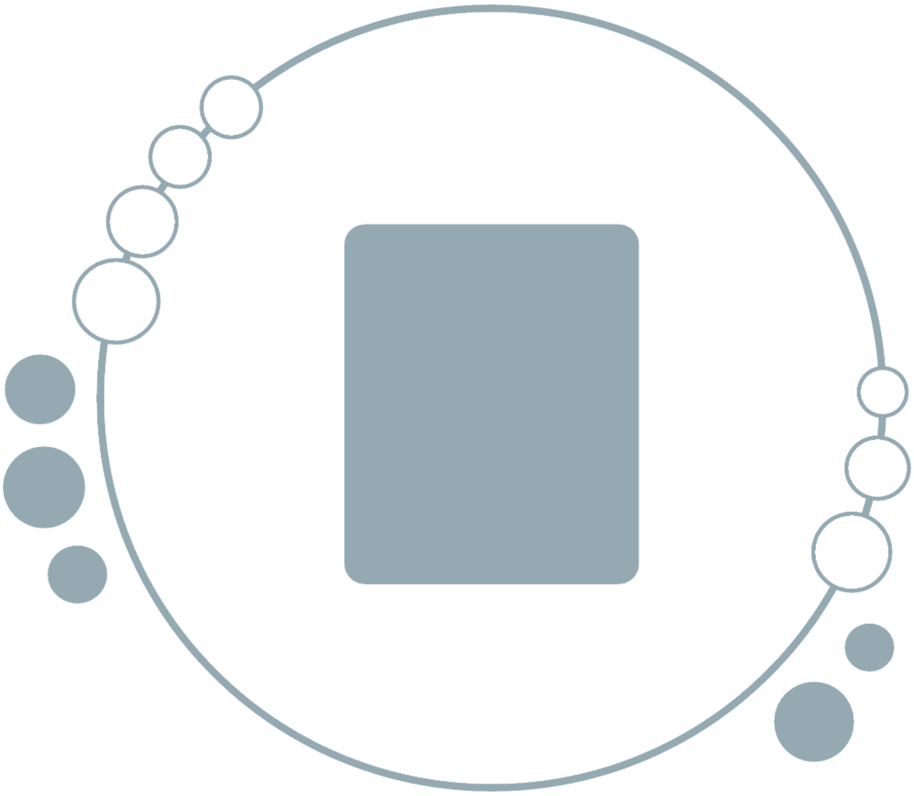

Calculating ductwork and pipework heat losses within the Home Energy Model

A technical explanation of the methodology

October 2025

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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).

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 paper sets out the methodology for heat losses affecting pipework and ductwork within the Home Energy Model core engine.

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

src/hem_core/pipework.py

src/hem_core/ductwork.py

1. Methodology

A home will usually have some kind of pipework and may also have some ductwork. Pipes may carry domestic hot water, cold water, or a heating fluid (e.g. water or a mixture of water and glycol), and the pipe may be at a different temperature to its surroundings. Similarly, ductwork may carry warm or cold air which may be at a different temperature to its surroundings. Where such temperature differences occur, there will also be heat transfer, causing heat gains and losses.

1.1 Sources used to develop methodology

- CIBSE Guide C Reference data, Section 3 Heat Transfer.
- CIBSE Guide B2 Ventilation and ductwork, Section 2.3.5.4 Airflow in ducts.
- BS 5422:2009 Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40 °C to +700 °C.
- BS EN ISO 12241:2022 Thermal insulation for building equipment and industrial installations. Calculation rules.

1.2 Key assumptions made in the absence of sources

For calculation of the internal heat transfer coefficient in pipes, the following is assumed. Water flow rate is assumed to be 0.2 m/s which is the lowest velocity stated in CIBSE Guide C, Table 3.32. Pipe diameter is assumed to be 20 mm. Hot water temperature is assumed to be 50°C. The associated convective film heat transfer coefficient from Table 3.32 was selected based on these values for water flow rate, pipe diameter and water temperature, and this is set as the default for the Home Energy Model.

