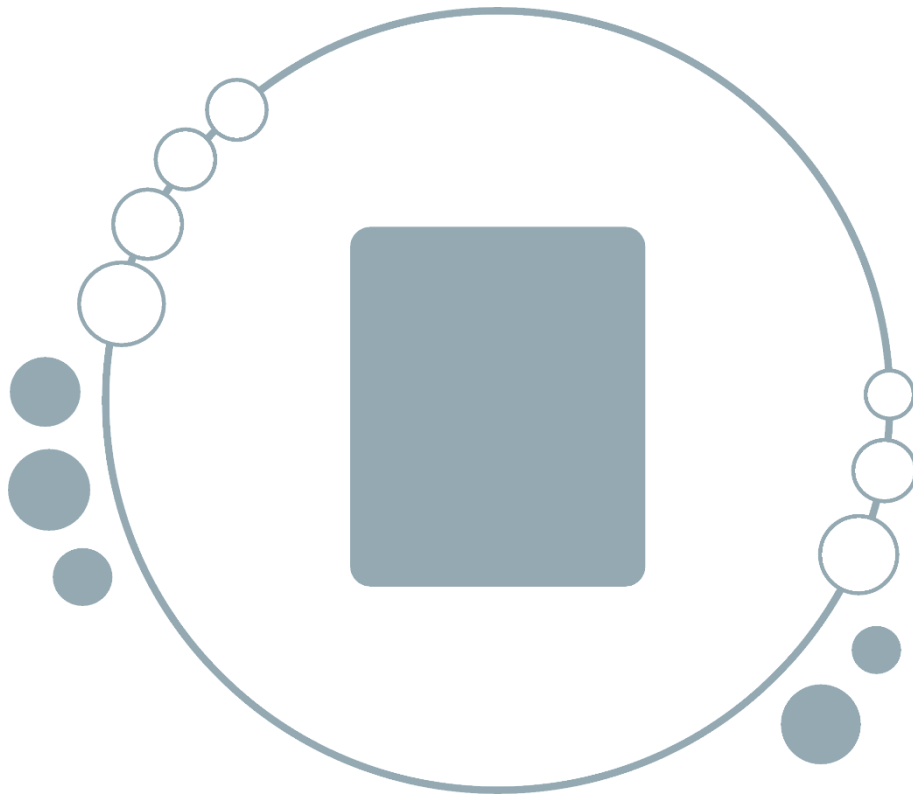




Calculating water heating energy demand within the Home Energy Model

A technical explanation of the methodology

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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 \(SAP\)](#).

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 explain the calculation methodology in detail. New documents will be added, and the content amended, when necessary to ensure documentation is sufficiently comprehensive. This will usually, but not always, occur alongside the release of a new version of HEM.

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 and government response

What: The [Home Energy Model consultation](#) introduces the overhaul to the SAP methodology and sought views on the approach taken by the new Home Energy Model. The [Home Energy Model consultation](#) summarises the feedback to the consultation and the actions taken subsequently in development, ahead of the initial release of HEM.

Audience: The Home Energy Model consultation will be of interest to those seeking a general introduction to HEM and its role in government policy on domestic energy performance.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model core engine has been published as a [Git repository](#). Note the reference code for official HEM wrappers is published separately.

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 or those wishing to use it within their own projects.

Related content

This document provides an overall description of the calculation of energy demand for water heating in the core Home Energy Model. For information on how the list of hot water draw-off events is constructed within the FHS assessment wrapper, see HEMFHS-TP-03 FHS domestic hot water assumptions.

To understand how this methodology has been implemented in computer code, please see:

src/hem_core/project.py

src/hem_core/water_heat_demand/dhw_demand.py

src/hem_core/water_heat_demand/shower.py

src/hem_core/water_heat_demand/bath.py

src/hem_core/water_heat_demand/other_hot_water_uses.py

src/hem_core/heating_systems/point_of_use.py

src/hem_core/heating_systems/storage_tank.py

src/hem_core/heating_systems/wwhrs.py

Methodology

1. Hot water demand

The calculation of the energy required to heat domestic hot water can be described as a series of steps which are detailed below. This calculation requires the details of water draw off events to be provided as inputs¹, either from the user or from a wrapper. For clarity, we shall first describe the case where the dwelling contains a single water heating system. The extension to multiple systems is detailed in Section 3.

