

# Calculating space heating and cooling demand within the Home Energy Model

A technical explanation of the methodology

## Acknowledgements

This methodology has been developed for the Department for Energy Security & Net Zero by a number of organisations and individuals, including Sustenic, Qidos, Scene Connect, City Science, Hoare Lea, Oxford Brookes University, University of Bath, 10-x, Building Research Establishment (BRE), AECOM, Kiwa Ltd., Loughborough University Enterprises Limited, Chris Martin and John Tebbit.

Quality assurance has been undertaken by a consortium led by Etude, including Levitt Bernstein, People Powered Retrofit, University of Strathclyde's Energy Systems Research Unit, Julie Godefroy Sustainability, and UCL.

**Document reference:** HEM-TP-04

**Document version:** v2.0

**Issue date:** January 2026

**Home Energy Model version:** HEM 1.0



© Crown copyright 2026

This publication is licensed under the terms of the Open Government Licence v3.0 except where otherwise stated. To view this licence, visit [nationalarchives.gov.uk/doc/open-government-licence/version/3](https://nationalarchives.gov.uk/doc/open-government-licence/version/3) or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or email: [psi@nationalarchives.gsi.gov.uk](mailto:psi@nationalarchives.gsi.gov.uk).

Where we have identified any third-party copyright information you will need to obtain permission from the copyright holders concerned.

Any enquiries regarding this publication should be sent to us at: [homeenergymodel@energysecurity.gov.uk](mailto:homeenergymodel@energysecurity.gov.uk)

---

# Contents

Background to the Home Energy Model	4
What is the Home Energy Model?	4
Where can I find more information?	4
Related content	5
Related technical documents	5
Code implementation	5
Methodology	7
1. Overview	7
2. Zone heat balance	7
3. Internal gains	9
4. Thermal bridging	10
5. Heating and cooling demand	10
6. Response of heating/cooling systems	11
7. Unmet demand	12
8. Additional summer ventilation to avoid overheating	12
8.1 Maximum cooling potential from additional ventilation	12
8.2 Required additional ventilation	12
Future development	14
Annex A – Initialisation of node temperatures	15

# 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

## Related technical documents

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. This is dependent on many factors including fabric heat loss, ventilation and infiltration heat loss, thermal mass, etc. Details of how these factors are modelled are covered in the following papers:

- HEM-TP-01 General summary of core calculation
- HEM-TP-03 External conditions
- HEM-TP-05 Fabric heat loss
- HEM-TP-06 Ventilation and infiltration
- HEM-TP-07 Thermal mass
- HEM-TP-08 Solar gains and shading
- HEM-TP-17 Controls

The core HEM can be used with a variety of heating and cooling periods and temperature settings and this document relates only to the way the core HEM uses these parameters, which may come from user inputs or from wrappers. For further information on space heating and cooling demand assumptions made within the FHS assessment wrapper, please see:

- HEMFHS-TP-01 FHS occupancy assumptions (for metabolic gains)
- HEMFHS-TP-02 FHS space heating and cooling assumptions
- HEMFHS-TP-04 FHS appliances assumptions (for gains from appliances, cooking and lighting)

## Code implementation

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

*src/hem\_core/project.py (for interaction with ventilation model, response of the heating/cooling systems and recording of unmet demand)*

