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Building Standards Non-Domestic Technical Handbook

Consultation proposals – NCM Modelling Guide for Scotland 2021

July 2021

The Building Standards Technical Handbooks provide guidance on achieving the standards set in The Building (Scotland) Regulations 2004.

Further information on the Scottish building standards system can be found at: www.gov.scot/policies/building-standards/.

This document sets out proposed changes to the mandatory standards and supporting guidance issued in support of **section 6 'energy'** within the Building Standards **Non-Domestic Technical Handbook**.

Where text is amended from the current, published 2015 edition of the Guide, this is shown by highlighting relevant passages in yellow.

The subject matter of these changes is set out in more detail within section 2 of the consultation document 'Scottish Building Regulations – Proposed Changes to Energy Standards and associated topics', published online at: https://consult.gov.scot/local-government-and-communities/building-regulations-energy-standards-review/.

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INTRODUCTION

NOTE: changes proposed in this document are offered for consultation in relation to the calculation of compliance with standard 6.1 in building regulations only. Further review will determine whether aspects of the proposed changes relating to assignment of benefit from on-site generation of power are included in EPC calculations (see note in Appendix B also).

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 greenhouse gas emissions and energy targets set in respect of non-domestic buildings under standard 6.1 of Scottish building regulations.

   b. Calculating asset ratings as part of preparing Energy Performance Certificates (EPCs) for non-domestic buildings, as required under standard 6.9 of The Building (Scotland) Regulations 2004 (as amended) and regulation 5 or regulation 9 of The Energy Performance of Buildings (Scotland) Regulations 2008 (as amended).

   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 2021 NCM Guide for Non-Domestic Buildings in Scotland

4. In support of the current consultation, this draft 2021 NCM Modelling Guide applies only to calculations undertaken by consultees in support of the proposed two options for target setting for new ND buildings in Section 6 Energy of the Non-Domestic

[1] 'Approved Organisations' are referred to as 'Protocol Organisations' in iSBEM and the iSBEM User Guide.
[2] Directorate for Local Government and Communities, Building Standards Division, www.gov.scot/bsd.

Technical Handbook. The main changes in the technical requirements of software since the issue of the previous (2015) NCM Modelling Guide are as follows:

- Proposed introduction of a new compliance metric based upon primary energy. Note: the consultation version of iSBEM will also report a **delivered energy** total.
- The new specifications for the notional building, which are used to determine the primary energy and greenhouse gas emissions targets. The latter have been defined to deliver an aggregate emissions reduction across all new non-domestic build profile of 16% (Option 1) or 25% (Option 2) relative to 2015 Section 6 Energy of the Non-Domestic Technical Handbook.
- Simplification of options for the assignment of the notional blinding specification based upon characteristics of the actual building, including:
    a. Fuel for space and water heating in the notional building will be assigned as either natural gas or electric (heat pump) based upon the fuel and heat solution specified for the actual building
    b. New classification of high and low hot water demand activities to determine the specifications for the Notional building's water heating system.
    c. Standardisation of fabric specification so that it is no longer assigned to each zone depending upon whether a zone is heated and naturally ventilated or heated and mechanically ventilated or cooled.
    d. The air infiltration value assigned to the notional building is no longer dependent upon building area, glazing type or the presence of metal cladding construction.
- Revised approach for accounting for the contribution to calculation of emissions and primary energy due to electricity generated on-site, excluding any exported component from the calculation of benefit.
- Proposed revision of compliance calculation where space and water heating demand is met from district heating.
- A new set of fuel emission factors and primary energy factors for buildings other than dwellings is provided in this document, including monthly factors for electricity. These are listed in Table 19 of this document.
- Revised approach for determining the illuminance level for a zone in the Notional building using minimum and maximum lighting levels for the activity type in the NCM Activity Database.*
- Upgrade to the 2016 CIBSE TRY weather data sets.*
- Updated options for HVAC systems in the Actual building and calculation of the corresponding fan energy.*

- Revised approach for calculating the fan energy associated with demand control of ventilation.*

* improvements made to v.6.0 of the UK NCM.

Approved software tools (section to be further updated following consultation)

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 Scotland[3]. The website also provides a list of Approved Organisations[4] 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)[5] in support of a building warrant application.

