Solar gains and shading within the Home Energy Model

A technical explanation of the methodology

October 2025

Acknowledgements

This methodology has been developed for the Department for Energy Security & Net Zero by a number of organisations and individuals, including Sustenic, Quidos, 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-08

Document version: v2.0

Issue date: October 2025

Home Energy Model version: HEM 1.0

Any enquiries regarding this publication should be sent to us at: homeenergymodel@energysecurity.gov.uk

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 accounting for solar gains and shading within the Home Energy Model core engine.

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

src/hem_core/external_conditions.py

src/hem_core/space_heat_demand/building_element.py

src/hem_core/space_heat_demand/zone.py

Methodology

1. Solar irradiance

The method described in BS EN ISO 52010-1:2017 is used to calculate the diffuse and direct irradiance on each surface of the dwelling.

2. Heat transmitted through opaque elements

The direct irradiance incident on an opaque surface may be reduced by a shading factor from distant objects (e.g. neighbouring buildings) calculated as described in section 4.

The amount of heat transmitted through opaque surfaces is taken into consideration using a solar absorption coefficient assigned to each external element, following the procedure described in BS EN ISO 52016-1:2017 section 6.5.6.

3. Solar gains through transparent elements

In the case of transparent elements, direct and diffuse solar irradiance may be reduced due to:

- distant shading objects (e.g. neighbouring buildings), as described in section 4
- nearby shading objects (e.g. balconies, overhangs, fins, reveals) as described in section 5.

The amount of heat gain from solar energy incident on transparent surfaces is taken into consideration via an input g-value, following the procedure described in BS EN ISO 52016-1:2017.

- The solar energy transmittance of non-scattering glazing for radiation perpendicular to the glazing (g-value) shall be calculated in accordance with ISO 9050.
- In practice, the total energy transmittance varies with respect to the angle of incidence of the solar radiation. To account for this, a fixed correction factor F_w (given in BS EN ISO 52016-1:2017 Annex B Table B.22) is applied to the g-value, as per BS EN ISO 52016-1:2017 equation E.3.

For elements equipped with curtains and/or blinds, the solar gains are further reduced by multiplying the incident radiation by a transmission reduction factor for each curtain or blind attached to the element which is closed. Curtains and blinds may only be fully opened or fully closed, and there is no reduction in transmission for an open curtain or blind. The transmission reduction factor is a user input for each curtain or blind, and details of the operation of curtains and blinds are provided in HEM-TP-05.

Solar gains are calculated for individual transparent elements but then summed per zone for use in the core heat demand calculation.

The total solar gains are apportioned to the air node and to internal surfaces via convective and radiative fractions as given in BS EN ISO 52016-1:2017 Table B.11. PD CEN ISO/TR 52016-2:2017 section B.5 provides justifications for the choice of convective/radiative fractions.

4. Shading from distant objects

Shading from distant objects (e.g. neighbouring buildings) applies to both opaque and transparent elements, as well as photovoltaics. The geometrical information required for each shaded element is its height and the distance between the ground and the lowest edge of the element (base height).

4.1 Representation of distant shading objects

Distant shading objects are represented as follows: the ground plane is split into segments, and shading objects surrounding the building are assigned to the relevant segments and described by their height and distance from the dwelling. They are represented as infinite shading elements, therefore there is no depth to the shading element. Each shading segment is evaluated independently to determine its impact on each individual building element.

Two categories of distant shading objects are considered:

- Obstacles are modelled as ground-attached objects with a specified height above the ground (H_{obst}) and distance from the building (L_{obst}).
- Overhangs are treated as suspended objects with no sky view above, characterized by a bottom boundary height (H_{ovh}) and distance from the building (L_{ovh}).

The distance to the remote object is defined in the model input as a single effective distance from the building and would typically be based on the distance from the centre of the building as shown in Figure 1. The shading segment angles are also defined as a series of inputs based on the same building datum point and can be any input angle, including fractional. The number of segments is not fixed and the segments may be of different sizes.

