Flexible Domestic Hot Water Implementation Guide:

A General Reference Guide for Using the Add HPWH (Heat Pump Water Heater) Measure in OpenStudio

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1 Purpose of the Guide

This measure is designed to permit the assessment of the potential load flexibility associated with electric domestic hot water systems, especially heat pump water heaters. This guide explains how various systems and flexibility controls may be implemented in OpenStudio.

2 Measure Overview

2.1 General Description

This measure adds or replaces existing domestic hot water heater with air source heat pump system and allows for the addition of multiple daily flexible control time windows. The heater/tank system may charge at maximum capacity up to an elevated temperature, or float without any heat addition for a specified timeframe down to a minimum tank temperature.

Due to the intentional focus on electrical demand flexibility, natural gas heated domestic hot water systems cannot be simulated with this measure.

2.2 Measure Repository Contents

The measure folder contains the following directories and files:

- flexible_domestic_hot_water/
  - docs/
    - Flexible Domestic Hot Water Implementation Guide.pdf
  - tests/
    - flexible_domestic_hot_water_test.rb
    - SmallHotel-2A.osm
  - LICENSE.md
  - measure.rb
  - measure.xml
  - README.md
  - README.md.erb

2.3 User Arguments

See README.md file for complete list of user arguments.

2.4 Model Pre-Requisites

This measure requires an OpenStudio model with an existing domestic hot water loop with defined water usage object(s). An existing hot water heater system is not required.

3 Tank Heating Options

This measure only simulates domestic hot water systems that use electricity as their primary energy source. Because of the poor exergetic efficiency of electric resistance heating, it may be preferable to use heat pump water heaters over tanks heated by electric elements. However, it is atypical to use domestic hot water tanks that do not include some form of internal heating

mechanism. This measure may be used to simulate exclusively heat-pump heated tanks, exclusively electrically heated tanks, or, preferably, a combination of both.

3.1 Heat Pump: Pumped Condenser

The pumped condenser heat pump simulates a system where the heat pump is physically separated from the hot water storage tank. This configuration is more-common in a larger, commercial building application. The model includes the heat pump, a mixed water tank, and an on/off fan.

See EnergyPlus Input Output Reference Section 1.23.5 for additional detail on this object.

3.2 Heat Pump: Wrapped Condenser

The wrapped condenser heat pump simulates a system where the heat pump condensing coil is physically integrated into the hot water storage tank. This configuration applies to integrated units, typically of smaller physical size and capacities. The model includes the heat pump, a stratified water tank, and an on/off fan.

See EnergyPlus Input Output Reference Section 1.23.6 for additional detail on the object.

3.3 Heat Pump: Simplified Approach

Adding a heat pump, or multiple heat pumps, and stratified tank(s) to a model can significantly increase simulation run time. A less accurate, but faster option is available in the measure. The 'Simplified' option will use an electric resistance heater but divide the energy input by a nominal heat pump coefficient of performance to approximate the reduced electrical requirement. This method does not capture temperature effects for a heat pump's energy extraction from a zone.

Accuracy at a fixed temperature setpoint (i.e. baseline operation) may be acceptable, particularly when conditions at the evaporator are relatively constant. However, accuracy is severely impacted when attempting to simulate load flexibility. It is not recommended to use the simplified approach beyond approximating the impact of a heat pump relative to electric resistance heating with a constant tank temperature setpoint.

3.4 Electrical Resistance Heating

To simulate a domestic hot water tank heated only by electric resistance heating, users should use one of the two following implementation options:

The first method is the set the heat pump capacity to zero, but use a non-zero electrical backup capacity. In this case, the heat pump will be added, but cannot meet any load.

The second method is to add a 'Charge – Electric' flexibility period that lasts the entire day (00:00 – 23:59). The maximum tank temperature should be set to the fixed baseline temperature (typically ~140°F). In this case the heat pump will be added, but the electrical resistance heaters in the tank will take priority over the heat pump.

4 Baseline Control Options

Baseline controls are implemented by selecting a schedule from the existing schedule objects within the model or by creating a new baseline with a constant setpoint of 140°F.

5 Flexible Control Options

Flexibility analysis with this measure is limited to routine load shifting. All flexibility periods added to the model are converted into schedule objects that apply to the entire simulation run period. Four distinct daily flexibility periods may be set within the user arguments; by default, they are turned-off. Start and stop times for each flexibility window must be entered as HH:MM-HH:MM using a 24-hour format.

5.1 Temperature Settings

Flexibility in domestic hot water control is made possible by modulating the temperatures at which it is stored and delivered. Maximum and minimum tank temperatures are required to define flexibility periods. Heat pump water heaters can produce water up to ~185°F; electric resistance heaters face no such limitation.

5.2 Flex Option: “None”

This option is the default for all four flexibility periods. It maintains the baseline control scheme described above in Section 4 by not performing any model articulations. This setting should be used to establish as baseline energy use prior to conducting flexibility assessments.

5.3 Flex Option: “Charge – Heat Pump”

This setting will use the heat pump to charge the domestic hot water tank up to the user-defined maximum temperature and will maintain that tank temperature within the deadband for the specified time period. Any electric resistance heaters within the tank are effectively turned-off during this period to ensure all water heating is performed exclusively by the heat pump.

5.4 Flex Option: “Charge – Electric”

This setting will use the tank’s internal electric resistance heater(s) to charge the tank up to the user-defined maximum temperature and will maintain that tank temperature within the deadband for the specified time period. The heat pump is effectively turned-off during this period as the electric resistance heaters take priority over the heat pump when the two devices have overlapping temperature setpoints. (See EnergyPlus Input Output Reference Section 1.23.5.1.4 or 1.23.6.1.4 for further explanation of how device setpoints and deadband temperature differences are handled.)

5.5 Flex Option: “Float”

This option allows users to turn-off all the domestic hot water tank heating elements for a specified period of time. The user-set minimum tank temperature triggers an override of the float period and allows tank heating in the event of an insufficient hot water supply. Any backup heating will be provided with first priority by the heat pump, then by electric resistance.

6 References

"EnergyPlus 9.5.0," ed: U.S. Department of Energy, 2021.

"OpenStudio 3.2.0," ed: U.S. Department of Energy, 2021.