Building Standards Division


2015 edition
Document Version Control

Purpose: To provide guidance on compliance with building regulations, namely the application of the calculation methodology used for non-domestic buildings under standards 6.1 and 6.9, as set out in section 6 (energy) of the 2015 Non-domestic Technical Handbook. This guidance is applicable as described in the note provided above.

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>February 2015</td>
<td>Initial issue in support of the 2015 revision of section 6 (energy) of the Scottish building regulations.</td>
</tr>
<tr>
<td>1.1</td>
<td>September 2015</td>
<td>Correction to Table 2; Glazing data for DSM tools in Tables 6/7 updated; Appendix C on DSM thermal capacity values (construction details) added.</td>
</tr>
<tr>
<td>1.2</td>
<td>April 2018</td>
<td>Amended text to support use of both v5.4b and v5.3a of SBEM.</td>
</tr>
</tbody>
</table>
INTRODUCTION

1. This document gives guidance on the use of SBEM and other approved software tools comprising the National Calculation Methodology (NCM) when:

   a. Demonstrating compliance with the carbon dioxide emissions requirements of Section 6 in respect of non-domestic buildings.

   b. Calculating asset ratings as part of preparing Energy Performance Certificates (EPCs) for non-domestic buildings, as required by the Energy Performance of Buildings (Scotland) Regulations 2008.

With regards to paragraph 1(b) above, it is expected that Approved Organisations\(^1\) have produced separate guidance regarding the forward transmission of the results of these calculations for the purposes of the formal issue of the EPC and the Recommendations Report for the building to the building owners.

2. Separate guidance has been published for the application of the methodology when using approved tools to demonstrate compliance with the applicable regulations in England, Wales and Northern Ireland.

3. This document is subject to regular review and it will be updated as and when the need for additional clarification is identified. This routine updating will help improve the consistency of application of the various tools to the building regulations compliance and energy certification processes. The latest version of the NCM Modelling Guide for Scotland will be available on the website of the Scottish Government Building Standards Division\(^2\) (BSD). The guide will refer to a specific edition of the NCM and its implementation in relation to compliance with building regulations from a particular date.

Main Changes to 2015 NCM Guide for Non-Domestic Buildings in Scotland

4. The 2015 NCM Modelling Guide applies to calculations submitted as part of a building warrant from 01 October 2015 in support of the 2015 Section 6 Energy of the Non-Domestic Technical Handbook. The main changes in the technical requirements of software since the issue of the previous (2010) NCM Modelling Guide are as follows:

   - Introduction of a new methodology based on concurrent specifications for the notional building. The specifications of the 2015 notional building have improved building fabric and fixed building services efficiencies and revised opening areas.

   - The new specifications for the notional building, which are used to determine the carbon dioxide (CO\(_2\)) emissions target, have been defined to deliver an aggregate 43% CO\(_2\) emissions reduction across an new non-domestic build profile relative to 2010 Section 6 Energy of the Non-Domestic Technical Handbook.

\(^1\) ‘Approved Organisations’ are referred to as ‘Protocol Organisations’ in iSBEM and the iSBEM User Guide.

• Introduction of side-lit and top-lit glazing types for the notional building, which are determined by the activity type assigned to each zone of the actual building. The possible zones types, based on their access to daylight are: unlit, side-lit (heated only), side-lit (heated and mechanically ventilated, or heated and cooled), and top-lit.

• A particular specification is assigned to each zone in the notional building depending upon whether it is heated and naturally ventilated or heated and either mechanically ventilated or cooled.

• The air infiltration value assigned to the notional building is also varied for zones which are defined within the NCM activity database as either as top-lit or having metal cladding construction.

• The 2015 target emission rate is the 2015 notional building emission rate (i.e. no additional improvement factors). The notional building specifications are an indication of what a compliant building looks like, however developers are free to vary the specifications, provided the target emission rate is achieved or bettered and backstop values for the various specification elements are observed.

• In implementing version 5 of SBEM, updated fuel emission factors and primary energy factors are applied. These are listed in Table 19 of this document.

• Solar gains (aggregated from April to September) for any zone that is either occupied or receives cooling are checked against a benchmark value.

• Large extensions are assessed for compliance with the carbon dioxide emissions standard (6.1).

• April 2018 – for v5.4b assessments only: updated inference data for default luminous efficacy for LEDs; auxiliary energy recognised in heating systems with integral fans; corrected lower threshold for CO₂ emission factor for district heating in Notional Building. For full v5.4b changes, refer to iSBEM User Guide, section 2.1³.

Approved software tools

5. Energy calculation software packages for compliance with Section 6 Energy of the Non-Domestic Technical Handbook and certification of energy performance of non-domestic buildings must be approved by the Scottish Government Building Standards Division (BSD) before they can be available for commercial use in Scotland. Information on the validation procedure and the approval scheme is available from the BSD.

6. The BSD website lists software approved for demonstrating compliance with Section 6 Energy and for calculating asset ratings as part of the production of an Energy Performance Certificate (EPC) in Scotland⁴. The website also provides a list of

³ Available to download at https://www.uk-ncm.org.uk/
⁴ http://www.gov.scot/Topics/Built-Environment/Building/Building-standards/techbooks/sectsixprg
Approved Organisations\(^5\) who can accredit persons wishing to engage in the production of EPCs for existing non-domestic buildings in Scotland and information on the use of Approved Certifiers of Design for Section 6 (Energy)\(^6\) in support of a building warrant application.

7. To be approved, the software tool must satisfy the criteria as published\(^7\) by the BSD. These requirements can be updated from time to time and cover a number of generic issues. The software tool has to demonstrate that:

   a. The calculations are technically robust and that they cover a necessary minimum set of energy flows.

   b. It follows the procedures for demonstrating compliance and issue of Energy Performance Certificates as defined in this document, including the use of the National Calculation Methodology (NCM) databases, the definition of notional building, and other issues as defined from time to time.

   c. It reports a minimum set of output parameters and that these parameters can be passed appropriately to standard modules for:

      i. Checking compliance with Section 6 Energy

      ii. Producing an Energy Performance Certificate (EPC) through lodgement to the Scottish EPC Register\(^8\)

      iii. Deriving a set of recommendations for energy efficiency improvements.

8. In addition to ensuring that the software tools are compatible in terms of technical scope, the approval process also requires software providers to check that the procedural guidance is being followed in terms of the calculation and reporting processes.

9. Approved Dynamic Simulation Model (DSM) software must automatically generate the notional building from information provided by the user for the actual building.

10. DSM software must meet or exceed the classification of dynamic modelling under CIBSE AM11.

11. DSM software will be expected to be developed in accordance with ISO 90003:2014 Guidelines for the application of ISO 9001:2008 to computer software.

**Version policy**

12. All software tools, both the government’s Simplified Building Energy Model (SBEM) and commercial Dynamic Simulation Models (DSMs), evolve with time as


\(^8\) [https://www.scottishepcregister.org.uk/](https://www.scottishepcregister.org.uk/)
improvements are made to the functionality and the quality of the underlying algorithms. This means that it is necessary to have a procedure whereby new versions can be accepted as appropriate for use within the compliance/certification process. The rules in the following paragraphs define the approved procedures.

13. For certifying compliance with Section 6, when submitting a building warrant:

a. The latest version of a software tool should generally be used. However, following the introduction of v5.4b tools on 6 April 2018, applicants may still use v5.3a tools to demonstrate compliance in building warrant applications made on or after that date. This option is retained as v5.4b can result in small changes in calculated TER and BER, affecting the efficacy of proposals when demonstrating compliance.

b. The previous version of a software tool (i.e. software and NCM databases) may be used for a period not exceeding six months following introduction of a new version, provided a change in regulations does not require use of the current version (as would be the case, for example, from 1 October 2015).

c. Whilst the same version of a software tool may be used for any amendment to warrant as for the original warrant, at any stage, applicants can elect to adopt a more recently approved version of the tool, but having elected to use a later version, building developers cannot subsequently revert to using a previous one.

14. For the production of Energy Performance Certificates, the Scottish EPC register will only accept lodgement of data which conforms to the current NCM schema. The approved version of the adopted software tool must be used. An up-to-date list of approved software for EPC lodgement is published by Building Standards Division.

15. To allow the transfer and reuse of project data from an older to a newer version of the tool, part of the procedure for approving a software tool is that a new version must be backwardly compatible with all previous versions of the tool, i.e. it can either read the data files of previous versions directly, or a file conversion utility must be provided.

Choosing a software tool

16. While all calculation methods involve a degree of simplification, two classes of software tools are available for use for Section 6 compliance checking and EPC generation:

a. SBEM, which is the Simplified Building Energy Model developed for the BSD. This can be applied to any building (irrespective of size) although there are some constraints, as discussed later in this guide. Such constraints are for example, where representation of certain building features require some approximation, entailing additional demands of the assessor’s input time and effort; and

b. Approved Dynamic Simulation Models (DSMs). These are applicable for any building unless approval of an individual DSM specifically excludes certain types of

building or building features. They may prove more flexible than SBEM in handling certain building features and are also more suited as design support tools (SBEM is not a design tool, carrying out compliance and certification calculations only).

17. There are a number of approved software interfaces to SBEM. These interfaces must also be approved before the overall software tool can be used. Interface approval as well as software approval is necessary to ensure that procedures are followed appropriately as well as the calculations being carried out correctly.

**SBEM constraints**

18. All calculation processes involve some approximations and compromises, and SBEM is no exception. The most obvious limitations relate to the use of the CEN monthly heat balance method. This means that processes which vary non-linearly at shorter time-steps have to be approximated or represented by monthly parameters. The HVAC system efficiencies are an example of this.

19. It is, therefore, difficult to give absolute rules about when SBEM can and cannot be used. As broad guidance, it is more likely to be difficult to use SBEM satisfactorily if the building and its systems have features that:

   a. Are not already included in SBEM; or
   b. Have properties that vary non-linearly over periods of the order of an hour.

20. It should be noted that there are also constraints to the use of other software. Any software tool has limits to the building and system options that it can model.

**COMPLIANCE WITH BUILDING REGULATIONS**

21. Compliance with standard 6.1 of Section 6 Energy requires that a new non-domestic building must show, by calculation, that it is designed to limit carbon dioxide emissions. This is achieved by demonstrating that the building as designed will have emissions no greater than a Target Emission Rate (TER), i.e. the Building Emission Rate (BER) is less than or equal to the TER.

22. The TER for the 2015 calculation which supports standard 6.1 of Section 6 Energy is based on the performance of a “notional building” and the following procedure must be followed in order to establish the TER. This approach is adopted to avoid the need to define system models appropriate to different types of building. It also ensures a consistent approach to the target setting process.

**THE NOTIONAL BUILDING**

23. As specified in the guidance under standard 6.1 of Section 6 Energy, the notional building must have the same size, shape, and zoning arrangements as the actual
building, with the same conventions relating to the measurement of dimensions (see Table 20).

24. Each space must contain the same activity (and therefore the same activity parameter values) as proposed for the equivalent space in the actual building. The activity in each space must be selected from the list of activities as defined in the NCM Activity Database.

25. The notional building must be given the same orientation and be exposed to the same weather data as the actual building. For DSM software, the notional building must be subject to the same site shading from adjacent buildings and other topographical features as are applied to the model of the actual building.

26. Whatever servicing strategy (heating, ventilation, cooling) is specified in a zone in the actual building must also be provided in the corresponding zone in the notional building. Note that in some zones, heating need not be provided, even though the NCM Activity Database specifies a heating set-point. For example, the actual building may contain an unheated stairwell or atrium space. The corresponding zones in the notional building must also be unheated. However, if heating were provided to either of these spaces in the actual building, then heating must correspondingly be specified in the notional building, and then both buildings must heat those spaces to the heating set-point specified for the zone type in the NCM Activity Database.