7. To be approved, the software tool must satisfy the criteria as published[6] 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[7]

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

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[3] https://www.gov.scot/policies/building-standards/energy-performance/
[4] https://www.gov.scot/policies/building-standards/energy-performance/#approved%20organisations
[5] https://www.gov.scot/policies/building-standards/energy-performance/#approved%20software
[6] https://www.gov.scot/publications/building-standards-approved-energy-assessment-software-guidance/
[7] https://www.scottishepcregister.org.uk/

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 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, the latest version of a software tool should generally be used. However, 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, for these proposed changes.
14. 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.
15. 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[8].
16. 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.

[8] https://www.gov.scot/publications/building-standards-approved-energy-assessment-software-guidance/

Choosing a software tool

17. 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).

18. 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

19. 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.

20. 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 are not already included in SBEM or have properties that vary non-linearly over periods of the order of an hour.

21. 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.

22. Certain building features are not currently modelled explicitly in SBEM and so representing such features in an adequate way will require somewhat cumbersome data preparation work.

23. Examples of building features where such issues can arise include:

a. Buildings with ventilated double-skin facades

b. Light transfer between highly glazed internal spaces such as atria or light wells

24. Where these features are, found designers can expect the need to pay more attention to manipulating input data and recording any assumptions made and their justifications.

25. It is recommended that users make full use of features such as, the 'multiplier' function in SBEM and merging of all contiguous similar areas (see paragraph 179), in order to generally avoid creating more zones than necessary, enhance clarity of the models, and help with quality audits. The default version of the SBEM engine runs on 64-bit Windows operating systems[9]. There is an optional 32-bit version of the SBEM engine which can be used on computers running 32-bit Windows operating systems[10].

COMPLIANCE WITH BUILDING REGULATIONS

26. 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 both primary energy demand and greenhouse gas emissions. This is achieved by demonstrating that the building as designed will have:

    a. emissions no greater than a Target Emission Rate (TER), i.e. the Building Emission Rate (BER) is less than or equal to the TER; and

    b. primary energy demand no greater than a Target Primary Energy Rate (TPER), i.e. the Building Primary Energy Rate (BPER) is less than or equal to the TPER[11].

27. The TER and TPER for the 2021 calculation which supports standard 6.1 of Section 6 Energy is derived by defining a target based on the performance of a "notional building" and the following procedure must be followed in order to establish these targets. 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

28. 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).

NOTE: two options are proposed in the current consultation – where relevant in this document, they are described as 'Option 1' and 'Option 2', intended to deliver an aggregated reduction in building emissions of 16% and 25% respectively.

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9 The 64-bit version of SBEM will not run on computers with 32-bit Windows operating systems

10 Memory limitations might affect the maximum number of zones/objects which can be modelled on 32-bit Windows operating systems).

11 Within cSBEM, the total calculated delivered energy is also presented (TDER) to support discussion on options within the proposal to introduce an energy metric as an additional compliance target.

29. 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.

30. 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.

31. Whatever building services type (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.

32. The notional building specifications proposed in this consultation are assigned based upon the main space and water heating fuel and heat solution chosen for the actual building and are applied at a zone level within the building. For both Option 1 and Option 2 proposals, there are therefore two notional building specifications which differ only in their treatment of space and water heating elements and allocation of on-site generation (via assignment of a photovoltaic array).

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

34. The energy performance standards of the notional building [note: two options are specified in this consultation version of the guide[12]] are based on a concurrent specification that delivers a reduction in energy demand and emissions relative to the 2015 energy performance standards based on an assumed build mix. This means that the performance target for some buildings will improve by more than this percentage, others by less.

Activity glazing class

35. 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”

[12] The Business and Regulatory Impact Assessment and supporting research accompanying the consultation provides an estimate of the cost of carbon mitigation.

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*).

36. The assignment of glazing type is used to apportion elements of fabric to the external envelope of the notional building and in calculation of solar gain and overheating risk. Note that it is no longer used to vary other aspects of building specifications such as fabric U-values.

Building fabric

37. The U-values in the notional building must be as specified in Table 1. Taking into account guidance in BR 443[13], all U-values should be calculated in accordance with BS EN ISO 6946: 2017, where the U-values calculation methods are inclusive of repeating thermal bridges.