For calculation of the internal heat transfer coefficient in ducts, the following is assumed. CIBSE Guide B, 2.3.5.4, ‘Airflow in ducts’ states the recommended maximum velocity for domestic air ducts is 3 m/s. This value is used to determine the internal surface heat transfer co-efficient of the duct, and this is set as the default for the Home Energy Model. Note that air duct velocities in use may be lower than 3 m/s, which means the internal surface heat transfer may be lower for some ventilation systems.

Pipes are assumed to be cylindrical while ducts may have either a circular or rectangular cross-section. For rectangular ducts, the perimeter is entered instead of the diameter.

For hot water distribution pipework, at present it is assumed all stranded heat is lost from the pipework within one timestep.

1.3 Data inputs

1.3.1 Ductwork

The following data inputs are required to calculate the heat loss from ductwork:

- duct type (intake, supply, extract or exhaust)
- duct cross-section shape (circular or rectangular)
- internal diameter of the duct, in metres, if the duct cross-section is circular
- external diameter of the duct, in metres, if the duct cross-section is circular
- duct perimeter, in metres, if the duct cross-section is rectangular
- length of duct/pipe, in metres
- thermal conductivity of the insulation, in W / m·K
- thickness of the insulation, in metres (converted from user input in millimetres)
- whether the surface is reflective or not (Boolean input)

In addition, the location of the Mechanical Ventilation with Heat Recovery (MVHR) unit and its heat recovery efficiency are also required, but these are properties of the MVHR system rather than the ductwork.

1.3.2 Pipework

The following types of pipework can be represented in the Home Energy Model:

- Primary pipework (between heat source and hot water or thermal storage)
- Hot water distribution pipework (pipework carrying hot water to tapping points)

Space heating distribution pipework, that delivers hot water to the emitters, is modelled in the emitters module and documented in HEM-TP-16 Heat emitters.

The following data inputs are required to calculate the heat loss from both types of pipework:

- location, whether inside or outside
- internal diameter of the pipe, in metres
- length of pipe, in metres

The following additional data inputs are required to calculate the heat loss from primary pipework:

- external diameter of the pipe, in metres
- thermal conductivity of the insulation, in W / m·K
- thickness of the insulation, in metres (converted from user input in millimetres)

- whether the surface is reflective or not (Boolean input)
- whether the pipe is carrying water or "glycol25" (a mixture of 25% glycol and 75% water)

The total hot water distribution pipework length should be calculated as the sum of all lengths of pipework from the hot water source to a tapping point (i.e. tap, bath or shower), hence if a pipe is shared for multiple tapping points the length of shared pipe should be duplicated and added for each tapping point.

1.4 Calculation methodology

1.4.1 Calculation of surface resistances

The linear exterior surface resistance of a pipe or duct, $R_{l,se}$, is calculated as:

$$R_{l,se} = \frac{1}{h_{se} \cdot duct\ or\ pipe\ circumference\ including\ insulation} \tag{1}$$

where h_{se} is the exterior surface heat transfer co-efficient.

The same calculation is used for the interior surface resistance $R_{l,si}$, substituting the interior heat transfer co-efficient h_{si} for h_{se} , and using the internal circumference. The interior surface heat transfer coefficient is used for calculating the interior surface resistance, and the exterior surface heat transfer coefficient is used for calculating the exterior surface resistance. See Annex A for values of the surface heat transfer coefficients. This calculation is taken from BS 12241:2022, 4.1.4 'External surface resistance'.

Default values of the internal and external heat transfer coefficients are not included in BS 12241:2022. However, these values are available in CIBSE Guide C, and so have been selected for use in the calculations of surface resistances of pipes and ducts in the Home Energy Model. There are two possible values for the external surface resistance, depending on whether the insulation has a reflective surface or not, and two possible values for the internal surface resistance, depending on whether it is a duct (containing air) or a pipe (containing water or a water/glycol mix[1]).

