Modelling fabric heat loss within the Home Energy Model

A technical explanation of the methodology

Document reference: HEM-TP-05

Document version: v3.0

Issue date: January 2026

Home Energy Model version: HEM 1.0

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).

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

Heat loss through building fabric elements (e.g. walls, floors, roofs, windows) is one of the major components of heat loss from buildings. It is dependent on the thermal conductivity (or inversely, thermal resistance) and thickness of the materials used, the surface area of each fabric element, and the temperature difference between the internal and external environments.

This paper sets out the methodology for modelling fabric heat loss within the Home Energy Model core engine. For information on the specification of the Fabric Energy Efficiency metric within the FHS assessment wrapper, please see the [supplementary material to the Future Homes Standard consultation](#).

Related technical documents

Other relevant papers on the core engine include:

- HEM-TP-03 External conditions
- HEM-TP-04 Space heating and cooling
- HEM-TP-07 Thermal mass
- HEM-TP-08 Solar gains and shading
- HEM-TP-17 Controls

Code implementation

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

src/hem_core/space_heat_demand/building_element.py

src/hem_core/space_heat_demand/zone.py

Methodology

1. Overview

The calculation of fabric heat loss forms part of the core heat balance equations in the Home Energy Model (HEM) described in BS EN ISO 52016-1:2017 sections 6.5.6, 6.5.7 and 6.5.8 and summarised in HEM-TP-04 Space heating and cooling demand. In this, the temperatures of heat flow network nodes representing the internal air and the layers of building fabric elements (walls, floors etc.) are calculated at each timestep based on the heat capacity of each node, the thermal resistance between them and energy exchange with the internal and external environment (internal gains, solar gains etc.).

The boundary conditions at the external surface node of each element depend on whether the building element is adjacent to the ground, the outside air, a thermally conditioned space or a thermally unconditioned space.

The heat losses for each zone of the building are calculated independently (i.e. the zones are thermally uncoupled, as per Option C in BS EN ISO 52016-1:2017 section 6.4.6). At present zero heat is assumed to flow between different zones of the building.

2. Heat transfer between internal environment and building fabric elements

Surface heat transfer coefficients are taken from BS EN ISO 13789:2017, section 9.5, which gives separate heat transfer coefficients for convective and radiative heat transfer. The internal surface convective coefficient gives the rate of heat transfer between the internal air and the internal surface of each fabric element while the internal surface radiative coefficient gives the rate of heat transfer directly between the internal surfaces of different fabric elements. For convective transfer, the standard gives different coefficients depending on the direction of heat transfer (upwards, downwards, horizontal) and the calculation selects the appropriate one at each timestep, to account for the effect of convection at the internal surface of each building element. For example, when the floor is at a higher temperature than the internal air, this will drive convection currents in the internal air which lead to more rapid heat transfer from the floor to the air. Heat transfer is considered "horizontal" if it within 30 degrees of horizontal.

3. Heat transfer through building fabric elements

Building fabric elements are modelled as a series of connected nodes representing the internal and external surfaces and the layers between them (see HEM-TP-04 Space heating and cooling demand). All elements except for transparent elements are modelled as a series of five nodes. Each node has an associated heat capacity and each of the connections between the nodes has an associated heat transfer coefficient which is the reciprocal of the thermal resistance between them. The heat capacity and thermal resistance of each building element are assigned to the nodes and their connections as per BS EN ISO 52016-1:2017 section 6.5.7.

The heat losses through transparent elements have a slightly different treatment (described in BS EN ISO 52016-1:2017 section 6.5.7.4), based on a single thermal resistance between the internal and external surface nodes, rather than multiple layers. Transparent elements may also have curtains and/or blinds, which provide additional thermal resistance when closed, but have no effect when open, as per BS EN ISO 52016-1:2017 section 6.5.8.3. Details on the control logic used in HEM for opening and closing curtains and blinds can be found in [Annex B – Control logic for curtains and blinds](#).

4. Heat transfer between building fabric elements and external environment

The calculation of heat transfer with the external environment depends on whether the building element in question is adjacent to external (outside) air, adjacent zones (thermally conditioned or thermally unconditioned) or the ground. These cases are described in separate sub-sections below.

4.1 External air

For building elements exposed to the external air, external surface heat transfer coefficients are taken from BS EN ISO 13789:2017, section 9.5, which gives separate heat transfer coefficients for convective and radiative heat transfer. The external surface convective coefficient gives the rate of heat transfer between the external surface and the external air while the external surface radiative coefficient gives the rate of heat transfer between the external surface and the ground surface (assumed to be at the same temperature as the air) and between the external surface and the sky, which is assumed to be at a temperature 11°C lower than the external air (this value is from BS EN ISO 52016-1:2017 Table B.19 for intermediate climatic zone).