27. The notional building specifications introduced in 2015 are assigned based upon the servicing strategy identified for each zone within the proposed building. There are therefore two notional building specifications for:

a. Heated and naturally ventilated zones; and

b. Heated and mechanically ventilated or heated and cooled zones.

For each servicing strategy, different values for building fabric (Table 1), air infiltration (Table 4), glazing g-value (Table 5) and lighting efficacy (paragraph 75) are applied to the notional building.

28. Any fixed building services system not covered by Section 6 Energy must be ignored in both the actual and notional buildings.

29. The energy performance standards of the notional building are based on a concurrent specification that delivers a 43% reduction in CO₂ emissions relative to the 2010 energy performance standards based on an assumed build mix. This means that the emissions target for some buildings will improve by more than this percentage, others by less.

**Activity glazing types**

30. For 2015 in the notional building, the activity assigned to each zone determines whether it will have access to daylight through windows, roof-lights, or no glazing at all (i.e. no access to daylight), regardless of the type of glazing applied to the equivalent zone in the actual building. The glazing type assigned to each NCM activity is determined in the
“activity” table from the NCM Activity database in the “DRIVER2A” field (0 for activity with no daylight, i.e. unlit, 1 for side-lit activity, and 2 for top-lit activity).

31. There are 3 types of glazing which can be applied to each defined zone in the actual building based on the source of daylight (if any):
   a. Side-lit
   b. Top-lit
   c. Unlit

32. Variation in the notional building specification for air permeability apply in certain situations when the selected activity type identifies “top-lit” as the source of daylight from the NCM Activity database. Refer to paragraph 43 for further information.

### Building fabric

33. The U-values in the notional building must be as specified in Table 1. Taking into account guidance in BR 443\(^{10}\), all U-values should be calculated in accordance with BS EN ISO 6946: 2007, where the U-values calculation methods are inclusive of repeating thermal bridges.

<table>
<thead>
<tr>
<th>Element</th>
<th>Heated and naturally ventilated</th>
<th>Heated and cooled or Heated and mechanically ventilated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs</td>
<td>0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>Walls</td>
<td>0.23</td>
<td>0.20</td>
</tr>
<tr>
<td>Floors</td>
<td>0.22</td>
<td>0.2</td>
</tr>
<tr>
<td>Windows</td>
<td>1.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Roof-lights</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>External personnel doors</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Vehicle access and similar large doors</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Internal walls</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Internal windows</td>
<td>3.85</td>
<td>3.85</td>
</tr>
<tr>
<td>Internal ceilings</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Notes:
Any part of a roof having a pitch greater or equal to 70\(^\circ\) is considered as a wall.
U-value of rooflights is the overall U-value including the frame and edge effects, and also relates to adjustment for slope as detailed in section 11.1 of BR443.

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34. The U-values for the heated and naturally ventilated zones within the notional building are less challenging than for the heated and mechanically ventilated / heated and cooled zones. This is in recognition of the fact that heated only zones are less energy intensive than heavily serviced ones. Zones that use mechanical ventilation only to limit overheating in peak summer conditions and ventilation is provided naturally under normal conditions are modelled using the heated and naturally ventilated specification.

35. The effective thermal capacity of the construction elements, $\kappa_m$ (kappa-m) value, in the notional building must be as shown in Table 2. For DSMs the information in the NCM Construction Database includes the necessary technical parameters to evaluate the impact of thermal capacity. The thermal mass of windows should be ignored.

Table 2: Thermal capacity of construction elements in the notional building

<table>
<thead>
<tr>
<th>Element</th>
<th>Effective thermal capacity (kJ/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs</td>
<td>88.3 (1.40 if metal-clad)</td>
</tr>
<tr>
<td>Walls</td>
<td>21.8 (1.40 if metal-clad)</td>
</tr>
<tr>
<td>Floors</td>
<td>77.7</td>
</tr>
<tr>
<td>Vehicle access and similar large doors</td>
<td>2.1</td>
</tr>
<tr>
<td>Pedestrian doors and high usage entrance doors</td>
<td>54.6</td>
</tr>
<tr>
<td>Internal wall</td>
<td>8.8</td>
</tr>
<tr>
<td>Internal floor/ceiling</td>
<td>71.8 from above, 66.6 from below</td>
</tr>
</tbody>
</table>

Notes:
Any part of a roof having a pitch greater or equal to 70º is considered as a wall.

36. Zones in the notional building which use activity types flagged as involving metal cladding in the NCM Activity database will use metal-clad construction elements and the associated Psi values from Table 3 for thermal bridges. Whether or not the activity involves metal cladding is determined in the “activity” table from the NCM Activity database in the “META_CLADDING” field (0 for activity with no metal-clad constructions, and 1 for activity with metal-clad constructions).

37. The notional building does not have curtain walling or display windows, even when curtain walling or display windows are present in the actual building.

38. Smoke vents and other ventilation openings, such as intake and discharge grilles, must be disregarded in the actual and notional buildings, and their area substituted by the relevant (i.e. immediately surrounding) opaque fabric (roof or wall).

39. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be accounted for by adding 10% to the standard area-weighted average U-values, or by an equivalent method that satisfies BS EN ISO 14683 (see paragraph 40), and be consistently applied to both Actual and
Notional buildings. Note that the U-values as given in Table 1, and the corresponding construction elements in the database, DO NOT include this allowance so the calculation tool must make the adjustment explicitly.

40. Where an equivalent method that satisfies BS EN ISO 14683 is used to take account of non-repeating thermal bridges, the Psi values for the notional building will use the values from Table 3.

<table>
<thead>
<tr>
<th>Type of junction</th>
<th>Involving metal cladding</th>
<th>Not involving metal-cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof to wall</td>
<td>0.28</td>
<td>0.12</td>
</tr>
<tr>
<td>Wall to ground floor</td>
<td>1.0</td>
<td>0.16</td>
</tr>
<tr>
<td>Wall to wall (corner)</td>
<td>0.2</td>
<td>0.09</td>
</tr>
<tr>
<td>Wall to floor (not ground floor)</td>
<td>0.0</td>
<td>0.07</td>
</tr>
<tr>
<td>Lintel above window or door</td>
<td>1.0</td>
<td>0.30</td>
</tr>
<tr>
<td>Sill below window</td>
<td>0.95</td>
<td>0.04</td>
</tr>
<tr>
<td>Jamb at window or door</td>
<td>0.95</td>
<td>0.05</td>
</tr>
</tbody>
</table>

41. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made:\(^{11}\):

a. If the calculated value is greater than 0.22 W/m²K for heated only and top-lit heated only warehouses zones, the value of 0.22 W/m²K must be used in the notional building. If the calculated value is greater than 0.20 W/m²K for heated and cooled and heated and mechanically ventilated zones, the value of 0.20 W/m²K must be used in the notional building.

b. If the calculated value is less than 0.22 W/m²K with no added insulation for heated only and top-lit heated only warehouses zones this lower value must be used in the notional building. If the calculated value is less than 0.20 W/m²K for heated and cooled and heated and mechanically ventilated zones, this lower value must be used in the notional building.

42. When modelling an extension, the boundary between the existing building and the extension must be disregarded (i.e. assume no heat transfer across it).

43. Zones in the notional building will use the air permeability values from Table 4, provided that zones whose activity types are flagged as involving metal cladding in the NCM Activity database (see paragraph 36) will use the values in the ‘Top-lit’ column of Table 4.

\(^{11}\) This follows the guidance given in CIBSE Guide A (2006).
44. The calculation method used to estimate the infiltration rate must use the air permeability as the parameter defining the envelope leakage. For compliance and certification purposes, the same method must be used in the actual and notional buildings. Acceptable methods include:

a. The method specified in the SBEM Technical Manual\textsuperscript{12}, which is taken from EN 15242\textsuperscript{13}.

b. Other methods that use a relationship between infiltration rate and air permeability and are set out in national or international standards or recognised UK professional guidance documents which relate average infiltration rate to envelope permeability. An example of the latter would be tables 4.13 to 4.20 of CIBSE Guide A (2006). \textit{Methods that use flow networks are not acceptable for compliance or certification purposes as there is no simple way to check that the permeability of the Notional building delivers the required permeability standard.}

### Areas of windows, doors, and rooflights

45. The areas of windows, doors, and rooflights in the notional building must be determined as set out in the following sub-paragraphs and must also conform to the measurement conventions set out in Annex A, paragraph 169 and Table 20.

a. Copy the areas of high usage entrance, pedestrian, and vehicle access doors that exist in the corresponding element of the actual building.

b. In the notional building, high usage entrance, pedestrian, and vehicle access doors must be taken as being opaque (i.e. with zero glazing) and use the U-values in Table 1.

c. If the total area of these elements is less than the appropriate allowance for glazing from Table 5, the balance must be made up of windows or rooflights as appropriate.

d. If the total area of the copied elements exceeds the allowance for glazing from Table 5, the copied areas must be retained but no windows or rooflights added.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Gross internal area of the building & Side-lit or unlit, where heated and naturally ventilated & Side-lit or unlit, where heated and cooled or heated and mechanically ventilated & Top-lit \\
\hline
Less than 3,500 m\textsuperscript{2} & 5 & 3 & 7 \\
3,500 m\textsuperscript{2} - 10,000 m\textsuperscript{2} & 5 & 3 & 5 \\
10,000 m\textsuperscript{2} or more & 5 & 3 & 3 \\
\hline
\end{tabular}
\caption{Air permeability (m\textsuperscript{3}/h per m\textsuperscript{2} of envelope area at 50 Pa)}
\end{table}

\textsuperscript{12} SBEM Technical Manual (for SBEM version 5) available at \url{https://www.uk-ncm.org.uk/}

\textsuperscript{13} Ventilation for buildings – Calculation methods for the determination of air flow rates in buildings including infiltration, EN 15242, CEN/TC 156, 2006.
e. For DSM software, the shape of windows in side-lit activities should be modelled as a full facade width window with sill height of 1.1 m. Where doors have been copied across from the actual building, the window will occupy the remaining facade width, and the height adjusted such that the total area of opening areas still satisfies Table 5.

46. Display windows in the actual building are not copied across into the notional building and their area is substituted by the relevant (i.e. immediately surrounding) wall.

<table>
<thead>
<tr>
<th>Table 5: Glazing in the notional building</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity glazing type</strong></td>
</tr>
<tr>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Side-lit</td>
</tr>
<tr>
<td>Top-lit</td>
</tr>
<tr>
<td>Unlit</td>
</tr>
</tbody>
</table>

*The number of rooflights per roof element is determined using the following equation:

$$\text{Number of rooflights per roof element} = \frac{\text{roof element area}}{1.68 \times \text{zone height} \times \cos(\text{angle of slope})^2}$$

The number of rooflights should be rounded to the nearest integer and be greater than zero. Where the roof element is sloped, the zone height should be the height to the eaves or lowest point of the roof element.

47. DSM software are required to use the glass data provided in Table 6a, 6b and Table 7 to model the glazing specification required in Table 5, where $T_{solar}$ is the direct solar transmittance, $T_{visible}$ is the direct visible light transmittance, $R_{solar}$ is the solar reflectance, and $R_{visible}$ is the visible light reflectance. The subscripts 1 and 2 refer to the outer and inner surfaces of each pane of glass, respectively.

