Modelling controls within the Home Energy Model

A technical explanation of the methodology

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Contents

Background to the Home Energy Model

What is the Home Energy Model?

The Home Energy Model (HEM) is a calculation methodology designed to assess the energy performance of homes, which will replace the government's Standard Assessment Procedure (SAP).

The Home Energy Model is still under development and its first version will be implemented alongside the Future Homes Standard (FHS) in 2025. We are publishing information about the model while it is still at a formative stage to enable industry to participate in the ongoing development process.

Where can I find more information?

This document is part of a wider package of material relating to the Home Energy Model:

Home Energy Model technical documentation (e.g. this document)

What: This document is one of a suite of technical documents, which go into further detail on the methodology and the validation exercises that have been carried out. We intend to update and produce further technical documentation throughout the model development process.

Audience: The technical documentation will be of interest to those who want to understand the detail of how the Home Energy Model works and how different technologies are treated.

The Home Energy Model consultation

What: The Home Energy Model consultation, which explains the overhaul to the SAP methodology and seeks views on the approach taken by the new Home Energy Model.

Audience: The Home Energy Model consultation will be of interest to those who want to understand the proposed changes to the SAP methodology and wider SAP landscape.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model and the Home Energy Model: FHS assessment has been published as a Git repository. This code is identical to that sitting behind the consultation tool. We are currently considering whether the open-source code could serve as the approved methodology for regulatory uses of the Home Energy Model.

Audience: The reference code will be of interest to those who want to understand how the model has been implemented in code, and those wishing to fully clarify their understanding of the new methodology. It will also be of interest to any potential contributors to the Home Energy Model.

Related content

This paper sets out the methodology for modelling controls within the Home Energy Model core engine. These may include controls for heating systems, cooling systems or hot water systems. The control methodology may vary according to the system type.

For information on control assumptions within the FHS assessment wrapper, please see:

- HEMFHS-TP-02 FHS space heating and cooling demand assumptions
- HEMFHS-TP-03 FHS domestic hot water assumptions

To understand how this methodology has been implemented in computer code, please see the following modules within the source code:

core/controls/time_control.py

core/cooling_systems/air_conditioning.py

core/heating_systems/boiler.py

core/heating_systems/elec_storage_heater.py

core/heating_systems/emitters.py

core/heating_systems/heat_battery.py

core/heating_systems/heat_network.py

core/heating_systems/heat_pump.py

core/heating_systems/instant_elec_heater.py

core/heating_systems/storage_tank.py

core/project.py

Methodology

1. Overview

Systems requiring control (e.g. heating and hot water systems) can refer to one or more Control objects (containing schedules) that are defined as separate objects in the inputs to the core engine. As a minimum, these Control objects will define whether a system is on or off during a particular timestep but some types of control objects may also define numeric setpoints. Note: in this context “on” means the system is ready to provide heat, but actual operation will also depend on demand on the system (e.g. a heat pump providing water heating which is “on” will not operate if the hot water cylinder is still above the minimum hot water temperature). In some cases additional controls that are specific to the system, such as backup heating controls for heat pumps, are defined as part of the relevant system object instead of a control object.

For hot water systems with storage (e.g. an immersion heater supplying a hot water cylinder) the control is expressed in terms of a Boolean value for each timestep of the calculation which indicates whether or not the system is on (subject to the cylinder setpoint). If no Control object is referenced, then the system is assumed to be on at every timestep.

For space heating and cooling systems, a Control object defining a setpoint schedule must be referenced (see the description of SetpointTimeControl below). The relevant setpoint defined for each timestep is then used in the calculation of space heating/cooling demand at that timestep. If no setpoint has been set for a particular timestep (i.e. a null value is specified in the setpoint schedule) then the heating or cooling demand will be zero.

For space heating and cooling systems with storage, an additional Control object may be referenced so that input to the storage is controlled on a different schedule than output from the storage. For example, with a storage heater the input would typically be on at night when electricity is available at off-peak rates, whereas the output would typically be on during the day.

2. Control schedule object types currently implemented

2.1 OnOffTimeControl

This defines a Boolean value for each timestep of the simulation, which determines whether the system is on or off.