1.4.2 Calculation of thermal resistance of cylindrical insulation

The insulation around a duct or a pipe is assumed to be in the shape of a hollow cylinder. The linear thermal resistance, R_l, of a hollow cylinder of insulation is calculated as:

[1] In the absence of a specific figure, HEM uses the same value for a water/glycol mix as for water. Given that the value in this case is relatively high (meaning little resistance to heat flow between the fluid and the inside surface of the pipe) this is unlikely to make a significant difference.

$$R_l = \frac{\ln \frac{D_e}{D_i}}{2\pi\lambda} \tag{2}$$

Where D_e is the outer diameter of the insulation and D_i is the inner diameter of the insulation, both in metres, and λ is the thermal conductivity of the insulation.

1.4.3 Calculation of linear thermal transmittance

The linear thermal transmittance is the heat loss per metre of duct/pipe length, in units of W/m. It is calculated from the reciprocal of the sum of component linear thermal transmittances:

$$U_l = \left(R_{l,si} + R_l + R_{l,se}\right)^{-1} \tag{3}$$

Where:

$R_{l,si}$ is the interior linear surface resistance

R_l is the insulation linear thermal resistance

$R_{l,se}$ is the exterior linear surface resistance

1.4.4 Calculation of energy loss during flow through duct/pipe

Note: this is ignored for distribution pipework, as the duration of flow through the pipe is generally short enough that the energy loss during flow is negligible compared to the energy loss due to stranded heat (see section 1.4.5 Calculation of energy loss due to stranded heat in pipework).

The heat loss rate of a duct or pipe is:

$$\Phi_l = U_l \cdot L \cdot (T_i - T_a) \tag{4}$$

Where Φ_l is the heat loss rate in watts, U_l is the linear thermal transmittance, L is the length of duct or pipe, T_i is the temperature inside the duct or pipe, and T_a is the ambient room temperature (for pipework/ductwork inside the thermal envelope) or the external air temperature (for pipework/ductwork outside the thermal envelope). (From BS 12241:2022, 4.1.6 ‘Heat flow rate’)

The instantaneous heat loss rate is then multiplied by the duration over which there is flow through the ductwork/pipework in each timestep to calculate the energy loss.

1.4.5 Calculation of energy loss due to stranded heat in pipework

Note: this is not relevant for ductwork, as it is assumed that MVHR systems run continuously.

Where pipework is in use intermittently, there will be stranded heat remaining after the flow through the pipe has ceased. This can be very significant in some cases (e.g. where small draw-offs are made from domestic hot water outlets), so the amount of stranded energy is also calculated and included in the pipework loss total for each time step. Stranded heat for each draw-off is calculated using the energetic content of the remaining hot water in the entire run of the pipework, using the difference between the hot water temperature and the average internal air temperature. Stranded heat is allocated to the timestep in which the water draw-off occurs. At present it is assumed all stranded heat is lost from the pipework. It may be possible to refine this in future.

1.4.6 Internal heat gains

Losses from pipework that is inside the conditioned part of the dwelling are assumed to contribute to internal heat gains.

Heat transfer between external air and supply and extract ducts, and heat transfer between internal air and intake and exhaust ducts, is added/subtracted from internal heat gains.

2. Verification of methodology

BS 5422:2009 Table 13 lists indicative thickness of insulation to control heat loss for ductwork carrying warm air, assuming a horizontal duct at 35°C, with a 600 mm vertical sidewall in still air at 15 °C. These values were calculated by the standards authors according to BS EN ISO 12241:1998.

To verify that the Home Energy Model methodology follows BS EN ISO 12241:2022, the results from Home Energy Model ductwork calculations for cylindrical ducts were compared to BS 5422:2009 Table 13 and were found to be in agreement[2]. Note that it was not an exact comparison because it compared rectangular ducts to the cylindrical duct as used in the Home Energy Model. The unit tests for the module are based on this verification exercise.

[2] Although BS 5422:2009 and HEM are based on different versions of BS EN ISO 12241 (1998 and 2022 versions respectively), the equation for cylindrical insulation is the same in both versions, so the results can still be compared.

3. Validation of methodology

The calculation methodology in BS 12241:2022 is very widely used, and it is assumed that other applications of the methodology have validated it in a generic sense. However, there remains a possibility that are aspects of pipework and ductwork heat losses that are not fully considered when it is applied to modelling home energy consumption. For this reason, it may be worth considering empirical validation of the heat losses in a laboratory setting, with an experimental design that replicates ducts or pipes in a dwelling. Another option is the use of computational fluid dynamics modelling for an intermodel comparison.