<table>
<thead>
<tr>
<th>Table 6a: Glass properties for side-lit glazing – g=60% (heated and naturally ventilated zones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Outer pane</td>
</tr>
<tr>
<td>Cavity</td>
</tr>
<tr>
<td>Inner pane</td>
</tr>
</tbody>
</table>
Table 6b: Glass properties for side-lit glazing – g=50%
(heated and cooled or heated and mechanically ventilated zones)

<table>
<thead>
<tr>
<th>Thickness</th>
<th>T_solar</th>
<th>R_solar1</th>
<th>R_solar2</th>
<th>T_visible</th>
<th>R_visible1</th>
<th>R_visible2</th>
<th>Emissivity 1</th>
<th>Emissivity 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer pane</td>
<td>6 mm</td>
<td>0.530</td>
<td>0.179</td>
<td>0.260</td>
<td>0.839</td>
<td>0.057</td>
<td>0.042</td>
<td>0.837</td>
</tr>
<tr>
<td>Cavity</td>
<td>12 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Argon gas fill</td>
<td></td>
</tr>
<tr>
<td>Inner pane</td>
<td>6 mm</td>
<td>0.777</td>
<td>0.096</td>
<td>0.091</td>
<td>0.859</td>
<td>0.110</td>
<td>0.108</td>
<td>0.837</td>
</tr>
</tbody>
</table>

48. No glazed area should be included in basements. In semi-basements (i.e. where the wall of the basement space is mainly below ground level but part is above ground), the opening areas in Table 5 must apply to the above ground part (note that in such situations the 1.1 m sill height rule would not need to be followed), with zero glazing for the below ground part.

49. For curtain walling systems, the translucent and transparent areas should be modelled as glazing and the opaque parts as wall and use the U-values in Table 1.

**HVAC system**

50. Each space in the notional building will have the same level of servicing as the equivalent space in the actual building. In this context, “level of servicing” means the broad category of environmental control, summarised as follows:

   a. unheated
   b. heated only, with natural ventilation
   c. heated and mechanically ventilated
   d. heated and cooled (air-conditioned)
   e. mixed-mode cooling, where cooling operates only in peak season to prevent space temperatures exceeding a threshold temperature higher than that normally provided by an air-conditioning system.

51. A space is only considered as having air-conditioning if the system serving that space includes refrigeration.
52. Night cooling using mechanical ventilation is not air-conditioning. If the same mechanical ventilation system that is used for night cooling is also used to provide normal ventilation, then the space should be regarded as being mechanically ventilated.

53. Any boosted supply rate required to limit overheating must be ignored in the notional and actual buildings. If the mechanical ventilation system only operates in peak summer conditions to control overheating, and during normal conditions ventilation is provided naturally, then the space must be regarded as naturally ventilated, and the mechanical ventilation system can be ignored in both notional and actual buildings.

54. If a zone is naturally ventilated, the modelling strategy must provide for enhanced natural ventilation in the notional building to prevent overheating. If this is not done, heat will build up and artificially depress the demand for heating the next day, thereby making the energy target unrealistically harsh. For DSM software, the following modelling strategy must be used in the notional building. The strategy must increase the natural ventilation rate up to a maximum of 5 air changes per hour (ac/h) whenever the space temperature exceeds the heating set-point by 1 °K. This enhanced ventilation must cease immediately the space temperature falls below the heating set-point. By maintaining the increased natural ventilation until internal temperatures fall to the (high) heating set-point, the temperatures at start-up next day will be neither artificially high nor low.

55. Humidity control is ignored in the actual and notional buildings.

56. The system performance definitions follow the practice set out in EN 15243:
   a. Auxiliary energy is the energy used by controls, pumps, and fans associated with the HVAC systems. It is the term described as “fans, pumps, controls” in Energy Consumption Guides such as ECG019.
   b. Heating Seasonal Coefficient of Performance (SCoP) is the ratio of the sum of the heating consumption of all spaces served by a system to the energy content of the fuels (or electricity) supplied to the boiler or other heat generator of the system. The SCoP includes boiler efficiency, heat losses in pipework, and duct leakage. It does not include energy used by fans and pumps (but does include the proportion of that energy which reappears as heat within the system). For DSMs, the ventilation supplied to the zone must be taken as the outdoor air temperature. For SBEM, adjusted monthly average figures should be used as specified in the SBEM.
Technical Manual\textsuperscript{18}. Heating energy consumption is, therefore, calculated from the following expression:

**Equation 1**  \textit{Heating energy consumption} = \textit{Zones annual heating load} / \textit{SCoP}

\textbf{c.} The Seasonal System Energy Efficiency Ratio for cooling (SSEER) is the ratio of the sum of the sensible cooling consumption of all spaces served by a system to the energy content of the electricity (or fuel) supplied to the chillers or other cold generator of the system. The SSEER includes, amongst other things, chiller efficiency, heat gains to pipework and ductwork, duct leakage, and removal of latent energy (whether intentional or not). It does not include energy used by fans and pumps (but does include the proportion of that energy which reappears as heat within the system). Electricity used by heat rejection equipment associated with chillers is accounted for in the SSEER (not as auxiliary energy). Electricity used within room air conditioners for fan operation is also included in the SSEER value since it is included in the standard measurement procedure for their EER. Electricity used by fossil-fuelled equipment and its ancillaries, including fans in unit heaters and gas boosters, is included in the auxiliary energy. For DSMs, the ventilation supplied to the zone must be taken as the outdoor air temperature. For SBEM, adjusted monthly average figures should be used as specified in the SBEM Technical Manual\textsuperscript{18}. Cooling energy consumption is therefore calculated from the following expression:

**Equation 2**  \textit{Cooling energy consumption} = \textit{Zones annual cooling load} / \textit{SSEER}

\textbf{57.} For the purposes of heating, cooling, and auxiliary energy calculations, the ventilation should operate on a flat profile that is on during the occupied period only, (\textit{i.e. each hour when the NCM daily schedule for occupancy is greater than zero}). The flow rate is determined by the product of the peak occupancy density and fresh air rate per person (both from the NCM Activity database). The profile is the same for both natural and mechanical ventilation and does not modulate with the occupancy profile.

\textbf{58.} The notional building has heat recovery with sensible efficiency of 70\%, where appropriate (\textit{i.e. zones with mechanical ventilation providing supply and extract}), which is bypassed/switched off in cooling mode (\textit{i.e. variable efficiency}).

\textbf{59.} The cooling and auxiliary energy must be taken to be powered by grid-supplied electricity.

\textbf{60.} In air-conditioning mode, the cooling SSEER is 3.6, which already takes account of 20\% distribution losses and fan energy associated with heat rejection (\textit{i.e. SEER is 4.5}).

\textbf{61.} In mixed-mode operation, the notional building will have a cooling SSEER of 2.7 with cooling set-point of 27 °C (note that mixed-mode cooling is assumed to be provided by a direct expansion (DX) unit where the SSEER includes indoor and outdoor units, fans, pumps, and losses).

\textsuperscript{18} SBEM Technical Manual (for SBEM version 5) available at \url{https://www.uk-ncm.org.uk/}
<table>
<thead>
<tr>
<th>Heating fuel used in the Actual building</th>
<th>Efficiency (notional building)</th>
<th>Heating fuel emission factor in the notional building (kgCO₂/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Space heating</td>
<td>Hot water</td>
</tr>
<tr>
<td>Bio-fuels (emission factor &lt; emission factor of natural gas)</td>
<td>63.0%</td>
<td>66.5%</td>
</tr>
<tr>
<td>Natural gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual fuel (mineral + wood)</td>
<td>81.9%</td>
<td>86.45%</td>
</tr>
<tr>
<td>Fuel oil and other fuels (whose emission factor &gt; emission factor of fuel oil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity (direct)</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Electric heat pump</td>
<td>157.5%</td>
<td>166.25%</td>
</tr>
<tr>
<td>Non-electric heat pump</td>
<td>126.0%</td>
<td>133.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating fuel used in the Actual building</th>
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</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>Natural gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual fuel (mineral + wood)</td>
<td>86% for radiant heating*; otherwise 81.9%</td>
<td>86.45%</td>
</tr>
<tr>
<td>Fuel oil and other fuels (whose emission factor &gt; emission factor of fuel oil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity (direct)</td>
<td>86% for radiant heating*; otherwise 90%</td>
<td>95%</td>
</tr>
<tr>
<td>Electric heat pump</td>
<td>157.5%</td>
<td>166.25%</td>
</tr>
<tr>
<td>Non-electric heat pump</td>
<td>126.0%</td>
<td>133.0%</td>
</tr>
</tbody>
</table>
62. The fuel and associated Seasonal Coefficient of Performance (SCoP) for space heating and hot water generation in each zone of the notional building is linked to the type of fuel used for space heating and hot water in the equivalent zone in the actual building, based on the values provided in Table 8 and Table 9. Space heating and hot water generation are considered independently. For example, if a zone in the actual building uses electric heat pumps for space heating and natural gas for hot water generation, then the equivalent zone in the notional building will use electric heat pumps for space heating and natural gas for hot water generation. Note that the SCoP values already take account of distribution losses of 10% for space heating and 5% for hot water (i.e. generator efficiency is 91%).

* In Table 9, where a zone in the actual building is heated and naturally ventilated (i.e. there is neither mechanical ventilation, nor cooling), then the equivalent zone in the notional building will be modelled with direct-fired multi-burner radiant heating, where the thermal efficiency is 86%, and 65% of the thermal output is radiant (i.e. radiant component of 0.65). Zones with top-lit activities tend to be large/tall spaces where direct radiant heating allows a lower air temperature for a given level of thermal comfort, and this reduces ventilation losses. The SBEM Technical Manual provides the method used by SBEM to account for the benefit of radiant heating, and DSM software should model the radiant effect of this type of heating system to at least an equivalent level of detail as SBEM. Note that direct-fired radiant heating systems do not incur auxiliary energy for pumps or fans.

63. For hot water, the energy demand must be taken as that required to raise the water temperature from 10 °C to 60 °C based on the demands specified in the NCM Activity database. The Activity database defines a daily total figure in l/m² per day for each activity type. If users of DSMs wish to distribute this demand over the day, then the daily total should be distributed according to the occupancy profile.

64. Where district heating systems are used for space and/or water heating in the actual building, district heating will be used for space and/or water heating in the notional building, and its emission factor will be as follows:

- Where the emission factor of heat supplied in the actual building is less than or equal to 0.19 kgCO₂/kWh, the notional building will have an emission factor of heat supplied of 0.19 kgCO₂/kWh (and primary energy factor of 0.85 kWh/kWh).
- Where the emission factor of heat supplied in the actual building is greater than 0.19 kgCO₂/kWh and less than 0.4 kgCO₂/kWh, the notional building will have the same emission factor of heat supplied as the actual building.
- Where the emission factor of heat supplied in the actual building is greater than or equal to 0.4 kgCO₂/kWh, the notional building will have an emission factor of heat supplied of 0.19 kgCO₂/kWh.

---

19 v5.3a calculations apply a value of 0.15 kgCO₂/kWh to the above rules. v5.4b corrects this to 0.19 kgCO₂/kWh, improving the threshold at which benefit accrues from a lower carbon heat source.
supplied of 0.4 kgCO$_2$/kWh (and primary energy factor of 1.34 kWh/kWh), i.e. the emission factor of the notional building is capped at 0.4 kgCO$_2$/kWh.

The heating fuel emission factor of 0.19 kgCO$_2$/kWh represents a typical, though not exceptional, district heating system supplied by a gas-fired CHP with an electrical efficiency of 30% and a heat efficiency of 50%, supplying 70% of the heating load and a gas-fired boiler with an efficiency of 80% supplying the remaining 30% (a 15% uplift is applied to the CO$_2$ content of heat to account for network heat losses). In this way, district heating systems offering improved performance are incentivised.

