Modelling fabric heat loss within the Home Energy Model

A technical explanation of the methodology

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Acknowledgements

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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

Heat loss through building fabric elements (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

Code implementation

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

src/core/space_heating_demand/building_elements.py

src/core/space_heating_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 ground, outside air, thermally conditioned space or 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 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.

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. 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. In the main calculation, no additional thermal resistance for window covering (curtains/blinds etc) is assumed.

4. Heat transfer between building fabric elements and external environment

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 (figure 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

Building fabric elements adjacent to a thermally conditioned zone (e.g. another dwelling) are assumed to have zero heat loss, taking the 'adiabatic boundary conditions' option in the standard. The U-value is still an input, however, to model the rate of heat flow into or out of the thermal mass of the fabric element; the adiabatic boundary condition is applied in the model itself.

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 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 assessment).

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 should be calculated as per BS EN ISO 13370:2017 Annex H (at present HEM takes the results of the Annex H calculations as inputs) but for the consultation version of the software these have been set to zero. This means that when calculating the ground temperature, the consultation version of the calculation will not fully account for monthly variation in the ground temperature (i.e. the boundary condition for the model); the effect of this is relatively small.

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

The heat transfer coefficient and heat loss parameter give the rate of heat loss from the dwelling (including a component for total fabric heat loss) in steady-state conditions. Although the heat transfer coefficient (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, an 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 figure for blinds with high or very high air permeability taken from BS EN 13125:2001, section 5.3, halved as it is assumed that curtains/blinds are open for half the time over the course of a year.

The heat loss parameter (HLP) is simply the HTC divided by the total floor area of the dwelling, so the same assumptions apply.

Future development

Future development may include the following (either as replacements for the existing calculation procedures or additional options):

- Calculating periodic heat transfer coefficients for the ground floor within the HEM so that calculations from BS EN ISO 13370:2017 Annex H do not have to be done separately.
- Implementing the full calculation from BS EN ISO 52016-1:2017 for adjacent unconditioned zones.
- Accounting for window coverings (curtains/blinds) in the main calculation and not just the HTC/HLP calculation.
- 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:

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

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.

Apply the following R_u values 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 1 – 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 = $1.6\ W/(m^2K)$)

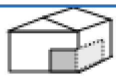
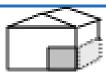
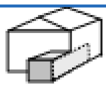
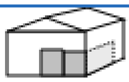
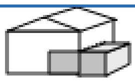
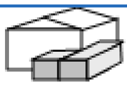
Garage type		Elements between garage and dwelling	R_u for a single garage	
			Inside[1]	*Outside*[2]
Single fully integral		Side wall, end wall and floor	0.70	0.35
Single fully integral		One wall and floor	0.55	0.25
Single, partially integral, displaced forward		Side wall, end wall and floor	0.60	0.30

Table 2 - 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 = $1.6\ W/(m^2K)$)

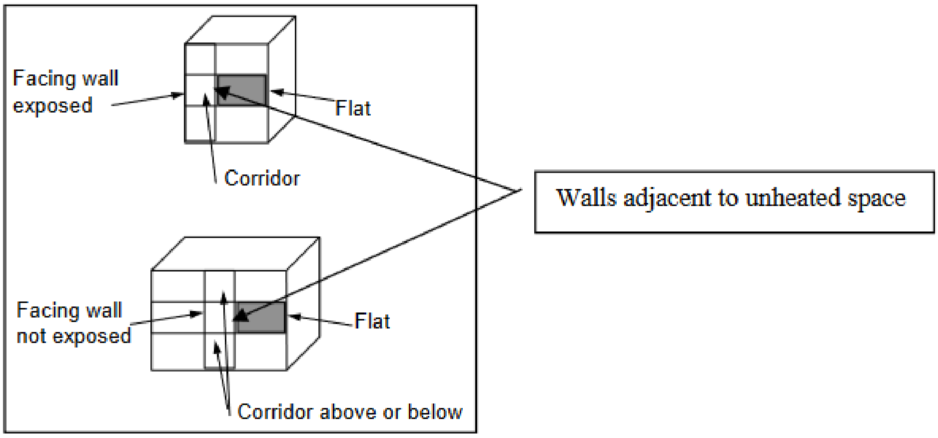
Garage type		Element between garage and dwelling	R_u for a double garage	
			Inside[1]	Outside[2]
Double garage fully integral		Side wall, end wall and floor	0.60	0.35
Double, half integral		Side wall, halves of the garage end wall and floor	0.35	0.25
Double, partially integral displaced forward		Part 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 3 - 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 = $0.3\ \mathrm{W/(m^2K)}$
- Floor/roof = $0.25\ \mathrm{W/(m^2K)}$
- Window = $2\ \mathrm{W/(m^2K)}$

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.

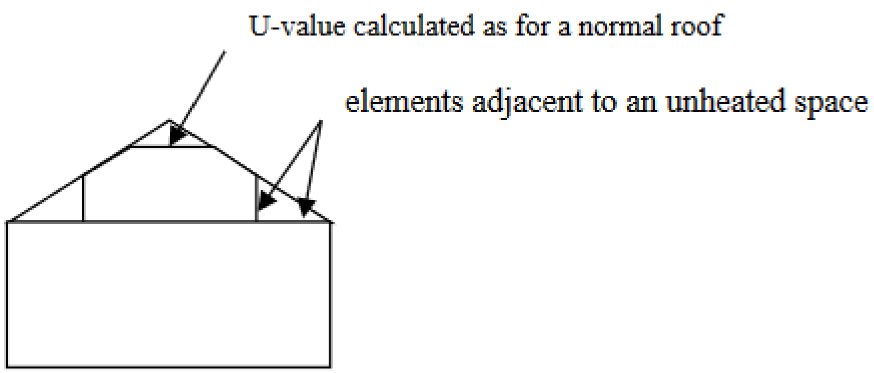


Table 4 - R_u for room in roof adjacent to unheated loft space

Area (figure 3.2)	Element between dwelling and unheated loft space	R_u
	insulated wall of room in roof	0.5

Room in roof built into a pitched roof insulated at ceiling level	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.

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