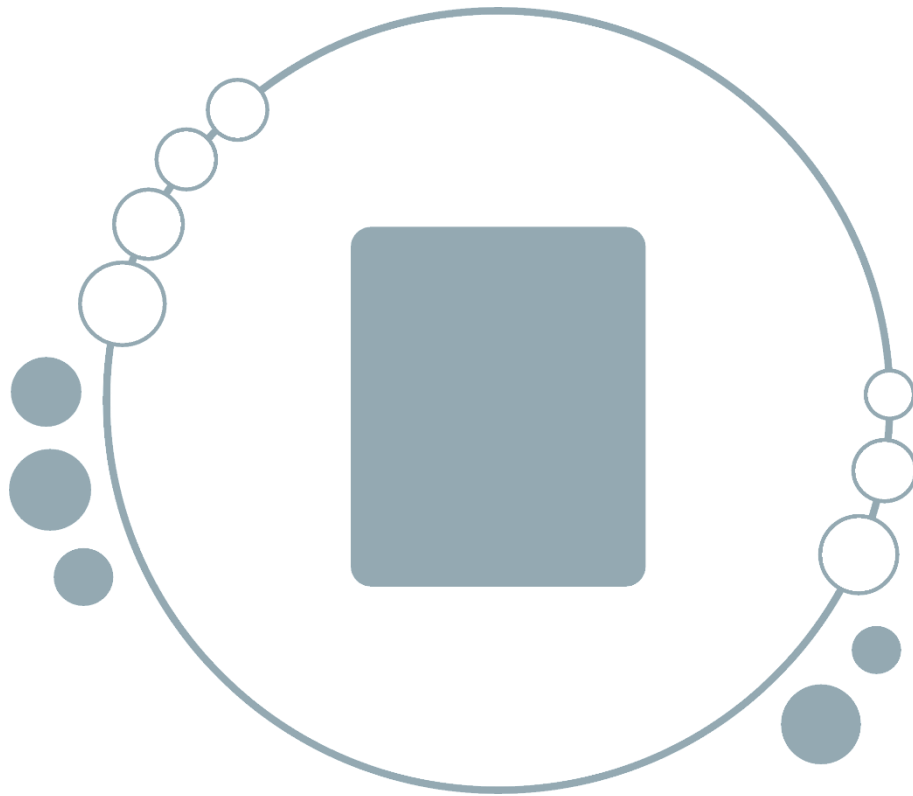




Modelling Ventilation and Infiltration within the Home Energy Model: FHS assessment

A technical explanation of the methodology

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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

For more information on the core ventilation methodology, see *HEM-TP-06 Ventilation and Infiltration*.

For more information on how the ventilation and infiltration heat loss is accounted for in the space heating and cooling demand calculations, see *HEM-TP-04 Space heating and cooling demand*.

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

In the Future Homes Standard repository:

`src/future_homes_standard/future_homes_standard.py`

`src/future_homes_standard/FHS_part_f_ventilation.py`

In the Home Energy Model core repository:

`src/hem_core/space_heating_demand/ventilation.py`

`src/hem_core/space_heating_demand/zone.py`

Methodology

1. Overview

The Future Homes Standard assessment wrapper specifies inputs and outputs for the Home Energy Model, for the use of the model in assessing whether a new home complies with the requirements of the future Part L of the Building Regulations. Among the inputs are standardised inputs relating to ventilation and infiltration.

The FHS wrapper contains logic to specify window opening behaviours, vent opening behaviours, and intermittent extract fan control schedules. It also performs some non-exhaustive checks against Part F ventilation requirements, to help ensure optimisations for Part L do not lead to violations of Part F.

2. Controlling Passive/Background Vent Opening and Closing

Use of half hourly weather data entails periods of time where wind speed is particularly high. These weather events lead to an increase in air change rates modelled by HEM as they drive higher rates of air mass flow through infiltration (leaks) and vents. The HEM core engine contains control parameters for the opening and closing of vents, with the following control parameters:

- An initial vent opening position value between 0 and 1, where 0 means the vents are fully closed and 1 means the vents are fully open, at the beginning of the simulation.
- A schedule containing minimum target air change rates below which vents will start to open.
- A schedule containing maximum target air change rates above which vents will start to close.

Vents open (and close) to the extent needed to maintain the minimum (maximum) air change rate. The FHS wrapper defaults the initial opening position of the vents to 1. For more information on how the core vent opening logic functions, see section 3. *Ventilation – Vents* in *HEM-TP-06 Infiltration and Ventilation*.

In the FHS wrapper, for each half-hourly timestep, both the minimum and maximum target air change rates are set to 10 air changes per hour. This permits relatively high rates of air flow without occupants adjusting the vents but ensures that dwellings highly reliant on natural ventilation will not benefit from unduly low heat losses at the expense of poor air quality and avoids unrealistic patterns of frequent manual adjustments.

The FHS wrapper assumes that cross-ventilation is possible in all dwellings (the core engine permits this to be disabled, but this is an experimental feature).