Solar absorption at the external surface of opaque fabric elements is taken into consideration by applying the solar absorption coefficient to the incident solar radiation, as per BS EN ISO 52016-1:2017 section 6.5.6.3.5. This requires the orientation, tilt and base height of each opaque element to be input. Solar energy absorbed at the external surface of a fabric element

will have the effect of reducing heat transfer through the fabric element by reducing the temperature difference between the internal and external surfaces.

The treatment of solar radiation entering the internal environment though transparent building elements is described in HEM-TP-08 Solar gains and shading.

4.2 Adjacent zones

BS EN ISO 52016-1:2017 section 6.5.6.3.6 offers adiabatic boundary conditions for elements adjacent to conditioned spaces (i.e. internal and party walls, floors and ceilings). That is, there is assumed to be no heat loss into the adjacent space. The U-value of the element is still required, to model the rate of heat flow into or out of the thermal mass of the fabric element.

However, there is evidence[1] of non-negligible heat loss in cavity party walls, associated with air movement within the cavity. The freer the circulation of air within a cavity, the greater the thermal bypass as air in the parts of the cavity adjacent to heated spaces can move to the parts of the cavity adjacent to the cold loft space or external environment. This effect is not accounted for in thermal bridging or infiltration calculations and must therefore be treated separately. This is a departure from the treatment in BS EN ISO 52016-1:2017.

There is some further potential for heat loss via air movement in the cavities of party ceilings/floors (especially if connecting to party wall cavities). This is not explicitly considered in HEM due to lack of evidence discriminating the effect. For the time being, it is assumed to be implicit within the values used for party walls, which are shown in Table 1.

Building fabric elements adjacent to a thermally unconditioned zone (e.g. an unheated corridor) are modelled by adding an additional thermal resistance to the external surface of the building element (see Annex A). This differs from BS EN ISO 52016-1:2017 (see sections 6.4.5 and 6.5.9), which requires more details about the thermally unconditioned zone (fabric heat transfer

---

[1] Lowe, R.J., Wingfield, J., Bell, M. and Bell, J.M. (2007). Evidence for heat losses via party wall cavities in masonry construction. Building Services Engineering Research and Technology, 28(2), pp. 161–181. DOI: https://doi.org/10.1177/0143624407077196

Wingfield, J., Bell, M., Miles-Shenton, D., South, T. and Lowe, R.J. (2007). Evaluating the Impact of an Enhanced Energy Performance Standard on Load-Bearing Masonry Domestic Construction – Final Report – Lessons from Stamford Brook: Understanding the Gap between Designed and Real Performance. Partners in Innovation Project CI 39/3/663. Leeds: Leeds Metropolitan University.

Wingfield, J., Miles-Shenton, D. and Bell, M. (2009). Evaluation of the Party Wall Thermal Bypass in Masonry Dwellings. Report to EURISOL. Leeds: Leeds Metropolitan University.

Palmer, J. and Terry, N. (2022). Looking critically at heat loss through party walls. Sustainability, 14(5), 3072. DOI: https://doi.org/10.3390/su14053072

Glew, D., Thomas, F., Miles-Shenton, D. and Parker, J. (2025). Quantifying inter-dwelling air exchanges during fan pressurisation tests. Buildings and Cities, 6(1), pp. 239–254. DOI: https://doi.org/10.5334/bc.557

CIBSE Guide A and SAP 10.2 table 3.10 include standard u-values for party wall heat loss, slightly different to those used in HEM.

coefficients, air change rate, solar and internal gains) which may be difficult to obtain in practice, for example if the adjacent thermally unconditioned zone is part of an adjacent building that is not in scope for the modelling work being carried out).

Table 1 – U-values representing heat loss from party wall cavities of different types (new build construction)

Cavity and seal	Wet plaster U-value	Dry lined finish U-value
Solid wall	0	0
Fully filled cavity with edge seal [2]	0	0
Fully filled cavity without edge seal [3]	0.2	0.2
Unfilled cavity with edge seal [4]	0.2	0.2
Unfilled cavity without edge seal	0.2 [5]	0.6 [6]

---

[2] Limited evidence from full cavity filling with mineral wool insulation:
•   EURISOL Bradford study: Full cavity filling eliminated the thermal bypass, reducing effective U-value to approximately 0 W/m²K (2 houses)
•   Glew et al. (2022): Two properties with insulated party walls had in-situ U-values <0.01 W/m²K
This provides a total sample of 4 dwellings. The evidence shows that full cavity filling largely eliminates convective heat loss and reduces conductive heat transfer to negligible levels.

