both schedules need to be defined for the simulation to run**. Both strategies can be simulated at the same time. However, if the user wishes to simulate a peak shifting operation without load leveling, they must still define the peak power schedule but make sure that the demand limit is high enough, such that it can never be attained by the building.

Similarly, if the user wants to simulate load leveling without peak shifting, they can define a charging schedule with an authorization value of 1 all year long. This is the analog of the Always_ON schedule in EnergyPlus.

3. **Brick target core temperature**

   Inputs 9 to 12 impact how the target setpoint temperature. Figure 1 shows the default variation of brick setpoint temperature according to outdoor temperature.

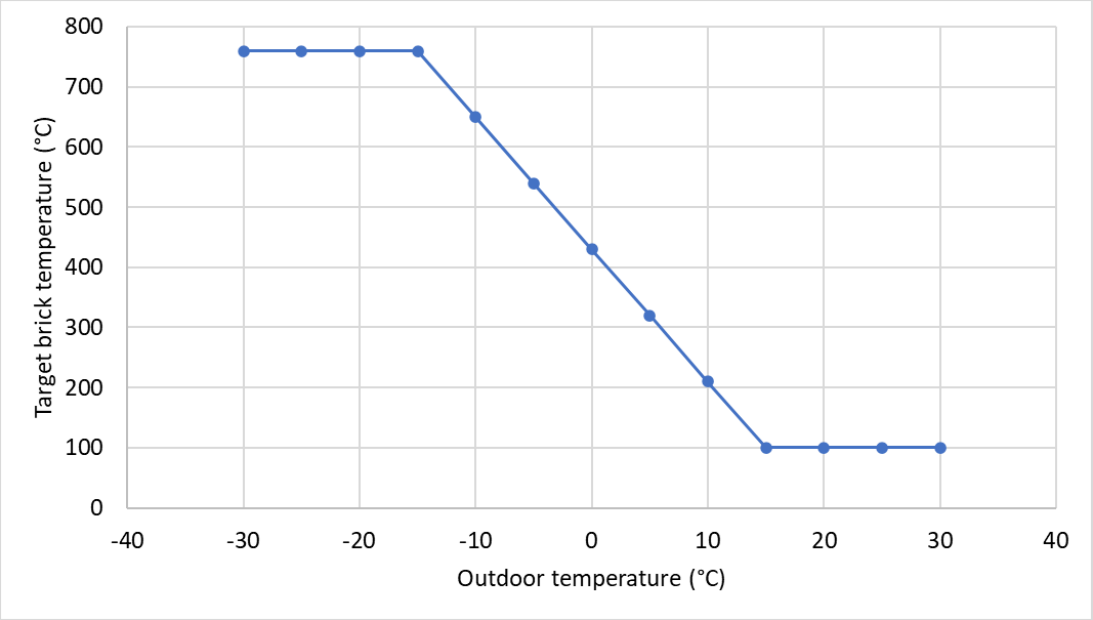

Figure 2 - Target brick setpoint temperature definition

Important remarks:

1. The ETS model is built using an existing EnergyPlus object called the **PlantComponent: Userdefined** (PCUD). This object was adapted to simulate and control an ETS system by using the **Energy management system** (EMS) feature and the **EnergyPlus runtime language** (ErL). The object communicates with EnergyPlus core routines using actuators, sensors and internal variables accessible via EMS. The ETS model is **not part of the EnergyPlus source code**. This leads to limitations such as EnergyPlus not accounting for the ETS object during the sizing phase of the simulation. Therefore, there is no autosize option for the ETS model and other equipment such as boiler must be specified with the hard-size option. An initial simulation without the ETS might be helpful to determine the peak demand of the building and determine the appropriate number of ETS units and the required size of other equipment operating with the ETS.
2. This model is based on ThermElect 80kW performance data.
3. The heating loop and boilers (if any) must be defined before adding ETS.
4. The heating operation schemes for the selected loop are altered when an ETS is added. The default logic gives priority to electric boilers, then ETS and finally any fossil fuel fired boilers. If the user wishes to override this logic, or include other equipment with different priorities, changes need to be made on the IDF text file or using the idf editor in EPLaunch.
5. Deleting ETS without adding a new one leaves orphaned EnergyPlus EMS objects in the IDF file which can create errors. If an ETS is deleted then replaced by another, any orphaned objects are detected and deleted automatically by the new instance of the measure. If an ETS is deleted without being replaced, you might have to delete orphaned objects manually from the IDF file or use another measure called remove_orphaned_objects_from_idf. For

convenience, you can add this measure as an ‘always run’ measure in the measures tab in Openstudio so that it ‘cleans’ any remaining orphaned objects before proceeding with the final simulation.