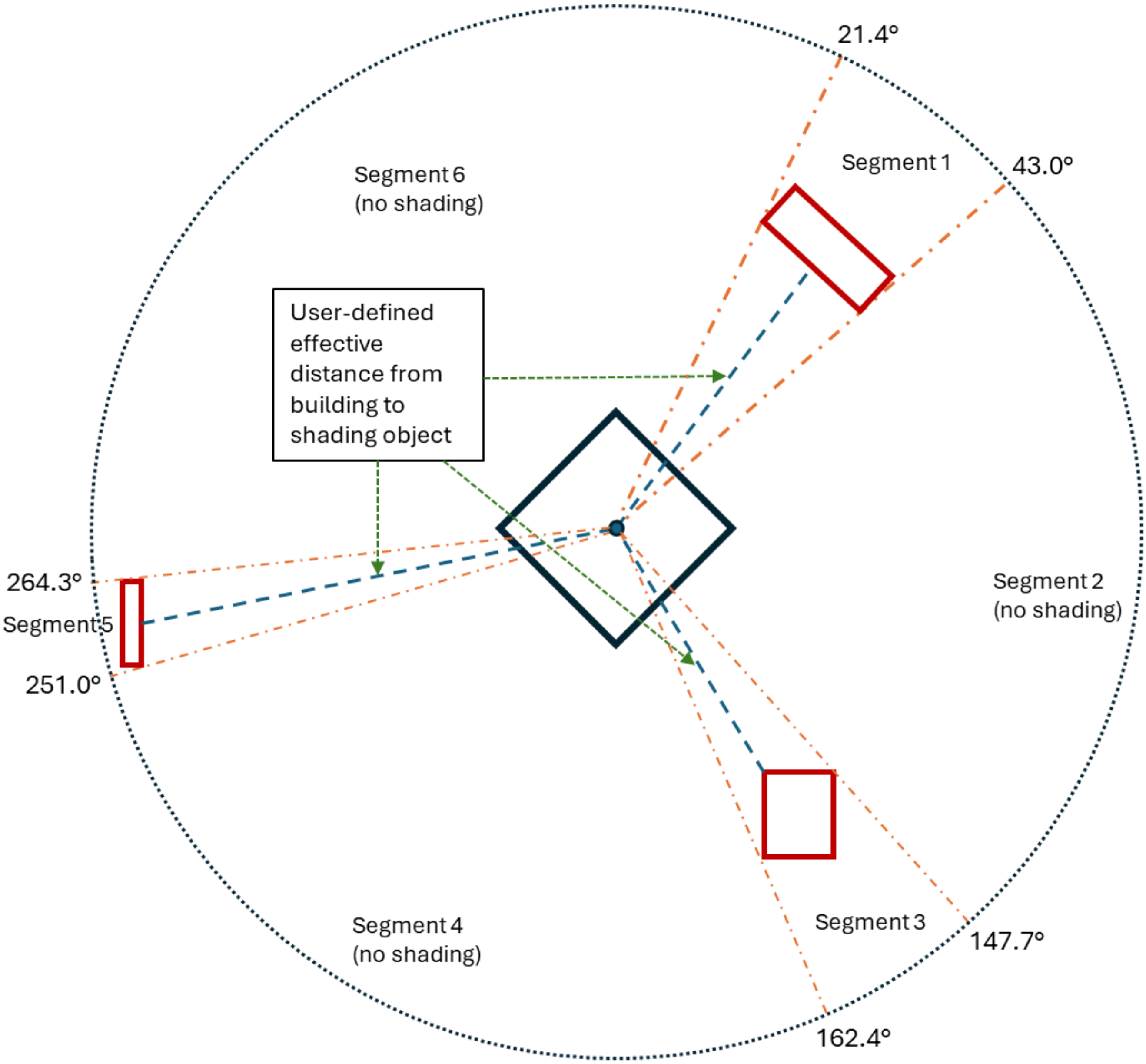

Figure 1 – Shading segments and user-defined effective distance to shading objects.

The model evaluates the impact of shading individually for each element/façade. The user-defined effective distance is used without further manipulation to define the distance to the remote object (L_{obst} or L_{ovh}) for each building element. However, the shading calculation assumes this distance is relative to the individual element position not the centre point. This is a simplification as defining an adjusted distance for each element would either require the distances to be defined individually or a complex assessment of the building layout. It is also assumed that in most cases the object distance will be significantly larger than the building dimensions and that it will be an estimated distance, and therefore any error associated with this simplification will not be significant.

The overall building-defined shading segments are also used individually for each element/façade without manipulation. As shown in Figure 2, the shading segment angles are modelled from the centre of the element, which will incur a slight error when using the angles defined from the centre of the building. However, this error should again be small where the distance to the object is significantly larger than the building dimensions.

The shading segments definition assumes they are relative to a nominal horizontal centre point location for building orientations and that any remote shading is applied equally horizontally for each element across the segment arc. The method does not, therefore, consider the relative horizontal position of any building elements, such as windows, which are located within another element and are not the full width of this parent element. The shading that is applied to these partial width elements is solely based on their vertical attributes as for full width elements. This assumption significantly reduces the input data and modelling complexity, and the error should be small based on the assumption that, for the majority of remote objects, the object distance is significantly greater than any centre-point offset dimension for partial width elements.