65. For bivalent heating systems (i.e. where more than one fuel is used in the actual building to provide space and/or water heating, such as a biomass boiler supplemented by a natural gas boiler), a demand-weighted conversion factor will be calculated for the notional building that is based on the proportion of heating demand met by each fuel type in the actual building.

This calculation is determined at zone level, where for each fuel type, the proportion of heating demand is multiplied by the appropriate fuel emission factor and then divided by the associated SCoP, both from Table 8 or Table 9. This is repeated for each fuel type and then summed to determine the demand-weighted conversion factor.

For example, if a zone with a side-lit activity in the actual building meets 70% of its space heating demand with biomass and the rest with natural gas, then the equivalent zone in the notional building would use a demand-weighted conversion factor of $(0.7 \times 0.031/0.630) + (0.3 \times 0.216/0.819)) = 0.113$. Note that the demand-weighted conversion factor already takes into account both the fuel emission factor and the SCoP.

**Auxiliary energy**

66. The auxiliary energy is the product of the auxiliary power density and annual hours of operation of the heating system as taken from the NCM Activity database (i.e. the hours when the heating set-point is above the set-back temperature based on the daily/weekly/annual schedules or the “SYS_HEAT_T_HOURS_#” from the “activity_sbem_D1_ACU” table in the NCM Activity database).

67. The auxiliary power density is the sum of the pump and fan power density.

68. The pump power density for the notional building will be zero in zones with top-lit activities satisfying the conditions in the note to Table 9. In all other cases, the pump power density for the notional building will depend on the configuration of the HVAC system in the actual building so that:

- If the HVAC system in the actual building is a wet system, the pump power density for the notional building is 0.30 W/m$^2$ where the HVAC system only provides heating, and 0.90 W/m$^2$ if it provides mechanical ventilation and/or air-conditioning;
- If the HVAC system in the actual building is based on a dry system (e.g. split system), then the notional building will have zero pump power.
69. For zones where the ventilation system also provides heating and/or cooling, the fan power density is determined for each zone using the following equations:

**Equation 3** \[ \text{Fan power density} = \text{Lesser of (FPS}_1, \text{ FPS}_2) \]

**Equation 4** \[ \text{FPS}_1 = \text{FAR}_{\text{max}} \times \text{SFP}_{\text{central}} + \text{SCR} \times \text{SFP}_{\text{terminal}} \]

**Equation 5** \[ \text{FPS}_2 = \text{Greater of (FAR}_{\text{max}}, \text{ SCR}) \times \text{SFP}_{\text{central}} \]

Where \( \text{SFP}_{\text{central}} = 1.80 \text{ W per l/s} \) and \( \text{SFP}_{\text{terminal}} = 0.30 \text{ W per l/s} \)

“\( \text{FAR}_{\text{max}} \)” is the peak fresh air supply rate (l/s/m²) that is set by the activity type in the NCM Activity database, while “\( \text{SCR} \)” is the space conditioning supply rate (i.e. the air flow rate needed to condition the space, in l/s/m²), and is calculated as follows:

**Equation 6** \[ \text{SCR} = \text{Greater of (PSH, PSC)} / (\rho \times \text{C}_p \times \Delta T) \]

Where \( \rho = 1.2 \text{ kg/m}^3 \), \( \text{C}_p = 1.018 \text{ kJ/kgK} \), and \( \Delta T = 8 \text{K} \)

“\( \text{PSH} \)” is the peak space heating load, and “\( \text{PSC} \)” is the peak space cooling load (i.e. in W/m² of floor area for each zone). For both parameters, the effects of thermal mass will be ignored. The peak space heating load is the sum of the steady state peak fabric losses and infiltration load based on an external ambient of 0 °C. The peak space cooling load is the sum of the individual peaks for occupancy, equipment, general lighting, display lighting, and solar. For SBEM, the peak solar gain is calculated using the solar data for September from Table 2.30 of CIBSE Guide A (using the beam and diffuse solar for each hour between 06:30 and 18:30). The total solar gain for each room is calculated, and the peak hour is used. DSM software will use the peak solar calculated during simulation.

70. The notional building benefits from variable speed pumping with multiple pressure sensors in the system.

71. For zones where the ventilation system does not provide heating or cooling (but can include heat recovery), the fan power density is the product of the fresh air supply rate for the activity type from the NCM Activity database and a specific fan power of 0.90 W per l/s.

72. For zones with local mechanical exhaust where the fan is within the zone, the fan power density is the product of the user-defined exhaust rate and a specific fan power of 0.40 W per l/s. For zones where the mechanical exhaust is remote from the zone, the fan power density is the product of the user-defined exhaust rate and a specific fan power of 0.60 W per l/s. The exhaust fan energy will be an addition to the fan energy for supply ventilation. Note that the user-defined exhaust rate is not considered in the air load calculations.

73. In zones with mechanical ventilation, the notional building benefits from demand control of ventilation through variable fan speed control based on CO₂ sensors.

74. The notional building has a power factor above 0.95 and automatic monitoring and targeting with alarms for out-of-range values (i.e. the adjustment factors in clause 6.1.7 Adjustment of BER of the 2015 Non-Domestic Technical Handbook apply).
Lighting power density

75. The general lighting in the notional building is based on lighting with efficacy of 60 luminaire lumens per circuit-watt for heated only zones and 65 luminaire lumens per circuit-watt for heated and cooled and heated and mechanically ventilated zones and top-lit, heated only warehouses, and the resulting power density (W/m²) will vary as a function of the geometry of each zone modelled, which will be determined using the following equation:

**Equation 7 = 60 luminaire lumens per circuit-watt**

\[
\text{Power density per 100 lux} = \frac{1.93 + 0.007 \times R + 0.063 \times R^2}{\text{MF}}
\]

**Equation 8 = 65 luminaire lumens per circuit-watt**

\[
\text{Power density per 100 lux} = \frac{1.79 + 0.007 \times R + 0.058 \times R^2}{\text{MF}}
\]

Where R is the ratio of the total wall area\(^{20}\) to the total floor area, where the maximum value for R is 8, and MF is the maintenance factor which, for the notional building, is taken as 0.8. The power density per 100 lux is then multiplied by the illuminance level for the activity type, which is determined by the NCM Activity database, and divided by 100. This equation was derived using regression analysis of parametric results produced using lighting design software for a range of space geometries and lighting systems.

76. All zones in the notional building which receive natural daylight directly (i.e. through glazing in the external walls of the zone) will be modelled with photo-electric dimming (as defined in the SBEM Technical Manual\(^{21}\)), without back-sensor control and with continuous (i.e. always on) parasitic power that is the lesser of either: 3% of the installed lighting load or 0.3 W/m².

77. Zones in the notional building which do not receive natural daylight directly (i.e. through glazing in the external walls of the zone), but are flagged in the NCM Activity database as appropriate to receive local manual switching, will be modelled with local manual switching (as defined in the SBEM Technical Manual\(^{21}\)) provided the floor area of the zone is less than 30 m². Otherwise, the general lighting is switched centrally based on the occupancy hours for the activity in the NCM Activity database.

78. Zones in the notional building do not benefit from constant illuminance control.

79. All zones in the notional building will be modelled with occupancy sensing (as defined in the SBEM Technical Manual) in the form of a “Manual-on-Auto-off” system (i.e. lights are manually switched on and automatically switched off when no movement has been detected for a set time, e.g. 5-15 minutes) with a continuous (i.e. always on) parasitic power density of 0.3 W/m².

---

\(^{20}\) For the purposes of the lighting power density calculation, the total wall area includes exposed facades and internal partitions, but not virtual partitions/walls used to define perimeter zones in open plan areas. The floor area should exclude voids in the floor or virtual ceilings.

\(^{21}\) SBEM Technical Manual (for SBEM version 5) available at [https://www.uk-ncm.org.uk/](https://www.uk-ncm.org.uk/)
80. The display lighting in the notional building is based on the display lighting power density from the NCM Activity database multiplied by 0.682 (i.e. adjustment between lamp efficacy of 22 and 15). Daylight harvesting and local manual switching do not apply to display lighting in the notional building (i.e. only affects general lighting).

81. The display lighting in the notional building does not benefit from automatic time switch control.

82. Both general lighting and display lighting (where appropriate) will use the same operating profile as defined in the NCM Activity database for each activity.

The target emission rate (TER)

83. The Notional Building includes an allowance for low and zero carbon technologies represented, as a proxy, by the inclusion of roof mounted photovoltaic panels. The notional building is therefore assumed to include onsite electrical generation equal to the lesser of Equation 9 or Equation 10 below:

   \[
   \text{Equation 9} \quad \text{Notional onsite electrical generation} = 4.5\% \times \text{GIA} \times 120 \text{ kWh/m}^2
   
   \text{Equation 10} \quad \text{Notional onsite electrical generation} = 50\% \times \text{roof area} \times 120 \text{ kWh/m}^2
   \]

84. Equation 9 models an area of photovoltaic panels equivalent to 4.5% of the actual building’s gross internal area assuming photovoltaic panels with an output of 850 kWh/kW(p) and 7 m²/kW(p). Equation 10 ensures that the area of photovoltaic assumed in the notional building is never larger than 50% of the building’s roof area.

85. The TER is the CO₂ emission rate of the 2015 Notional building.

THE ACTUAL BUILDING

86. The following paragraphs outline specific requirements for how the actual building is modelled that apply to both SBEM and DSM software.

Building fabric

87. Smoke vents and other ventilation openings such as intake and discharge grilles must be disregarded in the actual, and notional buildings, and their area substituted by the relevant (i.e. immediately surrounding) opaque fabric (roof or wall).

88. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be allowed for by adding 10% to the standard area-weighted average U-values, or by an equivalent method that satisfies BS EN ISO 14683, and be consistently applied to both Actual and Notional buildings.

89. Where an equivalent method that satisfies BS EN ISO 14683 is used to take account of nonrepeating thermal bridges in the Actual building, the user will have the option of either directly entering the relevant Psi values or use defaults as specified in Table 9 (based on BRE IP 1/0616 values degraded by the greater of 0.04 W/mK or 50%). Where the user
directly enters the Psi values, these values must be from a recognised source, such as published construction detail sets and/or have been calculated by a person with suitable expertise and experience\(^{22}\) following the guidance set out in BR497\(^{23}\).

<table>
<thead>
<tr>
<th>Type of junction</th>
<th>Involving metal cladding</th>
<th>Not involving metal cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof to wall</td>
<td>0.42</td>
<td>0.18</td>
</tr>
<tr>
<td>Wall to ground floor</td>
<td>1.73</td>
<td>0.24</td>
</tr>
<tr>
<td>Wall to wall (corner)</td>
<td>0.38</td>
<td>0.14</td>
</tr>
<tr>
<td>Wall to floor (not ground floor)</td>
<td>0.04</td>
<td>0.11</td>
</tr>
<tr>
<td>Lintel above window or door</td>
<td>1.91</td>
<td>0.45</td>
</tr>
<tr>
<td>Sill below window</td>
<td>1.91</td>
<td>0.08</td>
</tr>
<tr>
<td>Jamb at window or door</td>
<td>1.91</td>
<td>0.09</td>
</tr>
</tbody>
</table>

### Lighting

90. Lighting is defined at zone level. The user sets the required general power density (W/m\(^2\)) to achieve the design illuminance in each zone provided that the design illuminance is equal to or greater than the NCM lighting level for the activity in the Activity database. Where the design illuminance is less than the NCM activity lighting level, the general power density will be automatically pro-rated to the NCM activity lighting level. For example, an office with installed lighting load density of 6 W/m\(^2\) that delivers 300 lux illuminance (i.e. 2 W/m\(^2\) per 100 lux) would be adjusted to 8 W/m\(^2\) for the purpose of compliance because the NCM activity assumes 400 lux illuminance.