4. Limitations

Ducts and pipes also have fixings where they are fixed to a surface. Often these fixings cause thermal bridges and therefore there will be additional heat losses. Thermal bridges may also occur due to gaps in insulation. Thermal bridging is not currently modelled.

Sometimes pipework is embedded into walls, and heat transfer then occurs directly to the surrounding material. This is not currently modelled, and heat losses may differ in this situation.

For stranded heat in pipework, it is assumed that all heat is lost between hot water usage events. Hot water usage may be over-estimated if the occupant does not fully draw-off all the stranded water, and the occupant later makes use of the stranded water before it cools off fully.

Where the duct or pipe is enclosed, for example between floor and ceiling, or is boxed in, the ambient temperature around the pipe may be higher than the room temperature. This may result in overestimation of heat losses.

The mean temperature of the heating water in primary pipework may be lower than the flow temperature from the heat source, since the return temperature is lower than the flow temperature. The mean temperature is not currently calculated, and the flow temperature is used instead.

Secondary circulation pipework is not modelled (hot water pumped in a loop to reduce time waiting for hot water from taps).

The Part L regulations currently state that space heating pipes in voids should be insulated. Currently this is not modelled, and such pipework is instead considered to be part of the heat emitter system, with all heat losses being utilised as space heating. There is also a lack of evidence about the effect of pipework losses in voids such as an intermediate floor, and how this may affect heat loss into each zone.

5. Future development

The following may result in improved calculations:

- Modelling of thermal bridging
- Modelling of embedded pipes
- Modelling of re-used stranded hot water
- Calculation of mean water temperatures in primary pipework
- Modelling the insulation effect of boxed-in pipework

The following are additional features that may cover some types of pipework not currently modelled:

- Secondary circulation pipework, including energy used in the circulation pump
- Space heating flow and return pipework where they pass through a void such as an intermediate floor

There is another BS EN standard which handles pipework energy performance in buildings. This is BS EN 15316-3:2017. *Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies. Part 3: Space distribution systems (DHW, heating and cooling).* This standard could be used as a reference to improve the modelling of pipework in the Home Energy Model. The accuracy of heat loss predictions could be validated by either laboratory testing or the use of computational fluid dynamics modelling.

Other references which may be useful for further development include the following:

- The *NHBC Standards Chapter 8.1 Internal services, Pipe Insulation requirements for space heating and hot water systems in new dwellings*, TECHNICAL GUIDANCE 8.1/35 provide more detail about how the pipework insulation requirements are applied to new homes.
- BPEC (British Plumbing Employers Council) provide a free textbook online for the BPEC Level 2 Diploma in Plumbing Foundation. This contains details and diagrams of hot water plumbing systems and can help to ensure that realistic plumbing systems are modelled in the Home Energy Model. See Section 7 – F/602/2884 Understand and apply domestic hot water system installation and maintenance techniques

Annex A – Surface heat transfer coefficients

Surface heat transfer coefficient for type of surface	**W / m2 K**
h_{se} Exterior surface of duct or pipe: high emissivity non-reflective surface (convective and radiative combined) From CIBSE Guide C, Table 3.25	10
h_{se} Exterior surface of duct or pipe: low emissivity reflective surface (convective and radiative combined) From CIBSE Guide C, Table 3.25	5.7
h_{si} Inner surface of air duct, at air flow velocity of approximately 3 m/s (This includes the convective fraction only, since there is no radiative heat transfer to the outer surface. Therefore, this takes the value for a low-emissivity outside surface as an equivalent for convective only internal surface) From CIBSE Guide C, Table 3.25. Note that CIBSE Guide B, 2.3.5.4, 'Airflow in ducts' states the recommended maximum velocity for domestic air ducts is 3 m/s	15.5
h_{si} Inner surface of pipe, at water flow of approximately 0.2 m/s, and water temperature of 50°C From CIBSE Guide C, Table 3.32	1500

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