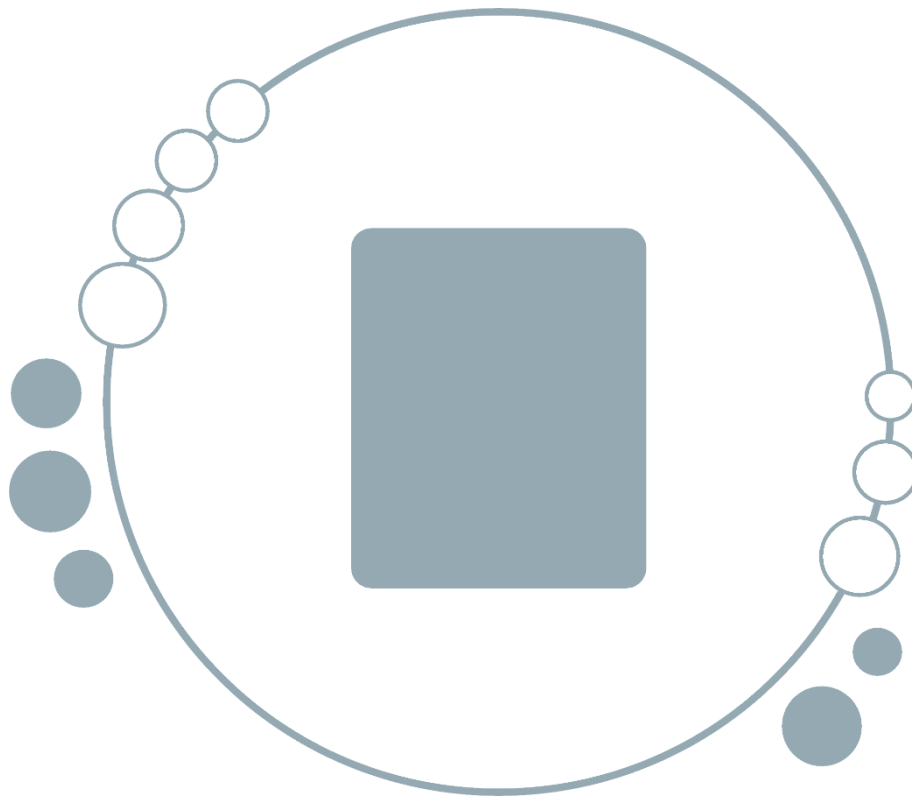




Space heating and cooling assumptions in the Home Energy Model: FHS assessment wrapper

A technical explanation of the assumptions

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Background to the Home Energy Model: Future Homes Standard assessment

What is the Home Energy Model: Future Homes Standard assessment?

The [Home Energy Model: Future Homes Standard assessment](#) is a calculation methodology designed to assess compliance with the [Future Homes Standard \(FHS\)](#). It builds on the government's [Home Energy Model](#), 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: FHS assessment technical documentation (e.g. this document)

What: This document is one of a suite of [technical documents](#), which explain the approach to developing the standard assumptions and methodology used in the wrapper.

Audience: The technical documentation will be of interest to those who want to understand the justifications and evidence base behind the assumptions used in the model.

The Home Energy Model: Future Homes Standard assessment consultation and government response

What: The [Home Energy Model: Future Homes Standard \(FHS\) assessment consultation](#) sought views on the proposed methodology for demonstrating compliance with the FHS.

Audience: The consultation and response will be of interest to those who want to understand the proposed standardised assumptions around occupancy, energy demand etc. to be used when assessing compliance with the FHS, as well as the methodology for the calculation of the FHS compliance metrics.

The Home Energy Model reference code

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

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.

Future Homes and Buildings Standards Government Response

What: The [FHS consultation and response](#) sets out the feedback received to the 2023 consultation on proposed Part L standards, and details the new regulations being introduced.

Audience: The consultation and response will be of interest to those wishing to understand the incoming standards for Building Regulations Part L.