Table 1: U-values of construction elements in the notional building (W/m².K)

Element	**Option 1 (16% emissions reduction)**	**Option 2 (25% emission reduction)**
Roofs	0.15	0.11
Walls [1]	0.18	0.15
Floors	0.15	0.13
Windows / Roof Windows	1.40	0.90
Roof-lights [2 3]	1.8	1.8
External personnel doors	2.0	2.0
Vehicle access and similar large doors	1.5	1.5
Internal walls	0.48	0.48
Internal windows	3.85	3.85
Internal ceilings	1.00	1.00

Notes:

1. Any part of a roof having a pitch greater or equal to 70º is considered as a wall.
2. U-value of rooflights is the overall U-value including the frame and edge effects, and already includes adjustment for horizontal orientation as detailed in BR 443: 2019.
3. All the roof-lights in the Notional Building are assumed to be conical or domed, and hence, for the purposes of heat transfer calculations, their developed to projected ratio is set to 1.3, i.e., the area of the roof-light is 1.3 times the area of the opening in the roof.

38. The effective thermal capacity of the construction elements, κ_m (kappa-m) value, in the notional building must be as shown in Table 2. For DSMs the information in the NCM

[13] https://www.bregroup.com/wp-content/uploads/2019/10/BR443-October-2019_consult.pdf

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	
Element	**Effective thermal capacity (kJ/m²K)**
Roofs	88.3 (1.40 if metal-clad)
Walls	21.8 (1.40 if metal-clad)
Floors	77.7
Vehicle access and similar large doors	2.1
Pedestrian doors and high usage entrance doors	54.6
Internal wall	8.8
Internal floor/ceiling	71.8 from above, 66.6 from below
Notes: Thermal capacity calculation in EN ISO 13790:2004. Any part of a roof having a pitch greater or equal to 70° is considered as a wall.	

39. 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 "METAL_CLADDING" field (*0 for activity with no metal-clad constructions, and 1 for activity with metal-clad constructions*).

40. For SBEM, the thermal capacity of the construction elements must be as defined in **Table 1 & 2**. For DSM software, the construction details in Appendix C (not provided as part of this consultation document) provide the necessary technical parameters to account for the effect of thermal capacity. The thermal mass of windows should be ignored.

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

42. 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).

43. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be allowed for by a method that satisfies BS EN ISO 14683 or by adding 10% to the standard area-weighted average U-values, of the Notional Building. Whichever method is applied must be applied to both Notional and Actual building calculations (see paragraph 106 for the latter). 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.

44. 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 3: Psi values for the Notional building (W/mK)		
Type of junction	**Involving metal cladding**	**Not involving metal-cladding**
Roof to wall	0.28	0.12
Wall to ground floor	1.0	0.16
Wall to wall (corner)	0.2	0.09
Wall to floor (not ground floor)	0.0	0.07
Lintel above window or door	1.0	0.30
Sill below window	0.95	0.04
Jamb at window or door	0.95	0.05

45. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made[14]:

a. If the calculated value is greater than 0.15 W/m²K (Option 1 calculation) or 0.13 W/m²K (Option 2 calculation), the value of 0.15 W/m²K or 0.13 W/m²K must be used in the notional building.

b. If the calculated value with no added insulation is less than the relevant value above, this lower value must be used in the notional building.

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

47. Zones in the notional building will use the air permeability values from Table 4 below. 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[15], which is taken from EN 15242[16].

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

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[14] This follows the guidance given in CIBSE Guide A (2018).

[15] SBEM Technical Manual (for SBEM version 6) available at https://www.uk-ncm.org.uk/

[16] Ventilation for buildings – Calculation methods for the determination of air flow rates in buildings including infiltration, EN 15242, CEN/TC 156, 2006.

guidance documents which relate average infiltration rate to envelope permeability. An example of the latter would be tables 4.16 to 4.23 of CIBSE Guide A (2021).

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.

Table 4: Air permeability (m^3/h per m^2 of envelope area at 50 Pa)	
Option 1	**Option 2**
4	3

Areas of windows, doors, and rooflights

48. 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 189 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.
    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.