*src/hem\_core/space\_heat\_demand/internal\_gains.py*

*src/hem\_core/space\_heat\_demand/thermal\_bridge.py*

*src/hem\_core/space\_heat\_demand/zone.py*

# Methodology

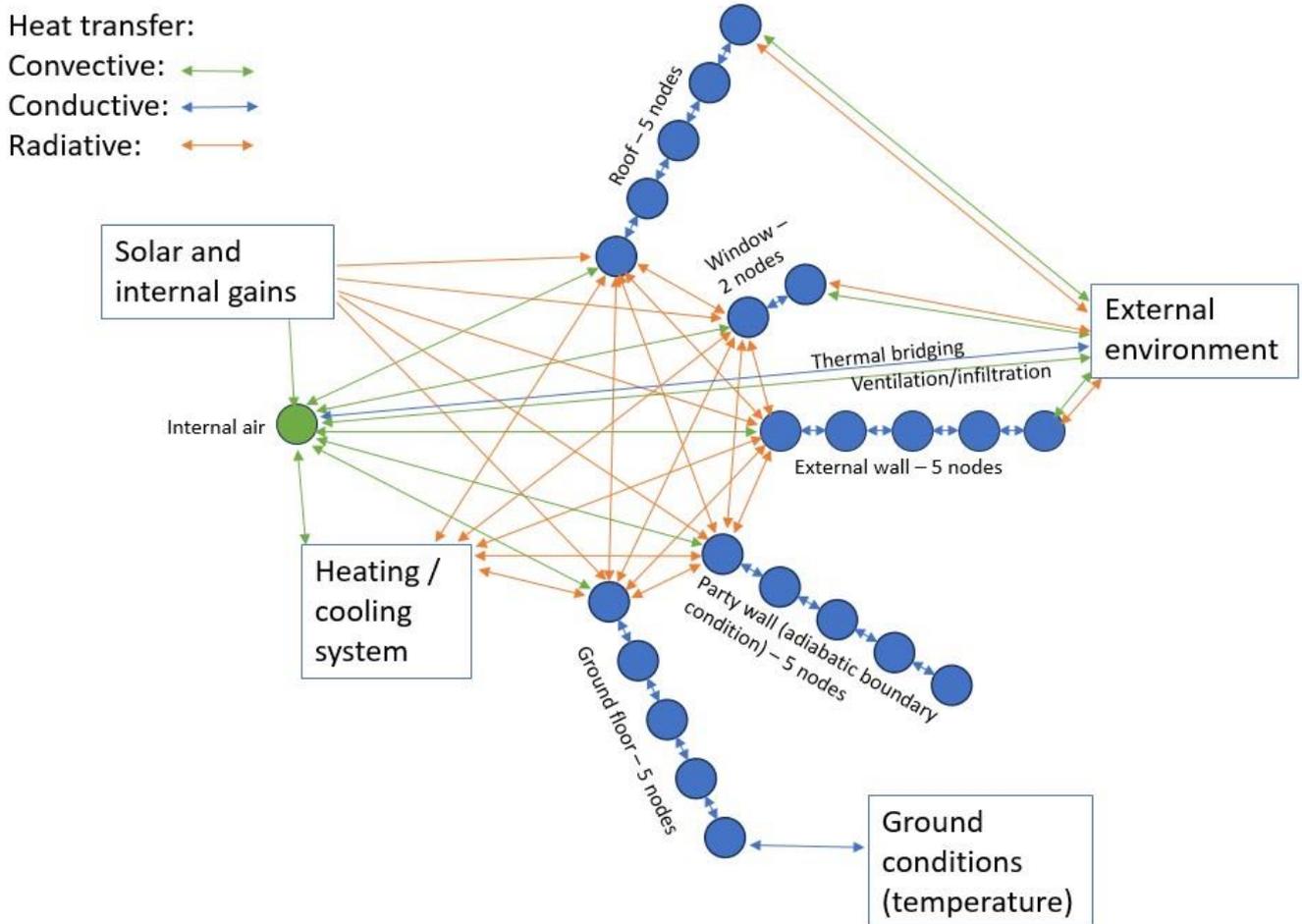
## 1. Overview

This calculation is based on BS EN ISO 52016-1:2017, which defines procedures for calculating internal temperatures and space heating and cooling demand. The calculation of unmet demand (described in section 7) is additional to the procedures in the standard but follows naturally. The calculation of the additional summer ventilation requirement to avoid overheating (described in section 8) is also additional but follows the same principles as the space cooling demand calculation from the standard.

## 2. Zone heat balance

The heat losses and solar gains 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. This may be an area for future development (see Future development section).

Each zone in the building is represented by a heat flow network (see Figure 1) consisting of one node representing the internal air linked to nodes representing the internal surfaces of the building elements, which are themselves linked to each other to account for radiative heat transfer between them. The internal surface nodes are also linked to nodes representing other layers of each building element: each transparent building element is represented by two nodes (for the internal and external surfaces) and each of the other building elements is represented by five nodes, as specified in BS EN ISO 52016-1:2017 section 6.5.6.3.1. Each node has an associated heat capacity and each of the connections between the nodes has an associated heat transfer coefficient. 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. For more details of how the properties of the different nodes and boundary conditions are assigned, see HEM-TP-05 and HEM-TP-07.