Related content

The core Home Energy Model (HEM) can be used with a variety of heating and cooling periods and temperature settings. This note relates only to the way the HEM is intended to be used for the Future Homes Standard assessment. For more information on space heating and cooling demand calculations in the core methodology, see the following technical papers:

- HEM-TP-04 Space heating and cooling demand
- HEM-TP-17 Controls

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

[src/wrappers/future_homes_standard/future_homes_standard.py](#)

Methodology

1. Overview

The Future Homes Standard (FHS) assessment wrapper specifies inputs and outputs for the Home Energy Model (HEM), for the use of the model in assessing whether a new home complies with the requirements of Part L of the Building Regulations 2025, i.e. the Future Homes Standard. Among the inputs are standardised assumptions relating to space heating and cooling demand.

This paper sets out the assumptions made in the FHS for space heating and cooling in HEM and explains how these have been derived.

Space heating and cooling demand is the amount of thermal energy that needs to be provided to the space (heating demand) or removed from the space (cooling demand) in order to achieve a desired temperature. The space heating and cooling demand calculated by the model is highly dependent on:

- Heat gains (entering the dwelling): internal gains, solar gains, heating/cooling setpoint temperatures and schedules, heating/cooling system, and pipework.
- Heat losses (leaving the dwelling): fabric losses (walls, roof, floor), window losses (glazing), ground losses, infiltration and ventilation and thermal bridges.

2. Heating/cooling setpoint temperatures and schedules

The FHS wrapper fixes the number of thermal zones in the dwelling to 1; that is, there is a single dry-bulb air temperature and operative temperature for the whole dwelling at any given time, and air is assumed to circulate freely within the dwelling. A single setpoint schedule is therefore simulated for the whole dwelling, but this is derived in a way which accounts for occupants moving around the dwelling throughout each day.

The HEM core requires a control schedule to be defined for each zone's heating system (see *HEM-TP-17 Controls* for a description of SetpointTimeControl), which defines an operative temperature setpoint for each timestep in the simulation. As the FHS specifies an annual simulation with a half-hourly timestep, this means that when running with the FHS assessment wrapper a setpoint needs to be defined for each half-hour of the year.

The FHS assessment wrapper therefore specifies a schedule of operative temperature set points. To do this, the FHS assessment wrapper needs an input for the time and temperature control.

Space heating setpoints

For space heating, the assumed operative temperature setpoint in the living room is 21°C, on the basis that this was the 75th percentile reported thermostat setting in the 2017 Energy Follow Up Survey¹ (EFUS). The mean and median setpoints were 20.4 and 20.0°C respectively, but it is known that some homes are underheated², so the 75th percentile was chosen.

In setting an assumed setpoint for the space not containing the living room, there are three issues that need to be considered together:

- **Nominal setpoint temperatures:** the temperatures to which different parts of the dwelling are intended to be heated.
- **Inter-zone heat transfer:** this effect is ignored in HEM, but in reality, may lead to significantly higher heat loss from the rest of the dwelling than would be modelled when ignoring this heat transfer. If one part of the dwelling is heated to a higher setpoint than another adjacent part, then there will be heat transfer from the warmer zone to the cooler zone, which may mean that the cooler zone spends much of its time at a temperature above its nominal setpoint. For a dwelling with lower overall heat loss, this effect would be expected to lead to a greater increase in the temperature of the cooler zone than would occur in a dwelling with higher overall heat loss.
- **Control arrangements:** In practice in UK homes there is often not a specific setpoint in other rooms with the supply of heat to those rooms being determined by the living room thermostat. In such a system arrangement, the temperature achieved in the other rooms is determined by the heat output of the emitters in the other zone relative to the heat output of the emitters in the zone containing the living room; this relative output will be determined by the system design/sizing. The temperature in other rooms may be limited further by the presence of separate temperature controls such as room thermostats or TRVs.

We note that guidance on design setpoint temperatures differs. For example:

- BS EN 16798-1:2019 Table B.2 suggests a design value of 20°C for the "medium expectation" scenario (category II in table) for both living rooms and bedrooms, and 21°C for the "high expectation" scenario (category I in table). The high expectation scenario is intended for occupants with special needs (e.g. the elderly).
- The CIPHE Domestic Heating Design Guide (2021) states that new (well-insulated) buildings should generally use a design temperature of 21°C everywhere except for bathrooms, which should use 22°C.