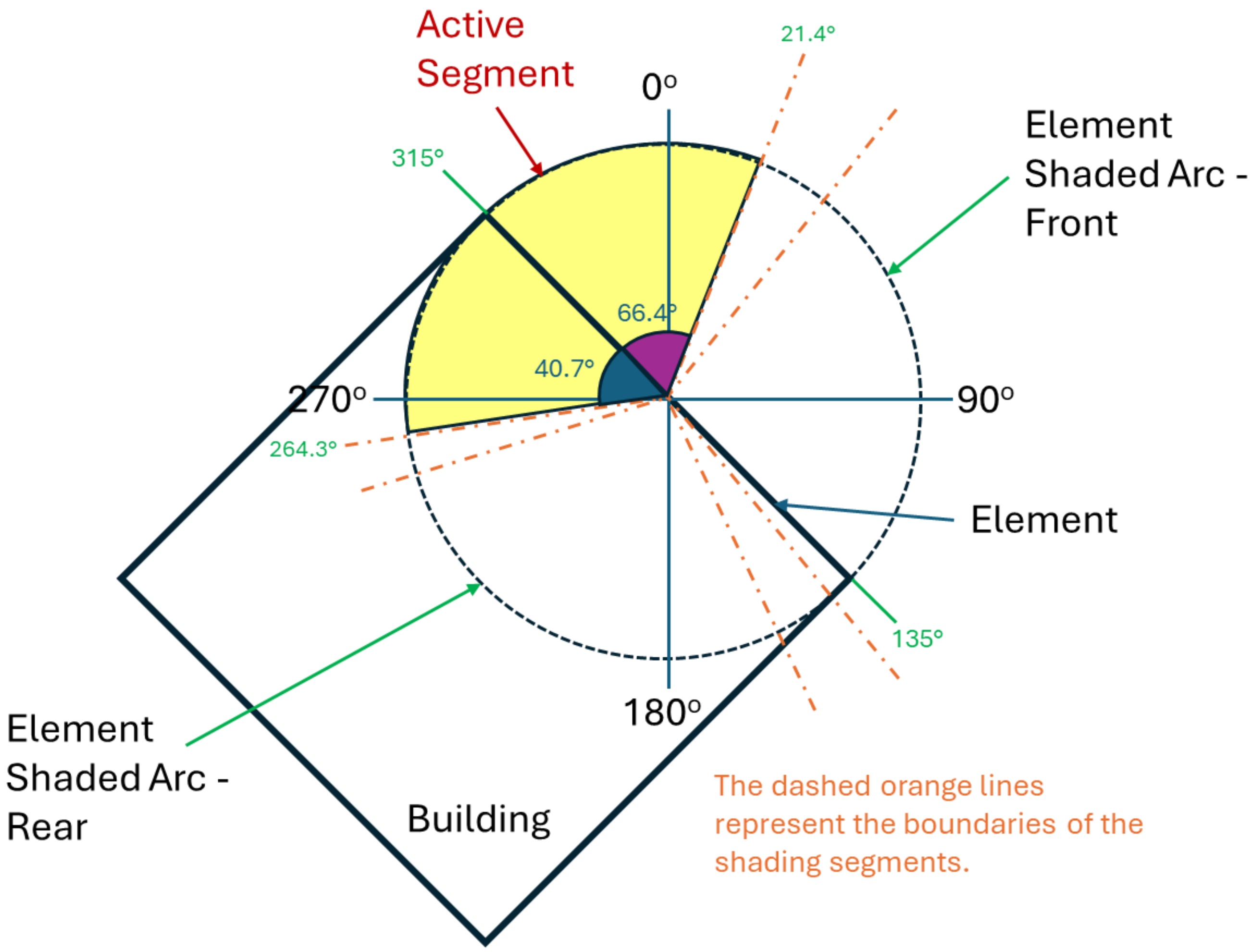

Figure 2 - Front and rear arcs and shading segments for a North-East facing building element.

In Figure 2, a north-east facing element of a building is considered for shading by remote obstacles and overhangs. The shading elements (with boundaries marked by orange dashed lines) are identical to those in Figure 1, but rebased to the centre of the element in question, as described above.

Any non-horizontal (i.e. not facing directly upwards or downwards) North-East facing building element has a front-facing arc extending from 315° to 135° as shown in Figure 2. For any surface with a tilt between 0° (horizontal upwards facing) and 90° (vertical), there is also a rear-facing arc. In Figure 2, for the highlighted shading segment ('Active Segment') that extends from 264.3° to 21.4°, 66.4° of the segment is within the front shaded arc and 40.7° is in the rear shaded arc (note: in this case, this segment does not contain a shading object). Shading to the front and rear of a surface requires different calculations, which are defined below.

4.2 Calculation of direct shading factor

The direct shading factor is derived by calculating the projected shadow on the shaded element according to BS EN ISO 52016-1:2017 section F.3. It is derived from the geometrical dimensions of the shading object and the shaded element, the direct irradiance, and the position of the sun (altitude and azimuth).

4.3 Calculation of diffuse shading factor

The relevant standards BS EN ISO 52016-1:2017 and PD CEN ISO/TR 52016-2:2017 define the requirements for remote and element-specific shading. However, the specific method required for shading of diffuse radiation by distant objects is not clearly defined. A new method has therefore been developed for this, incorporating general principles from the standards where appropriate.

Diffuse irradiance is reduced to account for shading objects, if necessary, by calculating changes in the Sky View Factor (f_{sky}), which represents the fraction of the sky visible to a building element. The base sky view factor for an unobstructed sky view from a building element is calculated using the following equation:

$$f_{sky} = \frac{1 + \cos\beta}{2}$$

where β is the tilt of the building element from horizontal.