3. Controlling Window Opening and Closing

If no window opening is assumed, HEM predicts very high peak indoor temperatures during hot weather, under certain circumstances. Section 8. *Additional summer ventilation to avoid overheating* in *HEM-TP-04 Space heating and cooling demand* describes how HEM incorporates an additional algorithm to model the impact of window opening in response to high indoor temperatures.

HEM applies two control schedules to window opening:

- **Adjustability:** This is a schedule of window opening setpoints. If the value is NULL for a given timestep, this means that the windows are not adjustable, and the assumption is that windows are closed if not adjustable. This control schedule is defined on a whole-dwelling basis and represents when occupants are and are not present to adjust the window positions.
- **Openability:** This is a simple Boolean schedule which defines whether the window can be opened or must remain closed. This control schedule is defined separately for each window.

The FHS Wrapper assumes that windows are always adjustable, with a temperature setpoint of 22°C. This means that if the temperature rises above 22°C, the windows will open to an extent that brings the temperature back down to 22°C if they can, otherwise they will open to their maximum extent subject to conditions described in Section 8. *Additional summer ventilation to avoid overheating* in *HEM-TP-04 Space heating and cooling demand*.

The FHS wrapper also assumes that windows are openable at all times unless the assessor identifies a security risk¹ or noise nuisance², in which case the affected windows are not openable during sleeping hours, between 23:00 and 7:00 every day (these standardised hours are defined by Part O). Security risk is defined separately for each window and noise nuisance is defined on a whole-dwelling basis (so if there is noise nuisance then all windows will be closed at night).

For information on the core logic for window opening behaviour, see Section 8. *Additional summer ventilation to avoid overheating* in *HEM-TP-04 Space heating and cooling demand*.

4. Mechanical ventilation

HEM models the provision of controlled ventilation of the following types:

- Intermittent mechanical extract ventilation (Intermittent MEV / iMEV)
- Continuous centralised mechanical extract ventilation (Continuous cMEV)
- Continuous decentralised mechanical extract ventilation (Continuous dMEV)

¹ Defined in section 2 in *Approved Document Q*.

² Defined in section 1.7 in *Approved Document F Volume 1*

- Balanced mechanical ventilation with heat recovery (MVHR)

4.1 Part F compliance

While the FHS wrapper is not a mechanism for demonstrating Part F compliance, checks are carried out in the wrapper to determine whether the ventilation systems and associated vents entered meet certain requirements of Part F, specifically whether the total air flow rate meets or exceeds the minimum whole dwelling ventilation rate. For intermittent MEV, continuous cMEV and continuous dMEV, Part F also specifies a minimum background vent area against which the FHS wrapper compares the total background vent area. In the FHS wrapper, dwellings must fulfil the Part F compliance criteria specified below for the relevant mechanical ventilation system. If more than one system type is present in the dwelling, the wrapper will check that at least one of the systems passes the compliance criteria. If the dwelling does not pass the compliance criteria, the wrapper will output the relevant failed checks, and the simulation will not run.

4.1.1 Checking Part F compliance for iMEV systems

For iMEV systems, the minimum background vent area is calculated from Approved Document F Volume 1: Table 1.7³, summing the minimum equivalent areas of background ventilators required for the number of bathrooms, kitchens, and habitable rooms⁴ in the dwelling, dependent on the number of storeys in the dwelling. In the FHS wrapper, it is assumed that each dwelling has one kitchen. The total actual background vent area is calculated by summing the area of all specified background vents in the dwelling. The dwelling vent area is then deemed compliant if the total actual background vent area is greater than or equal to the minimum background vent area.

The minimum ventilation rate is calculated from Approved Document F Volume 1: Table 1.1, summing the minimum ventilation rate required for the number of bathrooms, utility rooms, sanitary accommodations⁵, and kitchens, and then converting from l/s to m³/hr. In the FHS wrapper, there is an input to state whether the kitchen has a cooker hood extracting to the outside, in order to select the relevant minimum ventilation rate for the kitchen from Table 1.1. The total design flow rate of the dwelling is calculated by summing the design outdoor air flow rate (m³/hr) across all iMEV units. The design flow rate is then deemed sufficient if the total design flow rate is greater than or equal to the minimum ventilation rate.

The FHS wrapper also carries out the following checks:

- If iMEVs are present in the dwelling, the number of iMEV units is greater than or equal to the number of wet rooms⁶ in the dwelling,

³ [Approved Document F: Volume 1 applies to dwellings](#)

⁴ A habitable room is any that is not used solely as a kitchen, bathroom, utility room, cellar, or WC.

⁵ Room types are defined as per Part F: a bathroom is any room that contains a bath or shower; a utility room is any that contains a sink or other feature or equipment that may reasonably be expected to produce significant quantities of water vapour; a sanitary accommodation is any space containing one or more flush toilets or urinals but not a bath or shower.

⁶ A wet room is classed as any room with a hot water tapping point; for example sink, bath or shower.