91. In the case of modular and portable buildings where the date of manufacture of 70% of the modules making up the external envelope is prior to 1 October 2015, the calculated power density will always be pro-rated to the NCM activity lighting level if the design illuminance is different, i.e. whether it is greater or less.

92. For building regulations compliance, the general lighting can be defined explicitly, by calculating and inputting the design/installed circuit power, or by inference, but the resulting wattage in each zone must be reported in the SBEM Specification Information summary. Where general lighting is defined by calculation, a maintenance factor should be applied that is appropriate to the lighting installation as defined in the Society of Light and Lighting (SLL) Lighting Handbook.

93. For general lighting, the following inference methods can be used in addition to the explicit method to demonstrate compliance with Section 6 in terms of general lighting:

\(^{22}\) Further information available in the Introduction to the Accredited Construction Details (Scotland) 2015.

\(^{23}\) BR497 Conventions for calculating linear thermal transmittance and temperature factors, BRE, 2007.
• **Inference method 1** - User sets the lamp efficacy in lumens per circuit-watt and the light output ratio of the luminaire, to determine the efficacy of the lighting system in terms of luminaire lumens per circuit-watt, which can be pro-rated against the notional lighting curve *(which is based on 60 luminaire lumens per circuit-watt for heated only zones and 65 luminaire lumens per circuit-watt for heated and cooled and heated and mechanically ventilated zones and top-lit, heated only warehouses)* defined by **Equation 7** to infer a power density for the general lighting. The user can also input the design illuminance in the zone, if known, and the power density will then be subject to be pro-rated following paragraph 90 above.

• **Inference method 2** - User assigns a lamp type to each zone based on Table 11, where the luminaire efficacy can be pro-rated against the notional lighting curve *(which is based on 60 luminaire lumens per circuit-watt for heated only zones and 65 luminaire lumens per circuit-watt for heated and cooled and mechanically ventilated zones and top-lit, heated only warehouses)* defined by **Equation 7** to infer a power density for the general lighting. The user can also input the design illuminance in the zone, if known, and the power density will then be subject to be pro-rated following paragraph 90 above.

<table>
<thead>
<tr>
<th>Lamp type</th>
<th>Luminaire lumens per circuit-watt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Side-lit and unlit activities</td>
</tr>
<tr>
<td>LED(^{24})</td>
<td>50.0</td>
</tr>
<tr>
<td>Tungsten and Halogen</td>
<td>7.5</td>
</tr>
<tr>
<td>fluorescent - compact</td>
<td>22.5</td>
</tr>
<tr>
<td>T12 fluorescent - halophosphate - low frequency ballast</td>
<td>25.0</td>
</tr>
<tr>
<td>T8 fluorescent - halophosphate - low frequency ballast</td>
<td>27.5</td>
</tr>
<tr>
<td>T8 fluorescent - halophosphate - high frequency ballast</td>
<td>32.5</td>
</tr>
<tr>
<td>T8 fluorescent - triphosphor - high frequency ballast</td>
<td>36.3</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>25.0</td>
</tr>
<tr>
<td>High Pressure Mercury</td>
<td>22.5</td>
</tr>
<tr>
<td>High Pressure Sodium</td>
<td>35.0</td>
</tr>
<tr>
<td>T5 fluorescent - triphosphor-coated - high frequency ballast</td>
<td>37.5</td>
</tr>
<tr>
<td>fluorescent (no details)</td>
<td>22.5</td>
</tr>
</tbody>
</table>

94. The general lighting in the actual building will include the capability of modelling daylight harvesting, local manual switching (where appropriate), and occupancy sensor control (as defined in the SBEM Technical Manual). It will also include the capability of

\(^{24}\) Inference method 2 and LED lamp type - v5.3a calculation applies a value of 27.5 (side/unlit) and 33.0 (top-lit) in Table 11. These values are updated by v5.4b to be more representative of typical LED lamp efficacy.
modelling constant illuminance control (as defined in BS EN 15193:2007) by reducing the general lighting power density by 10%, if applicable.

95. The daylight contribution from display windows should be included in the consideration of daylight harvesting.

96. Display lighting will be defined in terms of the average display lighting lamp efficacy for each zone, which will be pro-rated against an efficacy of 15 lamp lumens per circuit-watt to adjust the NCM display lighting value associated with the activity.

97. For Section 6 compliance, any zone where the display lighting has efficacy less than 22 lamp lumens per circuit-watt will be reported in the SBEM Specification Information summary as not meeting the backstop value noted in the Non-Domestic Building Services Compliance Guide (Table 42 Recommended minimum lighting efficacy with controls in new and existing buildings).

98. There will be an option for assigning automatic time-switching control at zone level for display lighting in the actual building that will result in the annual display lighting energy being reduced by 20%.

99. Both general lighting and display lighting (where appropriate) will use the same operating profile as defined in the NCM Activity database for each activity.

Auxiliary energy

100. The following paragraphs outline how auxiliary energy should be calculated in both SBEM and DSM software.

101. DSM software should not allow the user to directly set the auxiliary power density. The users of DSM software should only be allowed to define the HVAC systems type, specific fan powers, and associated controls (i.e. demand control of ventilation, variable speed pumping, etc.).

102. The auxiliary energy is the product of the auxiliary power density and annual hours of operation of the heating system from the NCM Activity database (i.e. the hours when the heating set-point is above the set-back temperature based on the daily/weekly/annual schedules or the “SYS_HEAT_T_HOURS_#” from the “activity_sbem_D1_ACU” table in the NCM Activity database).

103. The auxiliary power density is the sum of the pump and fan power density.

104. The pump power density for the actual building will depend on the type of HVAC system and whether the pump has variable speed control. Table 12 determines which HVAC system types need to account for pump power and whether the option of specifying variable speed pumping is made available to the user. Table 13 gives the pump power densities for constant speed pumping as well as variable speed pumping.

---

<table>
<thead>
<tr>
<th>HVAC system type</th>
<th>Pump power</th>
<th>Variable speed pumping allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central heating using water: radiators</td>
<td>LTHW only</td>
<td>Yes</td>
</tr>
<tr>
<td>Central heating using water: convectors</td>
<td>LTHW only</td>
<td>Yes</td>
</tr>
<tr>
<td>Central heating using water: floor heating</td>
<td>LTHW only</td>
<td>Yes</td>
</tr>
<tr>
<td>Central heating with air distribution</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Other local room heater - fanned</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Other local room heater - unfanned</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Unflued radiant heater</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Flued radiant heater</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Multiburner radiant heaters</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Flued forced-convection air heaters</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Unflued forced-convection air heaters</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Single-duct VAV</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Dual-duct VAV</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Indoor packaged cabinet (VAV)</td>
<td>Both LTHW and CHW</td>
<td>Yes</td>
</tr>
<tr>
<td>Fan coil systems</td>
<td>Both LTHW and CHW</td>
<td>Yes</td>
</tr>
<tr>
<td>Induction system</td>
<td>Both LTHW and CHW</td>
<td>Yes</td>
</tr>
<tr>
<td>Constant volume system (fixed fresh air rate)</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Constant volume system (variable fresh air rate)</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Multizone (hot deck/cold deck)</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Terminal reheat (constant volume)</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Dual duct (constant volume)</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Chilled ceilings or passive chilled beams and displacement ventilation</td>
<td>Both LTHW and CHW</td>
<td>Yes</td>
</tr>
<tr>
<td>Active chilled beams</td>
<td>Both LTHW and CHW</td>
<td>Yes</td>
</tr>
<tr>
<td>Water loop heat pump</td>
<td>Both LTHW and CHW</td>
<td>No</td>
</tr>
<tr>
<td>Split or multi-split system</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>Single room cooling system</td>
<td>None</td>
<td>No</td>
</tr>
</tbody>
</table>
### Table 13: Pump power density for Actual building (W/m²)

<table>
<thead>
<tr>
<th>Pump configuration</th>
<th>LTHW only</th>
<th>Both LTHW &amp; CHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant speed pumping</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Variable speed pumping with differential sensor across pump</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Variable speed pumping with differential sensor in the system</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Variable speed pumping with multiple pressure sensors in the system</td>
<td>0.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

105. For zones where the ventilation system also provides heating and/or cooling, the fan power density is determined for each zone using one of the following equations as determined by Table 14:

- **Equation 8** \( FPS_1 = \text{FAR}_{\text{max}} \times SFP_{\text{central}} + \text{SCR} \times SFP_{\text{terminal}} \)
- **Equation 9** \( FPS_2 = \text{Greater of } (\text{FAR}_{\text{max}}, \text{SCR}) \times SFP_{\text{central}} \)
- **Equation 10** \( FPS_3 = \text{Greater of } (\text{SCR}/5, \text{FAR}_{\text{max}}) \times SFP_{\text{central}} \)
- **Equation 11** \( FPS_4 = \text{FAR}_{\text{max}} \times SFP_{\text{central}} \)

“\( \text{FAR}_{\text{max}} \)” is the peak fresh air supply rate (l/s/m²) that is set by the activity type in the NCM Activity database, while “\( \text{SCR} \)” is the space conditioning supply rate (i.e. the air flow rate needed to condition the space, in l/s/m²), and is calculated as follows:

- **Equation 12** \( \text{SCR} = \text{Greater of } (\text{PSH}, \text{PSC}) / (\rho \times C_p \times \Delta T) \)

Where \( \rho = 1.2 \text{ kg/m}^3 \), \( C_p = 1.018 \text{ kJ/kgK} \), and \( \Delta T = 8K \)

“\( \text{PSH} \)” is the peak space heating load, and “\( \text{PSC} \)” is the peak space cooling load (i.e. in W/m² of floor area for each zone). For both parameters, the effects of thermal mass will be ignored. The peak space heating load is the sum of the peak steady state fabric losses and infiltration load based on an external ambient of 0°C.

For SBEM, the peak space cooling load is the sum of peak internal gains, which will include occupancy, equipment, general lighting, display lighting, and peak solar gains. The peak solar gain is calculated using the solar data for September from Table 2.30 of CIBSE Guide A (using the beam and diffuse solar for each hour between 06:30 and 18:30). The total solar gain for each zone is calculated and peak hour is used. DSM software are allowed to use the peak solar calculated during simulation.
106. The fan power density equations are assigned to HVAC systems based on Table 14.

<table>
<thead>
<tr>
<th>HVAC system type</th>
<th>SBEM ID</th>
<th>Fan power density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan coil systems</td>
<td>4</td>
<td>Equation 8</td>
</tr>
<tr>
<td>Indoor packaged cabinet (VAV)</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Central heating using air distribution</td>
<td>2</td>
<td>Equation 9</td>
</tr>
<tr>
<td>Constant volume system (fixed fresh air rate)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Constant volume system (variable fresh air rate)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Single-duct VAV</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Water loop heat pump</td>
<td>13</td>
<td>Equation 10</td>
</tr>
<tr>
<td>Dual duct (constant volume)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Multi-zone (hot deck/cold deck)</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Terminal reheat (constant volume)</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Dual-duct VAV</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Active chilled beams</td>
<td>12</td>
<td>Equation 11</td>
</tr>
<tr>
<td>Induction system</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Chilled ceilings or passive chilled beams and displacement ventilation</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

107. For zones where the ventilation system does not provide heating or cooling (but can include heat recovery), the fan power density is the product of the fresh air supply rate for the activity type from the NCM Activity database and the specific fan power defined by the user at zone level.

108. For zones with mechanical exhaust, the fan power density is the product of the user-defined exhaust rate and the specific fan power defined by the user. The exhaust fan energy will be an addition to the fan energy for supply ventilation. Note that the user defined exhaust rate is not considered in the air load calculations.