**Figure 1 – Example of a heat flow network for a zone containing one roof, one window, one external wall, one party wall and one ground floor.**

The core heat balance equations for each node are based on BS EN ISO 52016-1:2017 section 6.5.6, which are solved simultaneously at each timestep to calculate the temperature of each node at that timestep. The temperatures of the internal air and internal surfaces of each zone of the building are then used to calculate the operative temperature (defined as the average of the internal air temperature and the area-weighted mean radiant temperature of internal surfaces) in each zone, upon which the space heating/cooling demand is based. The inputs to the heat balance equations are:

- Final node temperatures from the calculation at the previous timestep – see [Annex A](#) for how these are initialised before the first timestep.
- Heat capacity of each node – see HEM-TP-07 Thermal mass.
- Heat transfer coefficient between each pair of connected nodes and at the external boundary of the dwelling – see HEM-TP-05 Fabric heat loss.
- Ventilation heat transfer coefficient (based on air change rate and temperature of supply air) – see HEM-TP-06 Ventilation and infiltration.
- Thermal bridging heat transfer coefficient (sum over all thermal bridges) – see [section 4](#).

- Internal gains, made up of:
  - Gains profiles (e.g., for metabolic gains and gains from appliances, cooking and lighting) specified in inputs (or set in a wrapper) – see [section 3](#).
  - Gains from hot water distribution, storage and primary pipework – see HEM-TP-11 Hot water storage tanks and HEM-TP-10 Ductwork and pipework losses.
  - Gains from ventilation fans – see HEM-TP-06 Ventilation and infiltration.
  - Gains from space heating buffer tanks – see HEM-TP-12 Heat pump methodology
  - Gains from heat interface units (HIUs) – this is a flat rate (in kWh per day) taken from the input parameters for the HIU and divided between all timesteps equally
  - Gains from on-site electricity generation – see HEM-TP-18 Solar PV generation and self-consumption
- Solar gains – see HEM-TP-08 Solar gains and shading.
- Heating/cooling system output – see [section 5](#) and [section 6](#).
- Boundary conditions at external surfaces (e.g., for an external wall: external air temperature, solar radiation absorbed) – see HEM-TP-03 External conditions and HEM-TP-05 Fabric heat loss.

### 3. Internal gains

Internal gains profiles can be specified by the user and/or by a wrapper. There are two broad types of gains profile: “internal gains” and “appliance gains”, the latter of which can include, for example, profiles for lighting, cooking and other appliances. An “internal gains” profile simply specifies the internal gains to be used in the calculation at each timestep, whereas an “appliance gains” profile specifies energy consumption at each timestep and a “gains fraction” which is the proportion of the energy consumption that is treated as recoverable system thermal losses<sup>1</sup> and becomes internal heat gains.

In addition to user-input internal gains, the core model also calculates internal gains from systems within the building, such as ventilation fans; losses from hot water and space heating pipework; and heat battery standing losses.

The gains from each source are summed at each timestep and the sum becomes an input to the heat balance equations. Internal gains are summed for the whole dwelling and are assumed to be divided between zones in proportion to their floor area.

---

<sup>1</sup> As defined in ISO:52000-1:2017 section 3.3.9.

## 4. Thermal bridging

There are two broad types of thermal bridge in the model: linear thermal bridges and point thermal bridges. For each linear thermal bridge, the linear thermal transmittance ( $\Psi$ -value) and length are entered by the user. The heat transfer coefficient for the linear thermal bridge is then calculated by multiplying these together. For each point thermal bridge, the heat transfer coefficient is entered directly. The heat transfer coefficients for each thermal bridge are summed to an overall thermal bridging heat transfer coefficient which is then entered into the heat balance equations.

## 5. Heating and cooling demand

Note: The model calculates heating/cooling demand for one heating or cooling system at a time. For a description of how the model handles the interaction between different heating and cooling systems in the same zone, see HEM-TP-01 General summary of core calculation.