- That there is at least one iMEV with a flow rate of at least 30l/s (if there is a cooker hood extracting to the outside) or 60l/s (if not) to serve the kitchen as per the control schedule set out in section 4.2,
- That the number of background vents is at least 4, if the dwelling has fewer than 2 bedrooms, or 5 otherwise, in line with Part F Section 1.57.

4.1.2 Checking Part F compliance for MVHR systems

For MVHR systems, the minimum ventilation rate is calculated according to Approved Document F, Volume 1: section 1.24, setting the rate to 0.3 l/s per m² of total internal floor area or to (13l/s + 6l/s x [number of bedrooms]), whichever is larger, and converting to m³/hr. The total design flow rate of the dwelling is calculated by summing the design outdoor air flow rate (m³/hr) across all MVHR systems. The design flow rate is then deemed sufficient if the total design flow rate is greater than or equal to the minimum ventilation rate.

The FHS wrapper also checks that there are no background vents when there is an MVHR system, in line with Part F Section 1.72.

4.1.3 Checking Part F compliance for continuous dMEV and cMEV systems

For continuous dMEV and cMEV systems, the total design flow rate of the dwelling is checked in the same way as for MVHR systems described in section 4.1.2.

In addition, Approved Document F, Volume 1: section 1.64 specifies a minimum background vent area of 4000mm² for each habitable room in the dwelling. The FHS wrapper calculates the total actual background vent area by summing the area of all specified background vents in the dwelling. The dwelling vent area is then deemed compliant if the total actual background vent area is greater than or equal to the minimum background vent area multiplied by the number of habitable rooms. The FHS wrapper also checks that the number of background vents is at least the number of bedrooms in the dwelling plus two, as per Part F Section 1.64.

For dwellings with dMEV systems, the FHS wrapper also checks that the number of dMEV units is greater than or equal to the number of wet rooms in the dwelling.

4.2 Control schedules for intermittent extract fans

If present in the dwelling, intermittent extract fan control schedules are based on specific events like cooking, showering, or bathing. These event schedules control when the extract fans should be activated, ensuring that the fans run for a sufficient length of time when these activities occur. For more details of these event schedules, see HEMFHS-TP-04 for hot water events and HEMFHS-TP-05 for cooking events.

Section 2.1 of *HEM-TP-19 Appliance gains* explains how a time series is created from an event series. In short, appliance usage events are scheduled in continuous time, meaning they can start at any fractional time within a simulation timestep and may span multiple timesteps. To apportion demand, gains etc. from such a usage event to discrete time steps in the HEM simulation, the portion of demand that happens within each timestep is assigned to that timestep.

The FHS wrapper executes the following steps to produce a unique schedule for each intermittent fan, dependent on the type of event the fan is serving, specifying the fraction of each timestep during which each fan is running:

- Create a series of fan events corresponding to tapping events (shower, bath, other) and cooking events:
 - For shower events, set the start of the fan event to coincide with the start of the shower event and run until 15 minutes after the shower event has ended.
 - For bath events, set the start of the fan event to coincide with the start of the bath event, and run for 30 minutes or until the end of the bath event, whichever is longer.
 - For other tapping events, set the start of the fan event to coincide with the start of the tapping event and run until 5 minutes after the tapping event.
 - For cooking events, set the start of the fan event to coincide with the start of the cooking event and run until the end of the cooking event.
- For each fan event, assign a fan and convert to a Time Series – A Time Series is a schedule containing values between 0 and 1 for each timestep, determining run time in a timestep, e.g. a value of 0.5 means it will run for half of the timestep. Fans are assigned as follows:
 - The largest fan will be assigned to all cooking events.
 - The remaining fan(s) are assigned to tapping events (bath, shower, other). If there is more than one fan in this list, cycle through the fans sequentially so that each fan is used approximately equally.
- In the case of multiple events occurring at the same time, multiple fans will be triggered up to the maximum number of fans available i.e. if the fan events for a cooking and a shower event occur simultaneously then the largest fan will run and one other fan will also run. If a new event occurs while all fans are already running, then no additional fans will be triggered, as the dwelling will already be at its maximum ventilation rate.

Future development

Although Part F states that background (trickle) ventilators should be left open, evidence^{7 8 9} indicates that although householders say they are aware of trickle ventilators, their use of them is limited and, in most cases, the vents are left in the closed position. The evidence shows that householders prefer to open windows to provide the ventilation they require which they do periodically (e.g. once a day or a few times a week) to manage moisture, heat and improve

⁷ Ventilation and Indoor Air Quality in Part F 2006 Homes. Report BD502 for MHCLG (March 2010)

⁸ Ventilation and Indoor Air Quality in New Homes. Report for MHCLG (September 2019)

⁹ [Occupant Interactions and Effectiveness of Natural Ventilation Strategies in Contemporary New Housing in Scotland, UK](#)

indoor air quality. Evidence on the use of decentralised MEV systems in existing homes shows that the majority failed to have the extract fan flow rate and/or trickle vent area required by Part F, and in over half of cases the fans were not in continuous operation as they were only used intermittently by householders or even turned off altogether.

The assumptions on how occupants operate background ventilators and mechanical ventilators could be revised in future if better evidence is available.