109. For zones served by the HVAC systems listed in Table 14a, additional fan energy is included to account for integral fans using the ratio (to be input by the user) of associated fan power, in W per kW of heat output (delivered) by the heating system.

<table>
<thead>
<tr>
<th>HVAC system type</th>
<th>SBEM ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central heating using water; convectors (but only in cases where the system utilises fanned convectors)</td>
<td>24</td>
</tr>
<tr>
<td>Other local room heaters (fanned)</td>
<td>3</td>
</tr>
</tbody>
</table>

This element applies to v5.4b calculations but is absent in the previous v5.3a calculation.
110. Energy for other ancillary services in the building, such as secondary hot water circulation, de-stratification fans, forced circulation for solar water heating systems, etc. will be an addition to the fan and pump energy.

### Demand control of ventilation

111. The actual building will include the ability to model demand control of ventilation for zones with mechanical ventilation (but excluding exhaust-only systems) while for naturally ventilated zones, there will be the option of enhanced ventilation control (this refers to natural ventilation with BMS control, i.e. modifying the ventilation flow rate provided by natural means in the space based on some form of control). The details for implementing demand-controlled ventilation (as defined in the SBEM Technical Manual) are outlined below.

112. For zones with mechanical ventilation (but excluding exhaust-only ventilation), the following options will be available to the user:
   - a. No demand-controlled ventilation *(default option)*
   - b. Demand control based on occupancy density
   - c. Demand control based on gas sensors

   If the option selected is either (b) or (c) from above, then the parameter “air flow regulation type” will become active with the following options available to the user:
   - a. Damper control *(default option)*
   - b. Speed control

113. For zones with natural ventilation, the following options will be available to the user:
   - a. No demand-controlled ventilation *(default option)*
   - b. Enhanced ventilation

114. Depending on user inputs, a modified demand control fresh air rate \((FAR_{dc})\) is determined from the NCM fresh air rate \((FAR_{max})\) for the activity.

   **Equation 13**  
   \[
   FAR_{dc} = C_{dc} \times FAR_{lower} + (1 - C_{dc}) \times FAR_{max}
   \]

   where:
   - \(FAR_{max}\) is the ventilation rate per person from the NCM Activity database multiplied by the peak occupancy density during the occupied period (i.e. l/s/m²).
   - \(FAR_{min}\) is the ventilation rate per person from the NCM Activity database multiplied by the minimum occupancy density during the occupied period (i.e. this can be zero for some activities).
   - \(FAR_{lower}\) is the greater of either: \(FAR_{min}\) or \(0.6 \times FAR_{max}\).
   - \(C_{dc}\) = is a demand control coefficient and is determined based on the data in Table 15.
Table 15: Values for demand control coefficient

<table>
<thead>
<tr>
<th>Type of demand control</th>
<th>Demand control coefficient ($C_{dc}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Control based on occupancy density</td>
<td>0.85</td>
</tr>
<tr>
<td>Control based on gas sensor</td>
<td>0.95</td>
</tr>
<tr>
<td>Enhanced natural ventilation</td>
<td>0.50</td>
</tr>
</tbody>
</table>

115. In addition to affecting the fresh air load (i.e. energy to heat and cool the fresh air), demand control of ventilation can also affect the auxiliary energy. Where the air flow regulation uses fan speed control (i.e. using variable speed fans), the auxiliary energy calculation will use $FAR_{dc}$ instead of $FAR_{max}$, but if the air flow regulation uses damper control, then the auxiliary energy calculation will not be affected.

**Shell buildings**

116. In the context of application for building warrant, a shell building is defined as a building where elements of the fixed building services are absent and further installation work will be required before the building can be occupied and used. A staged building warrant, covering both shell and subsequent fit-out work, is not subject to the following process.

117. Shell buildings are subject to the compliance check against the TER under the conditions specified in clause 6.1.10 of Section 6. Guidance on provisions and details of the limiting standards for shell and fit-out buildings are specified in clauses 6.2.3, 6.2.4, 6.2.5, and 6.2.6 of Section 6.

118. Assessment under standard 6.1 is required both for the shell building warrant and also for the subsequent fit-out works, provided a continuing requirement in this respect is placed upon the shell warrant. Regardless of whether or not a building warrant is required for fit-out work, this continuing requirement must be discharged before the building can be occupied (refer to clause 5.6 of the BSD Procedural Handbook[^28]). Assessment of the fit-out work should be made using the category ‘other buildings’ under ‘S6 type of building’.

119. Assessment of the shell building should show that the building, as completed, could meet standard 6.1. This is done by providing a completed service specification for each zone, identifying which services are to be installed as part to shell works and which are assumed to form part of a subsequent fit-out. Assumed (uninstalled) services should be defined at zone level by identifying whether the zone is a fit-out area (approved software tools must allow for this identification). iSBEM enables this by providing a tick-box within the Geometry/ Zones tab if ‘shell building’ is selected under ‘S6 type of building’.

120. Energy associated to HVAC, lighting and HW systems serving ‘fit-out’ zones will be accounted for as normal in the calculation, which will assume that fit-out services are fully operational, designated temperatures are maintained, lighting and hot water provided in all zones. That means the boundary conditions between zones are unaffected. The calculation for the notional building is unaffected by this process.

121. Where these procedures apply to compliance with standard 6.1, EPC generation is also required for both shell and fit out stage of such a building.

**Modular and portable buildings**

122. For modular and portable buildings with an intended life of more than two years, the TER must be adjusted as described in Annex 6.C of Section 6. Annex 6.C also specifies the fabric limiting standards for these types of buildings. Approved tools must allow users to specify the necessary information to apply such adjustments. Users are expected to follow guidance in Section 6 to correctly populate these fields.

**Extensions to the insulation envelope**

123. Large extensions (extensions to non-domestic buildings where the extension will have an area which is both greater than 100 square metres and greater than 25% of the area of the existing building) must, from 1 October 2015, demonstrate compliance with the carbon dioxide emissions standard 6.1.

124. For all other extensions to the insulation envelope, the new building fabric should be designed to achieve the elemental performance set out in guidance clause 6.2.11 of Section 6. Alternatively, as noted in that clause, it is possible to assess the extension in isolation from the existing building or, alternatively, assess the entire building as extended using SBEM. Both these approaches are compatible with iSBEM.

**CHECKING SOLAR GAINS**

125. This section describes how solar gains should be checked in the actual building.

126. The solar gain check will include any zone in the actual building that is either receiving cooling or has an activity that is flagged in the NCM Activity database as being an occupied space for which the solar gain check is applicable. Whether or not the solar gain check is applicable to the activity is determined in the “activity” table from the NCM Activity database in the “SOLAR_GAIN_CHECK” field (0 for activity with no solar gain check, and 1 for activity with solar gain check).

127. The solar gain in the actual building is calculated at the point of absorption into the internal surfaces of each zone and includes the solar gain absorbed in the glazing and/or blinds, which subsequently enters the space via conduction/ radiation/ convection.
128. The contribution of solar gain from display windows will be checked for zones where the solar gain check applies.

129. The solar gain check is based on the solar gains through the benchmark glazing types described in Table 16, and selected according to paragraph 133, aggregated over the period from April to September, and using the same CIBSE TRY weather data used for the carbon dioxide emissions calculations (standard 6.1).

<table>
<thead>
<tr>
<th>Benchmark glazing type</th>
<th>Description</th>
<th>Glazing dimensions/ area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vertical glazing facing east with 10% frame factor and g-value of 0.68</td>
<td>Height of 1m and width equal to the total exposed facade* width of the zone being checked</td>
</tr>
<tr>
<td>2</td>
<td>Horizontal glazing with 25% frame factor and g-value of 0.68</td>
<td>Area equal to 10% of the total exposed roof area</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal glazing with 15% frame factor and g-value of 0.46</td>
<td>Area equal to 20% of the total exposed roof area</td>
</tr>
</tbody>
</table>

* The exposed facade width should take into account opaque/translucent wall elements, as well as external doors, external windows, and curtain walling systems.

130. The treatment of solar gains entering a space will vary between DSM software so for DSM software, it is necessary to define a standard test-space for each benchmark glazing type (refer to Figure 1 to Figure 3) that meets the requirements of Table 16. This allows the pre-calculation of the benchmark aggregated solar gain as a function of facade length and exposed roof area (i.e. kWh/m and kWh/m² respectively). This means that each DSM will have 3 values for benchmark aggregated solar flux for each CIBSE TRY weather data set.

131. The standard test spaces will have solar absorptance of 0.5 for all internal surfaces. The external ground reflectance should be 0.2. The glazing should use the appropriate glass data provided in Table 17 and Table 18 (where $T_{solar}$ is the direct solar transmittance, $T_{visible}$ is the direct visible light transmittance, $R_{solar}$ is the solar reflectance, and $R_{visible}$ is the visible light reflectance. The subscripts 1 and 2 refer to the outer and inner surfaces of each pane of glass respectively).

132. As part of validation, DSM software must to declare the benchmark aggregated solar flux values. Once approved, the declared benchmark aggregated solar flux values cannot be changed unless re-validation is carried out.

133. The solar gain limit is calculated and checked on a zone-by-zone basis in the actual building, using the following methods:

a. For zones with side-lit or unlit activities:
For each zone with exposed facade area greater than zero, the limiting solar gain will be the aggregated solar flux for benchmark glazing type 1 multiplied by the exposed facade length.

For each zone with zero exposed facade area (i.e. an internal zone that receives second hand solar gains), the limiting solar gain will be the aggregated solar flux for benchmark glazing type 2 multiplied by either the projected floor area or the exposed roof area (whichever is greater).

b. For zones with top-lit activities:
   - For each zone where the height\(^{29}\) is less than 6m, the solar gain limit will be the aggregated solar flux for benchmark glazing type 2 multiplied by either the projected floor area or the exposed roof area (whichever is greater).
   - For each zone where the height\(^{29}\) is greater than or equal to 6m, the solar gain limit will be the aggregated solar flux for benchmark glazing type 3 multiplied by either the projected floor area or the exposed roof area (whichever is greater).

134. The total solar gain aggregated over the period from April to September for each zone in the actual building where the solar gain check applies, will have to be less than or equal to the limiting solar gain calculated based on the benchmark glazing types. For DSM software, the total solar gain should include external solar gain from all orientations and inclinations as well as any “second hand” solar gain from adjacent zones (i.e. via internal glazing/ holes/ virtual partitions).

135. The aggregated solar gain should not include the conduction gains via window frames or solar gains through opaque envelopment elements (e.g. sol-air temperature gains through the roof/ walls).