[3] In HEM, both insulation of the cavity and edge sealing are required to achieve zero modelled heat loss from a party wall. The distinction has limited direct support from research as it is not consistently established in dwellings being tested, but may account for some of the observed variances, along with quality of installations.

[4] Testing of horizontal cavity socks (mineral wool barriers positioned at ceiling level) in modern construction:
•   Stamford Brook co-heating tests with cavity socks: 0.18 and 0.26 W/m²K (2 houses)
•   EURISOL Bradford study with cavity sock: approximately 0.2 W/m²K (2 houses)
This provides a total sample of 4 dwellings. The observed range is 0.18-0.26 W/m²K. The Stamford Brook report noted this represented "partial mitigation" of the thermal bypass, with the suggestion that full cavity filling in conjunction with edge sealing would be required for complete elimination.

[5] Glew et al. (2022) measured heat loss through uninsulated cavity party walls in 54 existing homes built between 1945 and 2010, involving 284 measurement sets:
•   Mean in-situ U-value: 0.21 W/m²K (95% confidence interval: 0.16-0.26 W/m²K)
•   Range: <0.05 W/m²K (6 properties) to 0.81 W/m²K (1 property)
•   More than 100-fold variation in measured spot U-values between different homes
The research attributed the substantially lower heat loss compared to modern construction to traditional wet plaster finishes applied directly to the masonry, which create a more airtight barrier than plasterboard on dabs.

[6] Research on modern dwellings (2000s construction – unfilled cavity with dry-lined finishes) provides the following measurements of effective party wall U-values:
•   Lowe and Bell (2007), Stamford Brook: approximately 0.6 W/m²K (2 houses)
•   Stamford Brook co-heating tests: 0.63 W/m²K and 0.50-0.64 W/m²K (6 attached dwellings)
•   Wingfield et al. (2009), EURISOL Bradford study: 0.6 W/m²K (2 houses)
This provides a total sample of 10 dwellings across two research sites, all new-build with plasterboard on dabs. The observed range is 0.5-0.64 W/m²K, with most measurements clustering around 0.6 W/m²K.

4.3 Ground

Heat loss from building fabric elements adjacent to the ground (typically floors) is treated somewhat differently to heat loss through other building fabric elements because there are significant three-dimensional effects. The procedure used is as described in BS EN ISO 52016-1:2017 section 6.5.7.3 and BS EN ISO 13370:2017 Annex F and Annex C.

The calculation uses an internal periodic heat transfer coefficient and an external periodic heat transfer coefficient when calculating the ground temperature for each month. These coefficients are calculated as per BS EN ISO 13370:2017 Annex H, which defines different calculations (with different input requirements) for five separate cases:

- Slab-on-ground floor uninsulated or with all-over insulation
- Slab-on-ground floor with edge insulation
- Suspended floor
- Heated basement
- Unheated basement

5. Steady-state heat transfer coefficient and heat loss parameter

The heat transfer coefficient (HTC) and heat loss parameter (HLP) give the rate of heat loss from the dwelling (including a component for total fabric heat loss) in steady-state conditions.

Although the HTC is not used in the main HEM calculation, a value for this is calculated to facilitate comparisons with SAP 10.2 and other tools. For consistency with SAP 10.2, a fixed additional thermal resistance for window covering (curtains/blinds etc.) is assumed for the HTC calculation. This assumes an additional thermal resistance of $0.04~(\mathrm{m^2K})/\mathrm{W}$, which is the based on the figure for blinds with high or very high air permeability taken from BS EN 13125:2001, section 5.3. The value used in the HTC calculation is half the value from the standard, as it is assumed that curtains/blinds are open for half the time over the course of a year.

The calculation of the HTC includes heat loss due to ventilation. This calculation assumes that the wind speed and direction are given by the corresponding averages from the input weather file[7]; that the external temperature is equal to the minimum of the daily average temperatures provided in the weather file (i.e. the coldest day's average temperature); and that the internal

---

[7] The average direction is given by taking a unit vector parallel to the sum of the wind vectors from each timestep.

air temperature is a user given input[8]. The temperatures are required for HEM's modelling of the ventilation stack effect.

The HLP is simply the HTC divided by the total floor area of the dwelling, so the same assumptions apply.

---

[8] This is set equal to the single zone's temperature in the FHS wrapper.