Considering the above, for the Future Homes Standard assessment a setpoint temperature of 20°C is assumed in the non-living area. The relatively small difference (1°C) between the living

¹ From the EFUS Heating Patterns and Occupancy report (published 2021):

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1018727/efus-heating-patterns-occupancy.pdf

² As compared with the occupants' preferences, when cost is not a limiting factor.

room and rest-of-dwelling setpoints assumed means that the calculation error arising from the lack of consideration of inter-zone heat transfer should be relatively small.

Space cooling setpoints

The wrapper assumes that occupants will open/close windows in an attempt to keep the temperature below 22°C, which is the temperature at which windows in occupied rooms are assumed to be fully closed but above which they start to open according to Approved Document O, 2021 edition.

For active cooling systems, a cooling setpoint of 24°C is assumed. This is the central figure in the range 23-25°C given for habitable rooms in CIBSE Guide A. It is noted, however, that BS EN 16798-1:2019 Table B.2 suggests 26°C for the "medium expectation" scenario. Given the relative rarity of active cooling systems in the UK, evidence as to how they are used in practice is sparse. If the internal temperature exceeds 24°C and an active cooling system is present, the windows are closed and the cooling system activates (see *HEMFHS-TP-06-Infiltration and ventilation assumptions* for the window opening logic).

Times of heating and cooling demand

Initial temperatures

The calculation for each timestep depends on the temperatures achieved for the previous timestep, which means that an assumption has to be made for the temperature at the start of the calculation. See *HEM-TP-04 Space heating and cooling demand* for details of the temperature initialisation.

For the FHS assessment, the two areas are initialised at their respective setpoint temperatures.

Standard times of heating and cooling demand

According to the 2017 EFUS the most common heating pattern on a weekday is a bi-modal one with the hours 07:00-09:30 and 16:30-22:00. The most common heating pattern at the weekend is a single 'all-day' period of 08:30-22:30. It is also possible to heat living and non-living rooms at different times where separate time and temperature controls have been installed. See Table 1 for a summary of these heating patterns.

We note that the EFUS 2017 data covers more dwellings heated by gas boilers than any other system type, as this is representative of the current building stock. Research³ suggests that

³ S.D. Watson, K.J. Lomas, R.A. Buswell, How will heat pumps alter national half-hourly heat demands? Empirical modelling based on GB field trials, *Energy & Buildings* 238 (2021) 110777, <https://doi.org/10.1016/j.enbuild.2021.110777>

while the bimodal and daytime heating patterns are typical of gas boiler use, for heat pumps daytime or continuous heating strategies are more common.

	Weekday	Weekday (rest of dwelling, where Separate Time and Temperature Controls are installed)	Weekend
Heating period 1	07:00-09:30	07:00-09:30	08:30-22:00
Heating period 2	16:30-22:00	18:30-22:00	N/A

Table 1 – Heating periods within the FHS assessment wrapper

In order to produce a fair comparison between different heating systems, the FHS wrapper specifies the same heating periods regardless of the characteristics of the system. These heating periods specify when the FHS assessment wrapper requires the setpoint temperature to be reached, else the shortfall is recorded as unmet demand. Outside the defined heating periods, the wrapper uses a fixed setback temperature of 18°C. This means that the heating system is permitted to run outside defined heating periods, but only to ensure that the temperature does not fall below the setback temperature (or via advanced-start control). The use of a consistent setback temperature maintains a minimum level of thermal comfort and brings the behaviour of high- and low-capacity heating systems into closer alignment.

For space cooling, the hours of active cooling are set to 07:00-09:30 and 18:30-22:00 on weekdays and 08:30-22:30 at weekends.

In addition to active cooling (if present), it is also assumed that occupants will open windows to avoid overheating (see *HEMFHS-TP-06-Infiltration and ventilation assumptions* on the window opening logic and *HEM-TP-04 Space heating and cooling demand* for how this is handled in the core calculation).