Table 17: Glass properties to achieve g-value of 0.68

<table>
<thead>
<tr>
<th>Thickness</th>
<th>T(_{\text{solar}})</th>
<th>R(_{\text{solar1}})</th>
<th>R(_{\text{solar2}})</th>
<th>T(_{\text{visible}})</th>
<th>R(_{\text{visible1}})</th>
<th>R(_{\text{visible2}})</th>
<th>Emissivity 1</th>
<th>Emissivity 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer pane</td>
<td>6 mm</td>
<td>0.783</td>
<td>0.072</td>
<td>0.072</td>
<td>0.889</td>
<td>0.081</td>
<td>0.081</td>
<td>0.837</td>
</tr>
<tr>
<td>Cavity</td>
<td>12 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner pane</td>
<td>6 mm</td>
<td>0.664</td>
<td>0.111</td>
<td>0.092</td>
<td>0.822</td>
<td>0.109</td>
<td>0.098</td>
<td>0.170</td>
</tr>
</tbody>
</table>

Table 18: Glass properties to achieve g-value of 0.46

<table>
<thead>
<tr>
<th>Thickness</th>
<th>T(_{\text{solar}})</th>
<th>R(_{\text{solar1}})</th>
<th>R(_{\text{solar2}})</th>
<th>T(_{\text{visible}})</th>
<th>R(_{\text{visible1}})</th>
<th>R(_{\text{visible2}})</th>
<th>Emissivity 1</th>
<th>Emissivity 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer pane</td>
<td>4 mm</td>
<td>0.468</td>
<td>0.165</td>
<td>0.185</td>
<td>0.654</td>
<td>0.104</td>
<td>0.026</td>
<td>0.837</td>
</tr>
<tr>
<td>Cavity</td>
<td>12 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner pane</td>
<td>4 mm</td>
<td>0.821</td>
<td>0.074</td>
<td>0.074</td>
<td>0.896</td>
<td>0.081</td>
<td>0.081</td>
<td>0.837</td>
</tr>
</tbody>
</table>

\(^{29}\) For zones with pitch roofs, use the average height.
Figure 1 Isometric view of standard test-space for benchmark glazing type 1

Figure 2 Isometric view of standard test-space for benchmark glazing type 2

Figure 3 Isometric view of standard test-space for benchmark glazing type 3
ENERGY PERFORMANCE CERTIFICATES (EPCs)

136. Energy Performance Certificates (EPCs) provide prospective buyers/tenants with information about the energy performance of a building and practical advice on improving performance. Cost effective recommendations for improving the energy performance of the building detailed on the certificate must meet the Scottish building regulations, be specific to the individual building and be technically feasible. The EPC displays the “rating” of a building in the form of the approximate annual Building CO₂ Emission Rate (BER) in kg per m² of floor area per year, rated on a seven band scale (see guidance to standard 6.9 in Section 6).

137. While an EPC is not required for permanently unconditioned buildings (i.e. buildings which do not use energy to condition the indoor climate and are expected to remain this way), it is possible to voluntarily produce EPCs for unconditioned buildings. Permanently unconditioned buildings are different to those which are currently unconditioned but are intended to be conditioned prior to occupation, and which should be modelled as per the guidance on shell and fit out buildings in Section 6. Further guidance on EPCs is provided in the BSD website\(^{30}\).

138. The EPC ‘A to G’ scale and energy labels present the calculated value of the BER are displayed on a seven band graphical scale where a letter band corresponding to a range of emissions ratings, with “A+ (net zero carbon or better)” being the most efficient (followed by “A”) and “G” being the least efficient.

<table>
<thead>
<tr>
<th>BER</th>
<th>A+ (net zero carbon or better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>0.0    &lt; BER ≤ 15.0</td>
<td>A</td>
</tr>
<tr>
<td>15.0   &lt; BER ≤ 30.0</td>
<td>B</td>
</tr>
<tr>
<td>30.0   &lt; BER ≤ 45.0</td>
<td>C</td>
</tr>
<tr>
<td>45.0   &lt; BER ≤ 60.0</td>
<td>D</td>
</tr>
<tr>
<td>60.0   &lt; BER ≤ 80.0</td>
<td>E</td>
</tr>
<tr>
<td>80.0   &lt; BER ≤ 100.0</td>
<td>F</td>
</tr>
<tr>
<td>100.0  &lt; BER</td>
<td>G</td>
</tr>
</tbody>
</table>

\(^{30}\) [http://www.gov.scot/epc](http://www.gov.scot/epc)
139. The EPC is accompanied by a “Recommendations Report”, which contains a list of NCM recommendations, edited and added to by the assessor, for the improvement of the energy performance of the building and their respective potential impact on the CO$_2$ emission rate of the building. The recommendations are grouped into the following sub-sections in the report: short payback (up to 15 recommendations), medium payback (up to 10 recommendations), long payback (up to 5 recommendations), and other recommendations created by the assessor (up to 10 recommendations).

140. The EPC itself displays up to six recommendations, beginning with the short payback (i.e. three years or less) NCM recommendations. If there are user-defined or user-edited recommendations, then the EPC displays the top 3 NCM cost effective recommendations with a payback period of three years or less and up to 3 user recommendations with the shortest payback.

141. The impact of the recommendations on the CO$_2$ emission rate of the building and their estimated payback\(^{31}\) is assessed based on the energy performance of the actual and notional buildings.

**Other reference values**

142. In addition to the building rating, the EPC displays two reference values as follows:

a. The potential rating of the actual building had it been built to building regulations standards current at the date of issue of the EPC.

b. The potential rating of the actual building if recommended cost-effective improvements were applied. Assessors can use the software tool to determine that improved rating by creating a scenario within the building model, in which to implement their selected cost-effective recommendations and running the calculation again. The value of the improved rating can then be inserted into the software tool and will be recorded as part of the XML output used to lodge data to the EPC register.

143. The EPC also displays other information such as, the approximate annual energy use of the building, in kWh/m$^2$ of floor area, the main heating fuel, the electricity source, the ventilation strategy and the main renewable energy source in the building (if applicable) and the calculation tool used to produce the assessment.

\(^{31}\) Details of the logic used for generating the NCM recommendations, their impacts, and paybacks are in the SBEM Technical Manual available from the NCM website at [https://www.uk-ncm.org.uk/](https://www.uk-ncm.org.uk/).
APPENDIX A - INPUT DATA TO APPROVED TOOLS

144. This section of the guide describes generally applicable approaches to data input and
tmodelling strategies, and it applies equally to Section 6 compliance and EPCs and
also to the modelling of the actual and notional buildings.

Defining internal gains and environmental conditions

145. In order to facilitate estimating energy performance on a consistent basis, a key part
of the NCM is an Activity database that defines the activities in various types of space
in different classes of building\(^\text{32}\). One of these standard activities must be assigned to
each space in the building\(^\text{33}\).

146. A 2015 version of the NCM Activity database has been updated from 2010 to
accompany the 2015 version of the NCM Modelling Guide.

147. The NCM Activity Database provides standard occupancy, temperature set-points,
outdoor air rates and heat gain profiles for each type of space in the building so that
buildings in Scotland with the same mix of activities will differ only in terms of their
geometry, construction, and building services. Thus, it is possible for the Section 6
compliance checks and EPCs to compare buildings on the basis of their intrinsic
potential performance, regardless of how they may actually be used in practice.

148. The fields of information in the database are as follows:

a. Occupancy times and density; total metabolic rate and percentage which is latent
   (water vapour);

b. Set-point temperature and humidity in heating and cooling modes; DSM software
   will use air temperature as the basis for temperature set-points for the actual and
   notional buildings;

c. Set-back conditions for unoccupied periods;

d. Sensible and latent heat gain from other sources;

e. Outside air requirement;

f. Level of illuminance for general lighting and the power density for display lighting;

g. Hot water demand;

h. Type of space for glazing, lighting, and ventilation classification within Section 6
   compliance;

i. A marker indicating whether the activity requires high efficiency filtration, thereby
   justifying an increased SFP allowance for that space to account for the increased
   pressure drop.

149. If there is not an activity in the Activity Database that reasonably matches the
intended use of a space, then this could be raised with the database managers (see

\(^{32}\) The NCM databases (Activity, Construction, and Glazing) can be downloaded from https://www.uk-ncm.org.uk/.

\(^{33}\) In a school, these activities might be teaching classrooms, science laboratories, gymnasiums, eating areas, food preparation, staff
room, circulation spaces or toilets. The parameter values vary between building types – e.g. offices in schools are not the same as
those in office buildings.
NCM website\textsuperscript{34} for details), and an appropriate new activity may be proposed. This will be subject to peer review prior to formal acceptance into the database. Note that it is NOT acceptable for users to define and use their own activities. Consistent and auditable activity schedules are an important element of the compliance and certification processes, and so only approved activity definitions can be used for these purposes\textsuperscript{35}. If a special use space is present in the actual building, and no appropriate activity is available in the database, it is accepted that time pressures may preclude waiting for the specific activity definition to be developed, peer reviewed, and approved. In such situations, the assessor must use their technical expertise or seek guidance from appropriate sources in order to select the closest match from the approved database. Because compliance and certification are both based on the performance of the actual building in comparison to that of a notional building, the impact of this approximation should be minimised.

Constructions

150. The thermal performance of construction elements must take account of thermal bridges:

a. Repeating thermal bridges must be included in the calculated plane element U-value as detailed in BR443\textsuperscript{36}. Simulation tools that use layer by layer definitions will need to adjust thicknesses of insulation layers to achieve the U-value that accounts for the repeating thermal bridges.

b. Non-repeating thermal bridge heat losses must be allowed for by adding 10\% to the standard area-weighted average U-values, or by an equivalent method that satisfies BS EN ISO 14683, and be consistently applied to both Actual and Notional buildings.

151. Available on the NCM website are databases of calculated U-values, etc. (NCM Construction database and NCM Glazing database), and for consistency, all implementations of the NCM should preferably use these databases. It is accepted that a required construction may not always exist in the NCM database. In such cases, alternative sources of data may be used, but the person submitting for Section 6 compliance must declare this and demonstrate how the values were derived.

152. When using the software tool to generate an EPC for an existing building, the performance parameters for some constructions may not be known. In such situations, the parameters must be inferred based on the data provided in the NCM Construction database. This is an important aspect of ensuring consistency in energy rating calculations, and so all software tools must adopt these procedures. This will be checked as part of the approval process.

\textsuperscript{34} See https://www.uk-ncm.org.uk/.
\textsuperscript{35} Clearly designers may wish to use alternative bespoke schedules for particular design assessments, but these exist outside the compliance/certification framework.
\textsuperscript{36} https://www.bre.co.uk/filelibrary/pdf/rpts/BR_443_(2006_Edition).pdf
Low and zero carbon systems

153. The following approach must be followed when calculating the impact of on-site electrical generation for both Section 6 compliance and EPC calculations as applied to non-domestic buildings.

a. Calculate the annual electrical energy used by the building irrespective of source of supply. Multiply that demand by the grid average CO₂ emission factor.

b. Calculate the electricity generated by the on-site system and multiply that by the grid-displaced CO₂ emission factor, irrespective of the proportion of the electricity that is used on site and how much is exported.

c. The electricity-related CO₂ emissions used to establish the BER is the net figure i.e. ‘a minus b’ above.

d. Any fuel used in generating the electricity (e.g. in a CHP engine) is added (at its appropriate CO₂ emission factor) to arrive at the total building CO₂ emissions.

Weather location

154. In order to calculate the reaction of the building and systems to the variable loads imposed by the external environment, the NCM needs an input of weather data. A standard weather set has been adopted for Scotland which must be used.

Zoning rules

155. The way a building is sub-divided into zones will influence the predictions of energy performance. Therefore, this guide defines zoning rules that must be applied when assessing a building for the purposes of Section 6 compliance or producing the Energy Performance Certificate. The following procedure defines the approach to zoning for HVAC and lighting that must be followed.

156. The zoning arrangement must mimic the control strategy in the actual building, and the same zoning arrangement must then be applied in the Notional building. In the actual building, zoning is defined by the extent of the control systems that modulate the output of the HVAC and lighting systems. Mapping the physical control zones into modelling zones should be the starting point for the zoning procedure. Any further adjustment to the zoning should only be:

a. As specified in the following general guidance (see paragraphs 157 to 159); or

b. Where specific limitations are imposed by the modelling tool that is being used (e.g. where a tool only permits each modelled zone to comprise one thermal zone and one lighting zone).

---

37 This is the 2006 CIBSE Test Reference Year for Glasgow (see http://www.cibse.org)
Zone types

157. A thermal zone is an area that:
   a. Has the same heating and cooling set-points; and
   b. The same ventilation provisions; and
   c. Has the same plant operating times; and
   d. Has the same set-back conditions; and
   e. Is served by the same type(s) of terminal device; and
   f. Is served by the same primary plant; and
   g. Where the output of each type of terminal device is controlled in a similar manner.