2.2 SetpointTimeControl

Note: This is currently only used to control space heating system output.

This defines a numeric value for each timestep of the simulation, which is used to determine demand. Null values may also be provided in which case demand for that timestep will be zero and the system will be off (it is important to differentiate between times when there is no demand because the setpoint has been reached and times when there is no demand because the system is off as this may affect standby power requirements for some systems).

Additional inputs can be provided on an optional basis, to set minimum or maximum setpoints which will be applied to all timesteps (i.e. if any of the setpoints in the specified schedule fall below the specified minimum or above the specified maximum, then the minimum or maximum temperature will be used instead, respectively). This allows for setback temperatures to be defined independently of the main setpoint schedule. Any null values will be overwritten with the maximum or minimum value (whichever has been provided) and the system is assumed to be always on. If both minimum and maximum values have been provided, then there a further input to specify which should be used when the main schedule contains a null value.

An "advanced start” duration can also be specified to define how long before the specified heating period the system should switch on. This is intended for use with systems with a low capacity and/or a high degree of thermal inertia (e.g. heat pump with wet distribution) to avoid situations in which demand at the start of the heating period cannot be met (efficiently or at all) due to the system taking time to warm up.

If a setback or advanced start period are specified, then the heating/cooling system will attempt to meet the target temperature but if it cannot do so then no unmet demand will be recorded (i.e. unmet space heating/cooling demand is only recorded for the setpoints specified by the main schedule). See HEM-TP-04 Space heating and cooling demand for how unmet demand is calculated.

2.3 ToUChargeControl

This is the same as the OnOffTimeControl except that it also defines a schedule of target charge levels (one per day) for a storage heater or heat battery (as a proportion of the total storage capacity). It is intended to be used to control the energy input to such systems.

2.4 OnOffCostMinimisingTimeControl

This generates a Boolean schedule based on a cost schedule and a desired number of operating hours per day (this does not have to be an integer number of hours). For each day of the simulation, the control will pick the required number of timesteps to meet this number of operating hours, prioritising the lowest-cost timesteps. For example, if the inputs state that 7 hours of operation are required and the timestep is half-hourly, then the 14 timesteps with the lowest cost in each day will be selected. The cost schedule can be based on any metric that needs to be minimised (e.g. financial cost, CO2 emissions, primary energy).

3. System-specific controls

3.1 Storage tank

The StorageTank module has the following control inputs:

- For each heat source, the position of the thermostat controlling that heat source
- Minimum hot water temperature (a single figure for the entire simulation)
- Maximum hot water temperature (a single figure for the entire simulation)
- Optional reference to a control schedule object defining a Boolean schedule defining which timesteps the temperature should be held at the maximum hot water temperature and not allowed to fall to the minimum before recharging (i.e. it sets the minimum temperature to equal the maximum temperature at the specified times). This provides some, albeit limited, ability to specify sterilisation cycles, as long as the maximum hot water temperature specified is high enough. If not provided, it will be assumed that this is not required for any timesteps.

Each heat source supplying the storage tank may also have a reference to a control schedule object defining a Boolean schedule defining when the heat source may heat the tank (see below).

Unless the control inputs indicate that the temperature is to be held at the maximum for a certain period, the temperature at the thermostat is allowed to fall to the minimum hot water temperature before triggering a heating event which continues (subject to any schedule defined for the heat source) until the maximum hot water temperature is reached.

3.2 Immersion heater and PV diverter

The immersion heater inputs may contain a reference to a control schedule object defining a Boolean schedule defining when the heater may provide heat to the storage tank. For example, the immersion heater may be set up to run only overnight. The setpoints are defined as part of the storage tank inputs and are common to all heat sources.

If the immersion heater is fed by a PV diverter, then this is assumed to operate whenever there is excess generated electricity available with no restrictions on time of day. It is assumed that the same storage tank setpoint applies as for any other heat source.

3.3 Boiler

For a combi boiler, water heating is assumed to be always available.

For a boiler heating a storage tank, the boiler inputs may contain a reference to a control schedule object defining a Boolean schedule defining when the boiler may provide heat to the storage tank. If this is not provided then the system is assumed to provide heat at any time. The setpoints are defined as part of the storage tank inputs and are common to all heat sources.