1. A list of hot water draw-off events for each tapping point is provided to the core Home Energy Model (HEM) as part of the input data; these events may be user-specified or come from a schedule defined in a wrapper. Tapping points are divided into showers, baths and other tapping points. Each event specifies the demand for hot water at the tapping point, with the desired output temperature:
 - a. for showers, the desired temperature and duration,
 - b. for baths, the desired temperature and either volume drawn off or duration to fill the bath to the required level,
 - c. for other events, the desired temperature and duration.
2. Hot water use for showers is calculated, based on the temperature and duration of shower events in the events schedule input.
 - a. For mixer showers, a constant flow rate is assumed (this is part of the shower specification in the inputs) to calculate the mix of hot and cold water required. The hot water use is added to the total hot water demand for the appropriate hot water source, accounting for any saving due to instantaneous wastewater heat recovery.
 - b. For instantaneous electric showers, a constant power output is assumed, and the flow rate is adjusted so that water flows at the desired temperature. The calculation is performed iteratively to account for a potentially varying cold water

¹ BS EN 12831-3:2017 provides a simple method to determine hot water use. Although there are no obvious inconsistencies between HEM and this standard in terms of underlying assumptions, the calculation in HEM is not based on this standard, and HEM accounts for additional variables such as tapping point flow rates which are not considered in the standard. The standard also provides suggested default load profiles, but these do not vary from day to day and as a result may over-fit the model to a particular pattern of use. Therefore, the HEM core calculation requires the details of draw-off events to be provided as inputs, either from the user or from a wrapper.

feed temperature. No additional demand is added to the total hot water demand because it does not have to be satisfied by the main water heating system. Instead, the electricity consumption of the electric shower is calculated and added to the total electricity demand.

3. Hot water use for baths is calculated, based on bath volume (or bath fill duration and flow rate) and temperature requirements from the events schedule input. The hot water use is added to the total hot water demand for the appropriate hot water source.
4. Hot water use for other tapping points is calculated, based on the flow rate of the tapping point and the temperature and duration of draw-off events in the events schedule input. The hot water use is added to the total hot water demand for the appropriate hot water source.
5. The volume of hot water left standing in distribution pipework is calculated and added to the total hot water demand. For the lengths of distribution pipework that are inside the thermal envelope of the dwelling, the heat losses resulting from water being left stranded in the pipework at the end of each draw-off event are also added to the total internal gains. It is assumed that all the energy left in the distribution pipework is lost between draw-off events. See HEM-TP-10 Ductwork and pipework losses for further details of how pipework loss is calculated.
6. The total hot water demand calculated is then an input to the calculation of the energy provided by and used by the water heating system. This calculation will differ completely depending on the type of system providing hot water.

For all tapping events other than instantaneous electric showers, the calculation of the hot water demand includes calculating the required mix of hot and cold water. By including this within the calculation of hot water demand, the potential for different cold feed temperatures at the outlet and the hot water source can be accounted for. The calculation is performed iteratively to account for potential changes in hot and cold-water temperature as water is drawn².

2. Water heating system

A water heating system in HEM can be comprised of several components (e.g. a hot water cylinder heated by multiple heat sources). Instantaneous electric showers may also be included separately.

Where an instantaneous water heating system is used (i.e., a system with no hot water storage tank) draw-offs are assumed to be provided directly by the heat generator. If an instantaneous

² For example, water drawn from the lower layers of a storage tank may be colder than that drawn from higher layers.

point of use water heater is used, then no distribution pipework should be entered into the model for that hot water source.

If a hot water tank is used to accumulate hot water, draw-offs are taken from the top layer of the hot water tank (or sequentially from lower layers if the top layer contains insufficient energy). The same volume of cold water (or pre-heated water from a separate tank) is added to the lowest layer and the temperature of each layer is recalculated at each time step. See HEM-TP-11 Hot water storage tanks for further details on the storage tank inputs and methodology. Where hot water tanks are used there are several additional factors:

- Standing losses from the tank (based on daily loss from standard lab test as specified in the inputs).
- Where applicable, primary pipework losses are calculated and added to the required energy output from the heat generator to heat the tank. For those parts of the primary pipework that are internal, these losses are also added to the internal gains.
- Where present, heat from a solar thermal system and/or PV diverter is added to the tank. See HEM-TP-18 PV generation and self-consumption for an explanation of diverters.

For each heat generator, if the controls allow, then the amount of energy required from the heat generator to reheat the tank is calculated, taking into consideration the draw-offs, losses and heat input from other sources described above. The heat generator is assumed to output this amount of heat, subject to its maximum power output (domestic hot water production is assumed to take priority over space heating).

The heat output required is then used to calculate the amount of fuel used for water heating according to the calculation procedure for the relevant type of heat generator. The total hot water energy or fuel requirement for each time-step is summed to give the relevant totals required and written to the output files.

3. Multiple water heating systems

HEM can support multiple water heating systems, and the calculation follows as detailed in the previous sections with the following adaptations. When specifying more than one hot water source, outlets other than instantaneous electric showers must be assigned to the relevant hot water heating system and distribution pipework must be entered for each hot water source (except for point of use water heaters).

The calculation loops over the hot water tapping events as before, identifying the corresponding outlet and from this the corresponding hot water source. The code then calculates the hot water demand associated with the event and constructs a list of draw-off events for each hot water source. These lists are then passed to the relevant water heating system where the calculations proceed separately.

Future development

Additional water heating system types (or components thereof such as storage and heat sources for storage) may also be added in future.