158. A lighting zone is an area that:
   a. Has the same lighting requirement (levels and duration); and
   b. Is served by the same type(s) of lamp/ luminaire combination; and
   c. Where the output of the lighting system is controlled in a similar manner; and
   d. Has similar access to daylight, i.e. the zone is bounded with fenestration having similar glazing ratio, light transmittance, and orientation. This means that where benefit is being taken of daylight-linked controls (manual or automatic), a given lighting zone must not extend beyond ~6m from the perimeter.

159. For the purposes of modelling, a thermal zone can contain multiple lighting zones (e.g. daylight control at the perimeter with manual switching in the interior), but a lighting zone cannot extend across the boundary of a thermal zone. If this does occur in the actual building, the relevant lighting zone must be subdivided into multiple smaller zones. The boundaries of these smaller zones are defined by the boundaries of the thermal zones.

Combining adjoining thermal zones

160. Adjoining thermal zones (horizontally or vertically\textsuperscript{38}) may be combined into a single larger zone provided that:
   a. The zones are all the same in terms of the characteristics defined in paragraph 157 above; and
   b. The zones all have the same combination of activities inside them; and
   c. The zones all have the same combination of lighting zones within them; and
   d. The zones all have the same exposure to the external environment in terms of glazing percentages, glazing types, and orientation.

\textsuperscript{38} If combining zones vertically, the zone height input should be that of a single zone, not the vertical sum of the zones’ heights.
161. Where adjoining thermal zones are combined, then the partitions that separate the physical spaces must be included in the thermal zone in order to properly represent the thermal storage impact.

162. It is recommended that users make full use of features such as, the ‘multiplier’ function and merging of all contiguous similar areas, in order to generally avoid creating more than 100-150 zones in SBEM.

**Fuel emission factors**

163. The CO\(_2\) emission factors for fuels will be as defined in Table 19.

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Emission Factor (\text{kgCO}_2/\text{kWh})</th>
<th>Primary Energy Factor (\text{kWh/ kWh})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>0.216</td>
<td>1.22</td>
</tr>
<tr>
<td>LPG</td>
<td>0.241</td>
<td>1.09</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.098</td>
<td>1.10</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>0.319</td>
<td>1.10</td>
</tr>
<tr>
<td>Coal</td>
<td>0.345</td>
<td>1.00</td>
</tr>
<tr>
<td>Anthracite</td>
<td>0.394</td>
<td>1.00</td>
</tr>
<tr>
<td>Manufactured smokeless fuel (inc. Coke)</td>
<td>0.433</td>
<td>1.21</td>
</tr>
<tr>
<td>Dual fuel (mineral + wood)</td>
<td>0.226</td>
<td>1.02</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.031</td>
<td>1.01</td>
</tr>
<tr>
<td>Grid supplied electricity</td>
<td>0.519</td>
<td>3.07</td>
</tr>
<tr>
<td>Grid displaced electricity</td>
<td>0.519</td>
<td>3.07</td>
</tr>
<tr>
<td>Waste heat</td>
<td>0.058</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**HVAC**

164. For the actual building, DSMs may represent HVAC systems explicitly but will be required to report system seasonal performance parameters as an aid to checking (see paragraph 7c).

165. For DSM software that model HVAC with temperature control bands, the activity cooling/ heating set-points from the NCM Activity database should be used as the mid-band point, and the control band should be ±0.5 K or less.

**Lighting**

166. For Section 6 compliance, the lighting power density for activities such as storage warehouses and retail spaces, which have racking/shelving, should be adjusted to ignore these elements (as the notional building does not take these into account).
167. For Section 6 compliance, the lighting power density for activities which require special light fittings (e.g. intrinsically safe/anti-ligature luminaires), or where full spectrum daylight lamps are required (e.g. for medical purposes), should be adjusted to compensate for the de-rated output so that there is a fair comparison against the notional building. Such adjustments need to be clearly documented and justified to Building Control.

**Adjustment factors**

168. In order to eliminate discrepancies between approved calculation tools with regards to the stage at which to apply adjustment factors for enhanced management and control features from Section 6, clause 6.1.7, the following approach should be followed if adjustments are applicable:

a. Apply the adjustment factor due to power factor correction on the CO₂ emissions and primary energy consumption which are attributed to grid electricity in the building.

b. Apply the adjustment factor due to automatic monitoring and targeting with alarms for out-of-range values to the energy consumption attributed to the lighting or HVAC system with the M&T feature.

**Measurement and other conventions**

169. In order to provide consistency of application, standard measurement conventions must be used. These apply to both DSMs and third party software interfaces to SBEM, although some parameters may only relate to the latter. These conventions are specified in Table 20 below:

<table>
<thead>
<tr>
<th>Table 20: Measurement and other conventions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
</tbody>
</table>
| Zone Area | Floor area of zone calculated using the internal horizontal dimensions between the internal surfaces of the external zone walls and half-way through the thickness of the internal zone walls. Used to multiply area-related parameters in databases.  
*NB*: If the zone has any virtual boundaries, e.g. no walls in certain orientations, the area of the zone is that delimited by the ‘line’ defining the virtual boundary. |
| Envelope Area | Area of vertical envelopes (walls) = h × w, where:  
* h = floor to floor height, i.e. including floor void, ceiling void, and floor slab. For top floors, h is the height from the floor to the average height of the structural ceiling.  
* w = horizontal dimension of wall. Limits for that horizontal dimension are defined by type of adjacent walls. If the adjacent wall is external, the limit will be the internal side of the adjacent wall. If the adjacent wall is internal, the limit will be half-way through its thickness.  
*NB*: Areas of floors, ceilings, and flat roofs are calculated in the same manner as the zone area. Area for an exposed pitched roof (i.e. without an internal horizontal ceiling) will be the inner pitched surface area of the roof. |
### Table 20: Measurement and other conventions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Area</td>
<td>Area of the structural opening in the wall/roof; the area, therefore, includes the area of glass + frame.</td>
</tr>
<tr>
<td>HWS Dead-leg Length</td>
<td>Length of the draw-off pipe to the outlet in the space (only used for zones where the water is drawn off). Used to determine the additional volume of water to be heated because the cold water in the dead-leg has to be drawn off before hot water is obtained. Assumes that HWS circulation maintains hot water up to the boundary of the zone, or that the pipe runs from circulation or storage vessel within the zone.</td>
</tr>
<tr>
<td>Flat Roof</td>
<td>Roof with pitch of 10° or less. If greater than 10°, the roof is a pitched roof.</td>
</tr>
<tr>
<td>Pitched Roof</td>
<td>Roof with pitch greater than 10° and less than or equal to 70°. If the pitch is greater than 70°, it must be considered a wall.</td>
</tr>
<tr>
<td>Glazed door</td>
<td>When doors have more than 50% glazing, then the light/solar gain characteristics must be included in the calculation. This is achieved by defining these doors as windows and accounting for the opaque part in the frame factor parameter.</td>
</tr>
<tr>
<td>Curtain walling</td>
<td>For curtain walling systems, the translucent and transparent areas should be modelled as glazing and the opaque parts as wall.</td>
</tr>
</tbody>
</table>
APPENDIX B – EPBD RECAST

170. This section describes the added requirements of the recast Energy Performance of Buildings Directive (recast EPBD) with regards to the calculation methodology and output reports.

Primary energy consumption

171. A value for the total primary energy consumption by the actual building will be calculated, based on the predicted delivered energy consumption for each fuel and the corresponding primary energy factors, as defined in Table 19, and will be reported in the SBEM Specification Information summary.

172. When calculating the primary energy consumption of the building, any electrical energy generated by renewable technologies (principally photovoltaic (PV) systems and wind turbines) must be disregarded. However, electrical energy generated by CHP generators will be counted towards reductions in the primary energy use, i.e. the reported value for primary energy consumption will be net of any electrical energy displaced by CHP. In other words, the following approach must be followed:

173. Calculate the annual electrical energy used by the building irrespective of source of supply. Multiply that energy use by the grid supplied primary energy factor.

174. Calculate the electricity generated by any on-site CHP system and multiply that by the grid displaced primary energy factor, irrespective of the proportion of the electricity that is used on site and how much is exported.

175. The electricity related primary energy of the building is the net figure i.e. ‘a minus b’ above.

176. Any fuel used in generating the electricity (e.g. in a CHP engine) is added (at its appropriate primary energy factor) along with any other fuels used in the building (at their respective primary energy factors) to arrive at the total primary energy consumption of the building.

Alternative energy systems

177. Software tools will include additional questions for the user to confirm that the designers have considered in the new building design, the technical, environmental and economic feasibility of ‘high-efficiency alternative systems’, as defined in the recast EPBD (renewable energy systems, CHP, district heating/cooling, or heat pumps), and to confirm that there is documentary evidence of the feasibility assessment. Software tools should also ask if designers have included any such systems in the proposed design solution. The answers to these questions will be reported in the SBEM Specification Information summary.
178. This section includes screen grabs from the BRE U-value calculator (version 2.02) that show the construction details used as the basis for the data for thermal capacity values in Table 2. These construction details are for use by DSM software to account for the effect of thermal capacity.

179. DSM software generally use less sophisticated methods for calculating the U-value of constructions (i.e., they do not take account of repeating thermal bridges due to fixings, etc.). Therefore, where appropriate, the thickness of the insulation layer should be adjusted to achieve the same U-value as specified in Table 1.

Heated and naturally ventilated.

Heated and cooled or Heated and mechanically ventilated.

Heated and cooled or Heated and mechanically ventilated.
182. External wall construction details - 2015 Notional building (not involving metal cladding) –

Heated and naturally ventilated.

Heated and cooled or Heated and mechanically ventilated.
183. External wall construction details - 2015 Notional building (involving metal cladding) –

Heated and naturally ventilated.

Heated and cooled or

Heated and mechanically ventilated.
184. Exposed floor construction details - 2015 Notional building –

Heated and naturally ventilated.

Heated and cooled or Heated and mechanically ventilated.
**Ground floor construction details - 2015 Notional building** (note that the aspect ratio and edge insulation parameters have not been set as these details are intended only for determining the thermal capacity as viewed from inside) –

Heated and naturally ventilated.

Heated and cooled or Heated and mechanically ventilated.

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>d (mm)</th>
<th>R (mm²·K/W)</th>
<th>R (mm²·K/W)</th>
<th>R (mm²·K/W)</th>
<th>R (mm²·K/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipboard</td>
<td>20</td>
<td>0.130</td>
<td>500</td>
<td>1600</td>
<td>0.154</td>
</tr>
<tr>
<td>Air layer unventilated</td>
<td>50</td>
<td>R 0.020</td>
<td>1</td>
<td>1000</td>
<td>0.210</td>
</tr>
<tr>
<td>Scewed</td>
<td>55</td>
<td>1.150</td>
<td>1600</td>
<td>1000</td>
<td>0.543</td>
</tr>
<tr>
<td>Reinforced concrete</td>
<td>100</td>
<td>2.300</td>
<td>2300</td>
<td>1000</td>
<td>0.043</td>
</tr>
<tr>
<td>Insulation</td>
<td>140</td>
<td>0.040</td>
<td>20</td>
<td>1000</td>
<td>3.500</td>
</tr>
</tbody>
</table>

Total thickness: 300 mm

Resistance (upper/lower limit): 4.121 / 4.121

**U-value Calculator - Floor - NCM 2013 Ground floor**
186. Vehicle access and similar large door construction details - 2015 Notional building.

188. Internal floor/ceiling construction details - 2015 Notional building.