For space heating, the heating setpoints are defined by a SetpointTimeControl object (see above).

In addition to the above, boiler performance will also be affected by flow and return temperature when there is presence of weather compensating controls – the flow and return temperatures are determined in the emitter calculation as the methodology is common to all systems with wet distribution (see section on Systems with wet distribution).

3.4 Heat pump

For water heating, the heat pump inputs may contain a reference to a control schedule object defining a Boolean schedule defining when the heat pump may provide heat to the storage tank. If this is not provided then the system is assumed to provide heat at any time. The setpoints are defined as part of the storage tank inputs and are common to all heat sources.

For space heating, the heating setpoints are defined by a SetpointTimeControl object (see above).

Other heat pump control inputs common to both space and water heating are:

- Modulating vs. On/off control
- Backup control type, one of:
  - "None" -- backup heater disabled or not present
  - "TopUp" -- when heat pump has insufficient capacity, backup heater will supplement the heat pump
  - "Substitute" -- when heat pump has insufficient capacity, backup heater will provide all the heat required, and heat pump will switch off
- Time after which the backup heater will activate if demand has not been satisfied

In addition to the above, heat pump performance will also be affected by flow and return temperature when there is presence of weather compensating controls – the flow and return temperatures are determined in the emitter calculation as the methodology is common to all systems with wet distribution (see section on Systems with wet distribution).

3.5 Heat battery

For water heating, the heat battery inputs may contain a reference to a control schedule object defining a Boolean schedule defining when the heat battery may provide heat to the storage tank. If this is not provided then the system is assumed to provide heat at any time. The setpoints are defined as part of the storage tank inputs and are common to all heat sources.

For space heating, the heating setpoints are defined by a SetpointTimeControl object (see above).

The energy input to the heat battery must also be controlled. This is specified by a ToUChargeControl object which specifies when the heat battery can charge and the target charge level (as a proportion of the total storage capacity)

3.6 Heat network / Heat interface unit

For an HIU providing hot water directly, hot water is assumed to be always available.

For an HIU heating a storage tank, the heat network inputs may contain a reference to a control schedule object defining a Boolean schedule defining when the system may provide heat to the storage tank. If this is not provided then the system is assumed to provide heat at any time. The setpoints are defined as part of the storage tank inputs and are common to all heat sources.

For space heating, the heating setpoints are defined by a SetpointTimeControl object (see above)

3.7 Systems with wet distribution

The design/maximum flow temperature must be entered in all cases, but additional flow temperature inputs are required for weather compensating controls. The emitter module requires the Ecodesign control class (I to VIII) to be specified and for those classes (II, III, VI and VII) which include weather compensation, the minimum flow temperature is also required along with the outside air temperatures at which the maximum and minimum flow temperatures will be set. The actual flow temperature (and implicitly, the return temperature, which is calculated from the flow temperature) at each timestep is then interpolated based on these inputs. The flow/return temperature will then affect the efficiency of the heat source (e.g. boiler, heat pump).

3.8 Direct electric heater

The heating setpoints are defined by a SetpointTimeControl object (see above).

3.9 Electric storage heater

The heating setpoints are defined by a SetpointTimeControl object (see above). This determines the output of the system (subject to other constraints such as system capacity and energy stored).

The energy input to the storage heater must also be controlled. This is specified by the following inputs:

- Target/maximum temperature for the core material on charging mode
- Reference to ToUChargeControl object which specifies when the heater can charge and the target charge level (as a proportion of the total storage capacity)
- Room temperature at which, if sensed during a charging hour, the heater won't charge

3.10 Instantaneous point-of-use water heater

This is assumed to be available all the time, so there are no control inputs.

3.11 Air conditioning

The cooling setpoints are defined by a SetpointTimeControl object (see above).

Future development

The current set of control options in the Home Energy Model can handle most of the typical situations for controls within a home. However, as the Home Energy Model becomes more widely used, there may be requests to add further control options to handle additional situations. For example, there may be some settings for heat pumps which are not currently modelled. Additional control options could be added as and when they are required.

This publication is available from: https://www.gov.uk/government/publications/home-energy-model-technical-documentation