Each building element is assessed for remote shading by cycling through each shading segment. For each building element, the following calculations are performed, with steps 1 to 5 being repeated for each segment:

1. The proportions of the front-facing arc (arc_prop) and rear-facing arc (rarc_prop) that are included in the shading segment are determined through analysis of the start and finish angles of the arcs and segment.
2. The contributions of the front and rear arc sections to the sky view factor (f_{sky}) within the shading segment are determined:
   a. For horizontal elements:

$$f_{sky\_seg\_front} = f_{sky} \cdot \frac{(segment\ angle)}{360}$$

$$f_{sky\_seg\_rear} = 0$$

b. For non-horizontal elements:

$$f_{sky\_seg\_front} = arc\_prop \cdot \min\left(0.5, f_{sky}\right)$$

$$f_{sky\_seg\_rear} = rarc\_prop \cdot \max(0, f_{sky} - 0.5)$$

3. Adjusted values for the sky view factor are calculated for obstacles. If there are no obstacles defined in the segment, then the unadjusted values from step 2 are used. If there is more than one obstacle in the segment, then the adjusted values are calculated for each obstacle and then the lowest of these values is used (this is in line with the principles in PD CEN ISO/TR 52016-2:2017 Annex F).
   a. Calculate height of obstacle relative to base height (H_0) of element:

$$H_{shade} = H_{obst} - H_0$$

   b. For horizontal elements:
      i. Calculate the angle from the building element to the top of the obstacle:

$$\alpha_{obst} = \tan^{-1}\left(\frac{H_{shade}}{L_{obst}}\right)$$

      ii. Recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_front\_new} = f_{sky\_seg\_front} \cdot \cos(\alpha_{obst})$$

   c. For non-horizontal elements, with obstacles in the front-facing arc (see Figure 3):
      i. Calculate vertically projected height of the element from the unprojected height (H_{ele}):

$$H_{proj} = H_{ele} \cdot \sin(\beta)$$

      ii. Calculate height of element above obstacle:

$$H_{above} = \max(0, H_{proj} - H_{shade})$$

      iii. Calculate the proportion of the element which is above the obstacle and is therefore unshaded by the obstacle:

$$P_{above} = \frac{H_{above}}{H_{proj}}$$

      iv. Calculate the angle from the midpoint of the shaded section of the element to the top of the obstacle:

$$\alpha_{obst} = \tan^{-1}\left(\left(H_{shade} - \frac{\min(H_{proj}, H_{shade})}{2}\right)/L_{obst}\right)$$

      v. Recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_front\_new} = f_{sky\_seg\_front} \cdot (P_{above} + (1 - P_{above}) \cdot \cos(\alpha_{obst}))$$

   d. For non-horizontal elements, with obstacles in the rear-facing arc (see Figure 4):
      i. Calculate effective height of element (projected height at obstacle distance):

$$H_{eff} = H_{proj} + (L_{obst} \cdot \tan(\beta))$$

ii. If $H_{eff} \geq H_{shade}$, the obstacle does not shade the element from the rear, so the unadjusted value from step 2.b should be used:

$$f_{sky\_seg\_rear\_new} = f_{sky\_seg\_rear}$$

iii. If $H_{eff} < H_{shade}$,, calculate the angle from the element to the top of the obstacle:

$$\alpha_{obst} = \tan^{-1}\left(\frac{H_{shade}}{L_{obst}}\right)$$

iv. If $H_{eff} < H_{shade}$, recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_rear\_new} = rarc\_prop \cdot 0.5 \cdot \cos(\alpha_{obst})$$