To calculate the space heating and cooling demand, the heat balance equations are first solved for the case where no active heating or cooling is being provided by the systems currently being considered (output from other systems that has already been calculated may also be accounted for and is treated in the same way as internal and solar gains). Then, the resulting “free” operative temperature achieved is compared to the target heating and cooling (setpoint/setback) temperature(s) for the timestep and heating and cooling systems currently being considered. Note that cooling setpoints must always be higher than heating setpoints for the same timestep.

If the comparison indicates that the operative temperature would be below the heating setpoint in the absence of heating being provided, then there is space heating demand. To calculate this, the heat balance equations are solved again, this time assuming a heating system output of 10 kW per m<sup>2</sup> floor area (this is an arbitrarily high figure used to set up an interpolation). The calculation then linearly interpolates between the operative temperatures achieved at these two points (i.e., for heating system outputs of 0 and 10 kW per m<sup>2</sup> floor area) to find the heating system output required to meet the desired operative temperature. This figure is the space heating demand for the timestep.

The calculation for cooling demand is similar to the calculation of space heating demand, but with an additional step. This additional step checks to see if the cooling could be provided by opening windows rather than with the use of an active cooling system (this calculation is described in section 8 and may use a setpoint which is lower than the active cooling setpoint). If, after checking for the impact of window opening, the comparison indicates that the operative temperature would be above the active cooling setpoint in the absence of active cooling being provided, then there is space cooling demand. In this case, the heat balance equations are solved again assuming a cooling system capacity of 10 kW per m<sup>2</sup> floor area (again, this is an arbitrarily high figure used to set up an interpolation). The calculation then linearly interpolates

between the operative temperatures achieved at these two points (i.e., for cooling system outputs of 0 and 10 kW per m<sup>2</sup> floor area) to find the cooling system output required to meet the desired operative temperature. This figure is the space cooling demand for the timestep.

If the comparison of the “free” operative temperature with the setpoints indicates that no heating or cooling is required, then the space heating and cooling demand on the systems being considered is zero.

## 6. Response of heating/cooling systems

Note: For a full description of how the model handles the interaction between different heating and cooling systems in the same zone, see HEM-TP-01 General summary of core calculation.

The calculated space heating demand for a heating system becomes an input to the heating system calculation, which will calculate the output of the system, based on this demand figure and the minimum and maximum output the system is capable of providing. The temperature of each node at the end of the timestep is calculated by solving the heat balance equations again using the calculated heating system output for all heating systems combined. This means that where some of the demand on a heating system was unmet, a lower operative temperature than the specified setpoint temperature for that system may be calculated (depending on the control settings and response of other heating systems). The final node temperatures achieved then become the starting temperatures in the next timestep.

Similarly, when demand is for space cooling rather than space heating, the space cooling demand for a cooling system becomes an input to the cooling system calculation, which will calculate the output of the system, based on this demand figure and the minimum and maximum output the system is capable of providing. The temperature of each node at the end of the timestep is calculated by solving the heat balance equations again using the calculated cooling system output for all cooling systems combined. This means that where some of the demand on a cooling system was unmet, a higher temperature than the specified setpoint temperature for that system may be calculated (depending on the control settings and response of other cooling systems). The final node temperatures achieved then become the starting temperatures in the next timestep.

Note that some heating/cooling systems may have several components (e.g., electric heat pumps may have a built-in backup heater, which helps to meet the demand when the heat pump itself has insufficient capacity), but the existence of and interaction between such components is internal to the heating/cooling system calculation and does not affect how the space heating and cooling demand calculation interacts with those systems.

## 7. Unmet demand

Once all heating/cooling systems have been considered, the unmet demand is calculated. For the purposes of the unmet demand calculation, the demand is based on the setpoint and convective fraction of the highest-priority heating/cooling system that is in its required heating/cooling period (and not just a setback or advanced start period). The Project object feeds these parameters into the relevant Zone objects which calculate new figures for the required space heating/cooling demand. The Project object calculates the unmet demand by summing the heating/cooling provided by each system and then subtracting this from the required space heating/cooling demand calculated in this step (if the result of this calculation is less than zero, then unmet demand is set to zero).