Future development

Future development of the fabric heat loss calculations could include the following (either as replacements for the existing calculation procedures or as additional options):

- Implementing the full calculation from BS EN ISO 52016-1:2017 for adjacent unconditioned zones.

- Adjusting external surface heat transfer coefficients to account for variations in wind speed and exposure.

- Representing layers of different materials explicitly in the heat flow network for each building fabric element instead of using the procedures in BS EN ISO 52016-1:2017 to divide the overall thermal resistance between a fixed number of nodes.

Annex A – Additional thermal resistance for elements adjacent to unheated space

Modelling elements adjacent to unheated space requires an additional input for the effective thermal resistance for the unheated space, denoted as R_u which can be calculated in the general case as described below.

R_u for typical unheated structures (including garages, access corridors to flats and rooms in roof) with typical U-values of their elements are also given in the relevant sections below (calculated using the formula from BS EN ISO 6946:2017, section 6.10.3). These can be used when the precise details on the structure providing an unheated space are not available, or not crucial.

General case

In most cases the effect of an unheated space will be small and can be disregarded. Where it needs to be accounted for a general formula for R_u (from BS EN ISO 6946:2017, section 6.10.3) is:

$$R_u = \frac{A_i}{\sum(A_e \times U_e) + 0.33nV} \tag{1}$$

A_i, A_e =   areas of internal and external elements (m²), excluding any ground floor

U_e =   U-values of external elements (W/m²K)

V   =   volume of unheated space (m³)

n   =   air change rate of unheated space (ach)

Typical values of the air change rate in unheated spaces are given in Table 7 from BS EN ISO 13789:2017. A default value of n = 3 ach should be used if the airtightness of the unheated space is not known.

Garages (integral)

The U-value of elements between the dwelling and an integral garage should be adjusted using R_u from Table 1 or Table 2. Attached garages (not integral) should be disregarded.

The following R_u values should be applied for typical configurations of single garages (3m × 6m), double garages (6m × 6m) or similar unheated spaces. If the garage is substantially different from the typical garages assumed, then the R_u value should be calculated using the procedure for the general case in the section above.

Table 2 – R_u for integral single garages (single garage is a garage for one car, assuming n = 3ach, U-value of internal walls = $0.3\ W/(m^2K)$, U-value of external walls = $1.6\ W/(m^2K)$)

Garage type		Elements between garage and dwelling	R_u for a single garage	
			Inside[1]	Outside[2]
Single fully integral		Side wall, end wall and floor	0.70	0.35
Single fully integral		One wall and floor	0.55	0.25
Single, partially integral, displaced forward		Side wall, end wall and floor	0.60	0.30

Table 3 – R_u for integral double garages (double garage is a garage for two cars, assuming n = 3ach, U-value of internal walls = $0.3\ W/(m^2K)$, U-value of external walls = $1.6\ W/(m^2K)$)

Garage type		Element between garage and dwelling	R_u for a double garage	
			Inside[1]	Outside[2]
Double garage fully integral		Side wall, end wall and floor	0.60	0.35
Double, half integral		Side wall, halves of the garage end wall and floor	0.35	0.25
Double, partially integral displaced forward		Part of the garage side wall, end wall and some floor	0.30	0.25

[1]inside garage – when the insulated envelope of the dwelling goes round the outside of the garage

[2]outside garage – when the walls separating the garage from the dwelling are the external walls

Stairwells and access corridors

Stairwells and access corridors are not regarded as parts of the dwelling. If they are heated the wall between stairwell or corridor and the dwelling is treated as party wall. If unheated, the U-value of walls between the dwelling and the unheated space should be modified by adding an additional thermal resistance.
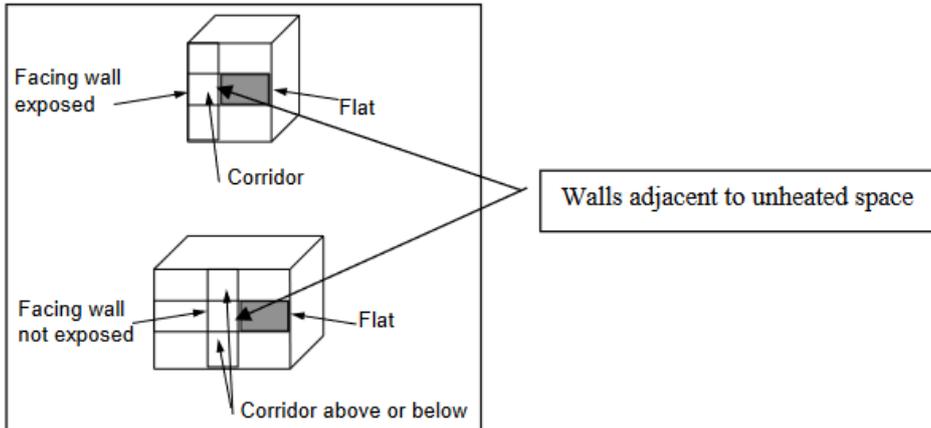
The following table gives recommended values of R_u for common configurations of access corridors and stairwells.