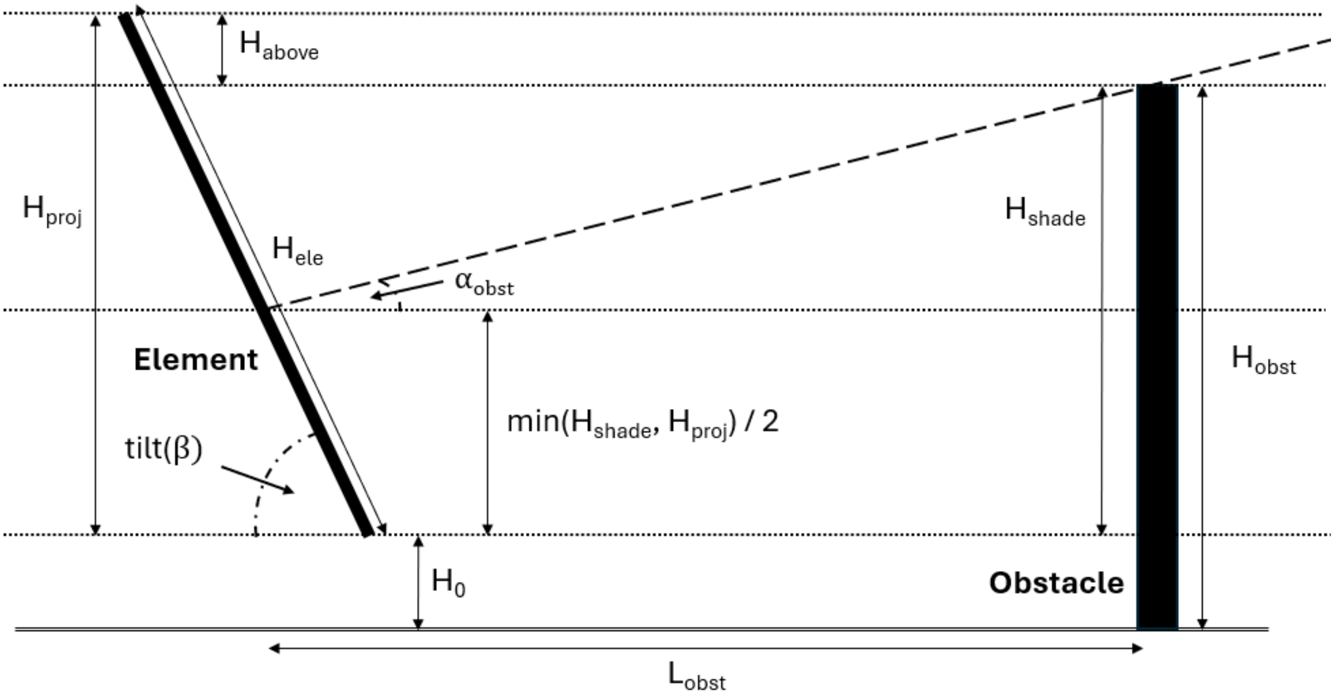

Figure 3 - Obstacle in front-facing arc for non-horizontal building element.

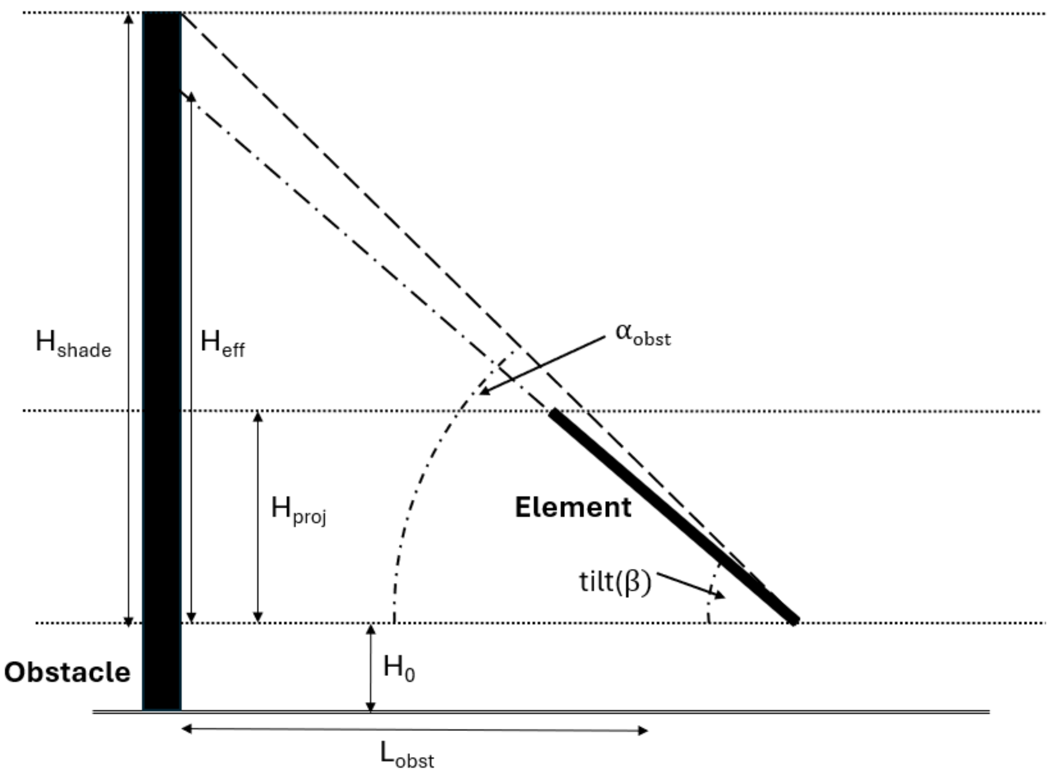

Figure 4 - Obstacle in rear-facing arc for non-horizontal building element.