Combining the two setpoint schedules into one

The user is required by the wrapper to input a floor area for the living room / primary living space and the heated rest-of-dwelling floor area. These areas are used to produce a single operative temperature setpoint schedule for the simulated thermal zone, based on a weighted mean average of the temperature desired in each area for each timestep.

Control types

There are currently two broad control types⁴ defined in FHS wrapper:

⁴ These correspond to control types 2 and 3 in SAP 10.2 Table 4e.

- Separate temperature control (e.g. room thermostat in one room and TRVs in others, but all rooms follow a single time schedule).
- Separate time and temperature control (independent heating schedules and target temperatures for the living and non-living areas)

Both control types ultimately produce a single setpoint temperature for each timestep, calculated as an area weighted mean:

$$T_{zone}(t) = \frac{A_{LA} \times T_{LA\ setpnt}(t) + A_{ROD} \times T_{ROD\ setpnt}(t)}{A_{LA} + A_{ROD}} \quad (1)$$

Where:

A_{LA} is the area of the living room area

A_{ROD} is the area of the rest of dwelling area

$T_{LA\ setpnt}(t)$ is the setpoint temperature of the living area at timestep t

$T_{ROD\ setpnt}(t)$ is the setpoint temperature of the rest of dwelling area at timestep t

This approach aligns with ISO 52016-1:2017 Section 6.4.2.6, which permits weighted mean values for the adjacent condition zones where setpoints are within 4 Kelvin of each other, and ISO 52000-1:2017 (Clause 10. ISO 52000-1:2017 Annex B Table B.29), which recommends useful floor area weighted for combined thermal conditions.

Separate temperature control

In this mode, both areas follow the same time schedule. When the heating is “on,” the living room target is 21 °C and the rest of dwelling is 20 °C. The weighted mean formula above is applied to calculate the overall zone setpoint. During periods when heating is “off,” the schedule records None, but the control object enforces a minimum setback of 18 °C.

Separate Time and Temperature Control

This mode has distinct weekday schedule for both areas (see Table 1), and a 2-hour advanced start is applied to each, allowing pre-heating before occupancy. The advanced start shifts “on” periods earlier by 2-hours for each area independently. At each timestep, the wrapper calculates an overall setpoint combining the living room setpoint, rest of dwelling setpoint and setback temperature, as applicable, using Equation 1. On weekends, there is a single heating window (see Table 1) without advanced start or separate schedules.

During periods where neither the living room nor rest of dwelling is occupied, the setpoint is not set and the setback temperature of 18 °C is enforced.

The 2-hour advanced start duration was determined based on modelling conducted on dwellings with medium thermal mass that met the notional specification with heat pumps and emitters sized using guidance from EN 12831-1. Because the method used to size the systems does not account for air pressure test results or MVHR performance, heat losses were

assessed conservatively, and under these assumptions the system required 2 hours to warm the dwellings to set point temperature.

3. Heating systems and pipework

Convective fraction of electric heaters

For instantaneous direct electric heaters, the FHS wrapper uses a heating type provided by the user to look up the convective fraction based on EN15316-2 Table B.17. Table 2 below lists the available options:

Convective type	Convective fraction
Air heating (convectors, fan coils etc.)	0.95
Free heating surface (radiators, radiant panels etc.)	0.70
Floor heating, low temperature radiant tube heaters, luminous heaters, wood stoves	0.50
Wall heating, radiant ceiling panels, accumulation stoves	0.35
Ceiling heating, radiant ceiling electric heating	0.20

Table 2 – Convective type to convective fraction based on EN15316-2 Table B.17

Charging hours for storage heaters and heat batteries

Storage heaters and heat batteries follow a standardised charging schedule, with a 7-hour overnight off-peak charging period set as 00:00 – 07:00 for both weekdays and weekends, to align with the off-peak periods in Economy 7 tariffs. See *HEM-TP-13 Modelling electric storage heaters and dry core heat batteries* for further details on how this schedule is used.