**Table 4 - R_u for common configurations of stairwells and access corridors.**

Elements between stairwell/corridor and dwelling	Heat loss from corridor through:	R_u
Stairwells:		
Facing wall exposed		2.1
Facing wall not exposed		2.5
Access corridors:		
Facing wall exposed, corridors above and below	facing wall, floor and ceiling	0.6
Facing wall exposed, corridor above or below	facing wall, floor or ceiling	0.5
Facing wall not exposed, corridor above and below	floor and ceiling	0.9
Facing wall not exposed, corridor above or below	floor or ceiling	0.7

The figures in Table 3 were derived using the following assumptions:

> n = 1 ach
> Storey height = 2.6 m
> Footprint (floor area)
>> Stairwells: 2.4 m by 10 m
>> Corridors: 3 m by 25 m
> Window area:
>> Corridors with facing wall exposed: 20% of exposed wall area
>> Corridors with facing wall not exposed: 15% of the end walls
> U-values:
>> Exposed wall = 0.3 W/(m²K)
>> Floor/roof = 0.25 W/(m²K)
>> Window = 2 W/(m²K)

Room in roof

In the case of room-in-roof construction where the insulation follows the shape of the room, use values of R_u from Table 4. The same applies to the ceiling of the room below.
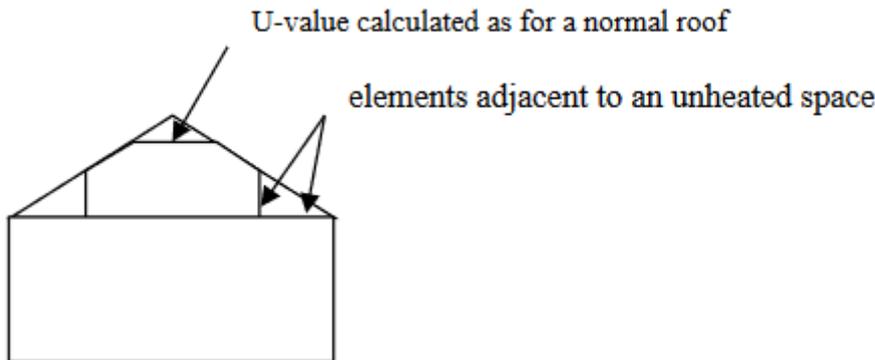
Table 5 - R_u for room in roof adjacent to unheated loft space

Area (figure 3.2)	Element between dwelling and unheated loft space	R_u
Room in roof built into a pitched roof insulated at ceiling level	insulated wall of room in roof	0.5
	or insulated ceiling of room below	0.5

If the insulation follows the slope of the roof, the U-value should be calculated in the plane of the slope.

Annex B – Control logic for curtains and blinds

The dynamic behaviour of curtains and blinds (window treatments) in the HEM core engine follows BS EN ISO 52016-1:2017 section G2.1. They are only ever represented in a fully closed or fully opened state - no intermediary states are modelled, and the opening or closing takes place once per timestep exactly at the start of the step. There may be multiple treatments on the same window, and they may be controlled either directly by a schedule or respond to sunlight.

Direct control

Window treatments may be opened and closed according to a schedule specified in an OnOffTimeControl object (see HEM-TP-17) where a value of True means that the window treatment is open, and False means that the window treatment is closed.

Responsive control

If no direct controls are supplied, curtains and blinds may instead respond to incident solar radiation on the window. This is achieved with a pair of SetpointTimeControl objects (see HEM-TP-17) – one which holds a threshold irradiance which if exceeded will close the treatment if it is open, and the other holds a threshold irradiance below which the treatment will be opened if it is closed. Due to being defined by SetpointTimeControl objects, both threshold values may vary over time if desired.

Additionally, an opening delay may be supplied which will prevent a treatment from being reopened until the specified time has elapsed since it was closed, regardless of the surface irradiance dropping below the second threshold. This requires one of the "automatic" control types to be specified, as suggested in BS EN ISO 52016-1:2017 Table B.24.