4. Adjusted values for the sky view factor are calculated for overhangs. If there are no overhangs defined in the segment, then the unadjusted values from step 2 are used. If there is more than one overhang in the segment, then the adjusted values are calculated for each overhang and then the lowest of these values is used (this is in line with the principles in PD CEN ISO/TR 52016-2:2017 Annex F).
   a. Calculate height of base of overhang relative to base height (H_0) of element:

$$H_{shade} = H_{ovh} - H_0$$

   b. For horizontal elements:
      i. Calculate the angle from the building element to the base of the overhang:

$$\alpha_{ovh} = \tan^{-1}\left(\frac{H_{shade}}{L_{ovh}}\right)$$

      ii. Recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_front\_new} = f_{sky\_seg\_front} \cdot (1 - \cos(\alpha_{ovh}))$$

   c. For non-horizontal elements, with overhangs in the front-facing arc (see Figure 5):
      i. Calculate vertically projected height of the element from the unprojected height (H_{ele}):

$$H_{proj} = H_{ele} \cdot \sin(\beta)$$

      ii. Calculate height of element below overhang:

$$H_{below} = \min(H_{proj}, H_{shade})$$

iii. Calculate the proportion of the element which is below the overhang and therefore is not completely shaded by the overhang:

$$P_{below} = \frac{H_{below}}{H_{proj}}$$

iv. Calculate the angle from the midpoint of the section of the element below the overhang to the base of the overhang:

$$\alpha_{ovh} = \tan^{-1}\left(\left(H_{shade} - \frac{\min(H_{proj}, H_{shade})}{2}\right)/L_{ovh}\right)$$

v. Recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_front\_new} = f_{sky\_seg\_front} \cdot P_{below} \cdot (1 - \cos(\alpha_{ovh}))$$

d. For non-horizontal elements, with overhangs in the rear-facing arc (see Figure 6):

i. Calculate effective height of element (projected height at overhang distance):

$$H_{eff} = H_{proj} + (L_{ovh} \cdot \tan(\beta))$$

ii. If $H_{eff} \geq H_{shade}$, the overhang completely shades the element from the rear:

$$f_{sky\_seg\_rear\_new} = 0$$

iii. If $H_{eff} < H_{shade}$, calculate the angle from the element to the base of the overhang:

$$\alpha_{ovh} = \tan^{-1}\left(\frac{H_{shade}}{L_{ovh}}\right)$$

iv. If $H_{eff} < H_{shade}$, recalculate the contribution of the segment to the sky view factor, accounting for shading:

$$f_{sky\_seg\_rear\_new} = rarc\_prop \cdot 0.5 \cdot (\cos(\beta) - \cos(\alpha_{ovh}))$$