## 8. Additional summer ventilation to avoid overheating

If no window opening is assumed, HEM calculates very high indoor temperatures during the summer under certain circumstances. In practice, occupants will take action (e.g. opening windows) to increase ventilation to disperse excess heat and so reduce the risk/extent of overheating<sup>2</sup>. To address this, the HEM incorporates an additional algorithm to model the impact of such window opening.

### 8.1 Maximum cooling potential from additional ventilation

To calculate the maximum cooling potential, first the maximum air change rate is calculated on a whole-dwelling basis, by running the ventilation calculation with the assumption that all windows are fully open and that vent positions are those determined in the baseline ventilation calculation for the timestep (see HEM-TP-06 Ventilation and infiltration). The heat balance solver for each zone can then be run (if additional ventilation is required – see section 8.2) using this maximum air change rate to determine the temperatures that would result from the maximum additional ventilation, which can be used to calculate whether additional ventilation is sufficient to avoid overheating.

### 8.2 Required additional ventilation

The following steps are taken to evaluate the additional ventilation via window opening in the cooling demand calculations:

#### 1. Compare Free-Floating Operative Temperature with the Window Opening Setpoint

- Check whether the "free-floating" operative temperature exceeds the window opening setpoint.

---

<sup>2</sup> The infiltration rate is likely to fall under these conditions because wind speeds will generally be low. The HEM calculation of infiltration should reflect this as it is tailored to the hourly wind speed.

- If it does, additional ventilation through window opening may be needed to maintain the temperature below the active cooling setpoint.

### 2. Determine the Cooling Potential of Window Opening

- Evaluate whether sufficient cooling can be provided by opening windows to keep the operative temperature below the active cooling setpoint.
- Note: A lower window-opening setpoint (compared to the active cooling setpoint) can be set. In such cases, windows may open even if the operative temperature does not exceed the active cooling setpoint.

### 3. Calculate the Required Additional Ventilation

- Compute the level of additional ventilation required to maintain the temperature at the window opening setpoint.
- Use a method similar to the calculation of active cooling demand.

### 4. Simulate Maximum Additional Ventilation

- Calculate the resulting ventilation rate and operative temperatures under the condition of maximum window opening (ratio of window opening = 1).

### 5. Interpolate for Required Ventilation

- Perform an interpolation to determine the amount of additional ventilation required to achieve the desired cooling effect.

### 6. Determine Final Ventilation Rate

- Compare the required additional ventilation with the maximum possible ventilation.
- Use the lower of the two values to proceed with further calculations.

### 7. Evaluate the Cooling Effect of Window Opening

- Check whether the additional ventilation (from window opening) is sufficient to keep the operative temperature below the active cooling setpoint:
- If sufficient:
  - Use the node temperatures calculated with the window opening as the final node temperatures for the timestep.
- If insufficient:
  - Assume that windows remain shut to retain actively cooled air within the dwelling.
  - No additional ventilation is applied for cooling purposes.

# Future development

Modelling of inter-zone heat transfer, via either a fully coupled or simplified calculation, may be added in the future. The calculation could also be changed so that internal gains are entered per-zone rather than for the whole dwelling.

Other potential changes are likely to be made to the individual components that feed into the space heating and cooling demand calculation and are covered in the relevant documents on each component.

## Annex A – Initialisation of node temperatures

The calculation described in this document depends on the final node temperatures from the calculation at the previous timestep, which are not available for the first timestep. Therefore, in order to initialise the node temperatures for the first timestep, the calculation requires an additional input for the desired starting operative temperature for each zone. Initially, the node temperatures are all set to the average of the starting operative temperature and the external air temperature for the first timestep. Then, the space heating/cooling demand is calculated (using the same external air temperature data for the first timestep) and the node temperatures are recalculated assuming that the required space heating/cooling demand can be provided in full. This process is then repeated until there are two consecutive iterations where all the node temperatures are the same (to within a relative tolerance of  $10^{-8}$ ). Each iteration uses a timestep of one year (but without varying the external conditions) as this requires fewer iterations to converge on a solution and gives the same initial temperatures (to approximately five significant figures) as using an hourly or half-hourly timestep.