Space heating distribution pipework lengths

For wet heating systems, the FHS wrapper does not require user-specified pipework inputs. Instead, it estimates the pipework lengths from the dwelling dimensions according to the methodology in BS 15316-3 Annex B.

BS 15316-3 Annex B2.2 defines different pipework length formulas depending on shaft placement and system configuration. The “Shafts inside the building with a two-pipe system” option was chosen, as this represents a common modern layout as reflected in most new homes.

The standards describe, in a typical domestic property, the pipework within a space heating system consists of three major sections:

1. Section V Mains/ Base collector – distribution pipes running horizontally through floors or ceiling voids, supplying heating circuits from the heat source or manifold.
2. Section S Risers/ Vertical shafts – vertical pipes within shafts connecting mains to individual levels.
3. Section A Laterals – short horizontal branches from risers to radiators or underfloor circuits.

The wrapper calculation generates two pipework sections, one for Section V large mains (22mm diameter) and one for small circuits (15mm diameter) composed of the sum of Section S vertical shafts and Section A laterals. The diameters chosen are industry 'default' sizes for space heating distribution pipework and are referenced in the Domestic Heating Design Guide.

Large mains circuit (Section V)

$$L_{mains} = 2L_{dwelling} + 0.0325A_{dwelling} + 6m$$

Where:

$L_{dwelling}$ is length of the dwelling

$A_{dwelling}$ is the floor area of the dwelling

0.0325 m/m² is the standard allowance per floor area for manifold take-offs and routing

6m is the service allowance for connection spurs and access risers

Small circuits (Section S and Section A)

$$L_{small} = \underbrace{0.025V_{shaft}}_{risers} + \underbrace{0.55A_{floor} \times N_{storeys}}_{laterals}$$

Where

V_{shaft} is the volume of the dwelling ($A_{dwelling}$ multiplied by habitable height).

$N_{storeys}$ is the number of storeys

0.025 m/m³ is the pipe per volume of shaft, averaging out typical vertical layouts.

0.55 m/m² is the extra return run needed in two-pipe loops versus a single loop in one-pipe systems.

Other pipework assumptions

The pipework sections created are all assumed to be internal to the heated space. No insulation has been assumed since the pipework is within the thermal envelope and is only hot when heat is required from the space heating system.

4. Input simplifications for solar absorption and areal heat capacity

Exterior opaque surfaces are assigned a solar absorption coefficient based on colour class based on EN 52016-1 Table B.15 as shown in Table 3 below. For opaque elements with a pitch greater than 120° or pitch less than 60°, the wrapper defaults to “Intermediate”. These pitch ranges correspond to surfaces that are close to horizontal or downward facing, where the solar incidence is highly uncertain. Using the “Intermediate” class avoids overestimating or underestimating solar gains.

Colour class	Fraction of sunlight absorbed
Light	0.3
Intermediate	0.6
Dark	0.9

Table 3 – Colour class to fraction of sunlight absorbed based on EN 52016-1 Table B.15

Each wall, floor or ceiling is assigned an aerial heat class by the user, which is converted to numeric areal heat capacity as shown in Table below based on EN 52016-1 Table B.14.

Areal heat class	Areal heat value (J / m ² .K)
Very light	50000
Light	75000
Medium	110000
Heavy	175000
Very heavy	250000

Table 4 – Areal heat class to Areal heat value based on EN 52016-1 Table B.14

Future development

The current implementation allows two predefined control types – separate temperature control and separate time and temperature control. However, it does not model the physical presence of thermostats or TRVs. Further developments may incorporate logic to adjust setpoints more dynamically based on user input.

Assumptions on setpoints and heating/cooling periods, setback temperatures, advanced start may be revised as new evidence or guidance becomes available.

At present, a fixed setback is applied for heating but not cooling. Adding a cooling set back could improve representation of occupant behaviour.

The space heating pipework model currently applies Case 2 from BS EN 15316-3 (“shafts inside the building with a two-pipe system”) as representative of typical new-build configurations. Further developments may explore alternative configurations, such as external shafts, one-pipe systems using methodology provided in BS EN 15316-3.