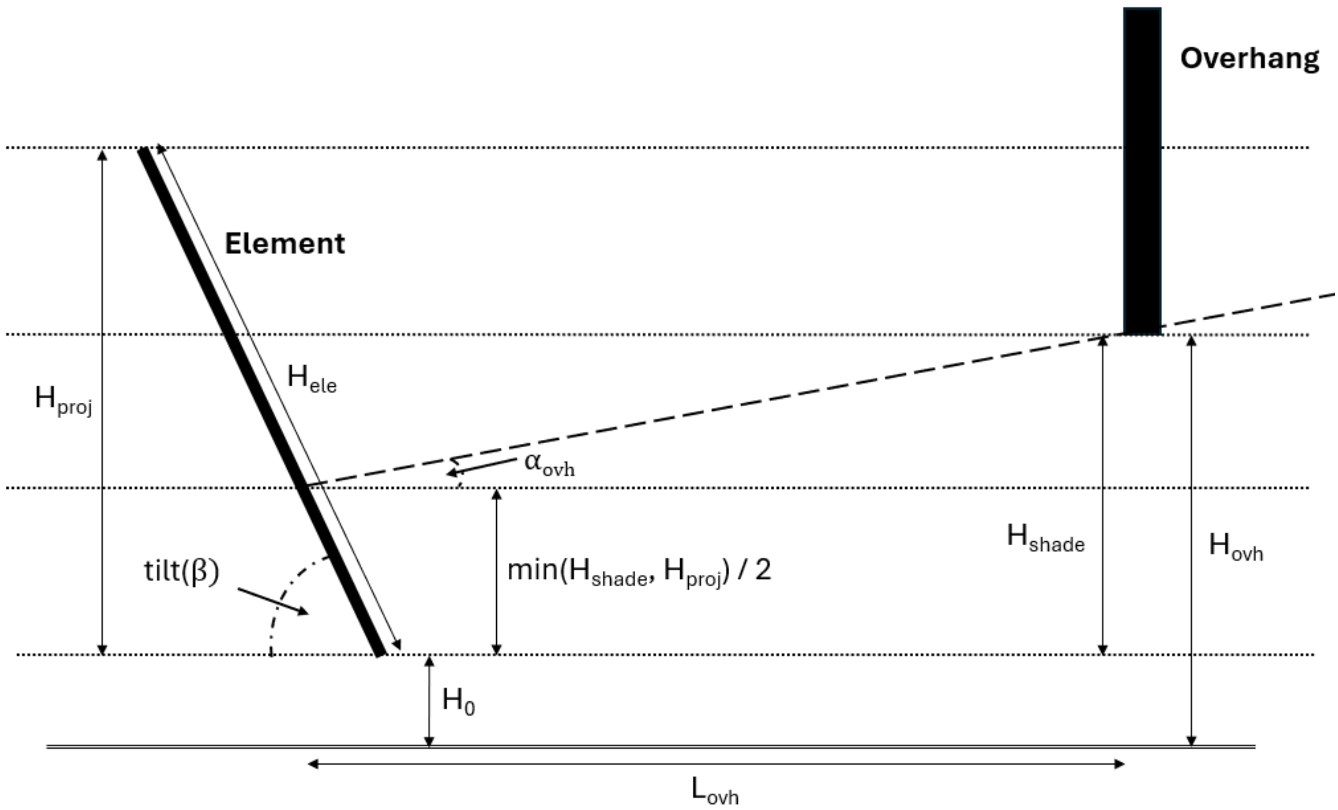

Figure 5 - Overhang in front-facing arc for non-horizontal building element.

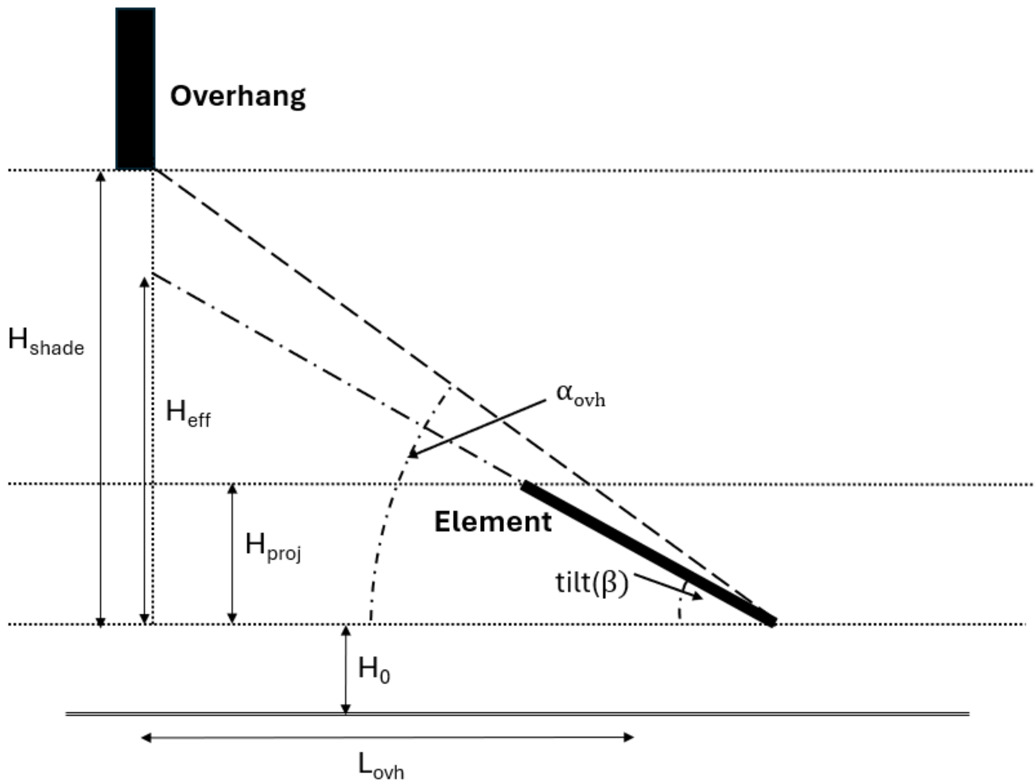

Figure 6 - Overhang in rear-facing arc for non-horizontal building element.

5. The lowest of the adjusted values for $f_{sky\_seg\_front\_new}$ and $f_{sky\_seg\_rear\_new}$ for all obstacles and overhangs in the segment are then used to calculate the revised sky view factor for the segment:

$$f_{sky\_new} = f_{sky\_seg\_front\_new} + f_{sky\_seg\_rear\_new}$$

6. The revised sky view factors for all segments are then summed, and the diffuse shading factor (for sky-diffuse and horizon-diffuse radiation) is calculated using the summed revised sky view factor:

$$F_{sh\_dif\_rem} = 1 - \frac{f_{sky} - f_{sky\_new}}{f_{sky}}$$

7. For the part of the sky that is blocked by distant shading objects, it is assumed that there is some reflectance of radiation from the distant shading objects. The distant shading object is assumed to have the same albedo as the ground, so this is modelled as an increase in ground-reflected radiation.
   a. For horizontal elements:
      i. Calculate the effective tilt angle (the element tilt that would be required to produce the required adjustment to the sky view factor):

$$\beta_{eff} = \cos^{-1}(2 \cdot f_{sky\_new} - 1)$$

      ii. Calculate the ground-reflected radiation ($I_{dif\_ref\_eff}$) that would result from this tilt angle, following the procedure in BS EN ISO 52010-1:2017 section 6.4.4.4.
      iii. Calculate the overall diffuse shading factor for distant objects:

$$F_{sh\_dif\_ref\_rem} = \frac{F_{sh\_dif\_rem} \cdot \left(I_{dif\_sky} + I_{dif\_hor}\right) + I_{dif\_ref\_eff}}{I_{dif}}$$

   b. For non-horizontal elements:
      i. Calculate the shading factor for ground-reflected radiation (this will be greater than one, which will lead to an increase in ground-reflected radiation):

$$F_{sh\_ref\_rem} = \frac{1 - f_{sky\_new}}{1 - f_{sky}}$$

      ii. Calculate the overall diffuse shading factor for distant objects:

$$F_{sh\_dif\_ref\_rem} = \frac{F_{sh\_dif\_rem} \cdot \left(I_{dif\_sky} + I_{dif\_hor}\right) + F_{sh\_ref\_rem} \cdot I_{dif\_ref}}{I_{dif}}$$

The method assumes that diffuse shading is applied to the angle that the midpoint of the shaded section of the element makes with the top (obstacle) or bottom (overhang) of the shading object. For obstacles close to the element (i.e. where the distance to the object is similar to the shaded height of the element, this method overestimates f_{sky} by 1-2%, becoming negligible for more distant objects.

5. Shading from nearby objects

Shading due to nearby objects applies exclusively to transparent elements. Shading due to nearby objects is modelled using:

- A direct shading factor, applied to the direct solar irradiance
- A diffuse shading factor, applied to the diffuse solar irradiance

The calculation of shading due to nearby objects must also take into account any shading from distant objects that has already been applied, to avoid over-counting the impact of shading (e.g. by counting overlapping shadows as separate reductions in solar radiation).

For shading due to nearby objects, the geometrical information required for each shaded transparent element is its height, width, and the distance between the ground and the lowest edge of the element (base height).

5.1 Representation of nearby shading objects

Nearby shading objects are categorized into four types:

1. Overhangs: Horizontal shading elements located above the transparent surface, defined by their depth and distance from the glazing.
2. Side fins: Vertical shading elements located on either side of the transparent surface, defined by their depth and distance from the glazing.
3. Reveals (setbacks): Horizontal and vertical shading elements surrounding the transparent surface, defined by their depth and distance from the glazing. Treated as a combination of equivalent overhangs and side fins due to incomplete variable definitions in the methods described in BS EN ISO 52016-1:2017 and PD CEN ISO/TR 52016-2:2017.
4. Obstacles: Ground-attached objects, such as balustrades, defined by their height, distance from the glazing, and transparency.

Nearby shading objects are attributed to individual transparent elements. They do not apply to all transparent elements of a façade and must be entered separately for each transparent element. Horizontal shading elements are assumed to be infinitely wide, and vertical elements are assumed to be infinitely tall.

5.2 Calculation of direct shading factor

Shading objects occlude specific portions of the transparent element based on their geometry and the sun's position (altitude and azimuth):

- For overhangs and side fins, the shadow is projected onto the transparent surface. The direct shading factor for overhangs and side fins is calculated following the method described in BS EN ISO 52016-1:2017 section F.3.
- For obstacles, BS EN ISO 52016-1:2017 does not define how to account for shading due to nearby obstacles, so the procedure defined by the standard for shading due to distant obstacles is used, but applied only to the relevant transparent element. In

addition, for nearby obstacles the impact of shading may be reduced for obstacles that let some radiation through by specifying a value for the transparency of the obstacle.

BS EN ISO 52016-1:2017 section F.3 also describes how the impacts of distant and nearby shading are combined for direct radiation.

5.3 Calculation of diffuse shading factor

The diffuse shading factor is calculated by calculating the proportion of sky that is obstructed by the shading object:

- For overhangs and side fins, this follows the procedures from PD CEN ISO/TR 52016-2:2017 annex F.6.
- For obstacles, PD CEN ISO/TR 52016-2:2017 does not define how to account for shading of diffuse radiation due to nearby obstacles, so the procedure described in section 4.3 for obstacles in the front-facing arc is used to calculate a revised sky view factor, but the adjustment is applied only to the relevant transparent element. In addition, for nearby obstacles the impact of shading may be reduced for obstacles that let some radiation through by specifying a value for the transparency of the obstacle.

The diffuse shading factor for nearby objects is combined with the diffuse shading factor for distant objects by taking the lower of the two values. This is aligned with the principles in PD CEN ISO/TR 52016-2:2017 Annex F.

Future development

The following potential areas for improvements have been identified:

- Nearby shading objects such as overhangs and side fins are currently assumed to be infinitely wide or high respectively. Therefore, nearby shading objects which only cover part of the width or height of a transparent element cannot be accurately modelled.
- The method from BS EN ISO 52016:1:2017 section F.3 for calculating shading of direct radiation uses a vertical projection of the height of the building element and does not account for shading of direct radiation from the rear of a building element (e.g. where a roof is pitched slightly to the north and is shaded by an obstacle to the south).

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