49. 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 5: Glazing in the notional building

Activity glazing type	Glazing area (glass + frame)	g-value (EN ISO 410)	Frame factor	Visible light transmittance
Side-lit	Exposed facades will have windows with area that is the lesser of either: 1.5 m high x full facade width or 40% of exposed facade area	29%	10%	60%
Top-lit	12% of exposed roof area will be made up of rooflights*	29%	15%	60%
Unlit	No windows or rooflights	n/a		

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

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

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.

50. DSM software are required to use the glass data provided in Table 6 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 6: Glass properties for Option 1 & 2 glazing types.

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6 mm	0.277	0.385	0.513	0.680	0.075	0.044	0.840	0.030
Cavity	16 mm	Argon gas fill							
Inner pane	6 mm	0.817	0.074	0.074	0.892	0.081	0.081	0.840	0.840

51. 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.

52. 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 and Hot Water systems

53. 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.

54. A space is only considered as having air-conditioning if the system serving that space includes refrigeration.

55. 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.

56. 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.

57. 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[17], 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[18] by 1 ^{0}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.*

[17] Such an approach is not needed in SBEM, since the form of the model means that there is no feedback between overheating on one day and the energy demands on the next.

[18] This guidance assumes that zone heat output is zero when the heating set-point is exceeded. If models use a proportional band to modulate heating output, the heating set-point in this context should be regarded as the temperature at the top of the proportional band, not its mid-point.

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

59. The system performance definitions follow the practice set out in EN 15243[19]:

a. Auxiliary energy is the energy used by controls, pumps, and fans associated with the HVAC systems.

b. Heating Seasonal System 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 generator (e.g. boiler, heat pump) 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[20]. Heating energy consumption is, therefore, calculated from the following expression:

Equation 1 *Heating energy consumption = Zones annual heating load / SCoP*

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[19]. Cooling energy consumption is therefore calculated from the following expression:

Equation 2 *Cooling energy consumption = Zones annual cooling load / SSEER*

60. 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, (*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

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19 EN 15243, Ventilation for Buildings – Calculation of room temperatures and of load and energy for buildings with room conditioning systems, CEN, 2007

20 SBEM Technical Manual (for SBEM version 6) available at https://www.uk-ncm.org.uk/

(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.

61. The notional building has heat recovery with sensible efficiency of 76%, where appropriate (i.e. zones with mechanical ventilation providing supply and extract), which is bypassed/ switched off in cooling mode (i.e. variable efficiency).

62. The cooling and auxiliary energy in the notional building must be taken to be powered by grid-supplied electricity.

63. In air-conditioning mode, the notional building will have a cooling SSEER of 5.1 (Option 1) and 5.7 (Option 2), which already takes account of 20% distribution losses and fan energy associated with heat rejection (i.e. SEER of 6.4 and 7.1 respectively).

64. In mixed-mode operation, the notional building will have a cooling SSEER of 2.7 with cooling set-point of 27 ^{o}C. Note that mixed-mode cooling is assumed to be provided by DX unit where the SSEER includes indoor and outdoor units, fans, pumps, and losses.

65. The fuel and associated Seasonal System Coefficient of Performance (SCoP) for space heating in each zone of the Notional building is linked to the type of fuel used for space heating in the equivalent zone in the Actual building, based on the values provided in **Table 8**. Note that the SCoP values already take account of distribution losses of 10%.

66. The fuel and associated seasonal generator efficiency for hot water generation in each zone of the Notional building is linked to the type of fuel used for hot water in the equivalent zone in the Actual building, based on the values provided in **Table 9**.

67. 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. Emissions and primary energy factors for fuels are listed in Table 19.

Table 8: Notional building space heating fuel and heat generator efficiency			
Actual building space heating fuel	**Notional building space heating fuel**	**Efficiency (SCoP)**	
		Option 1	**Option 2**
Bio-fuel	Natural gas	93% (boiler) 92%* (radiant)	93% (boiler) 92%* (radiant)
Dual fuel (mineral + wood)			
Waste Heat			
Natural gas			
LPG			
Fuel oil			
Non-electric heat pump			
Electricity (direct)			
District Heating (see para 70)			
Electric (heat pump)	Electric (heat pump)	400%	435%

* In Table 8, where a top-lit zone in the Actual building only receives heating (i.e., if there is mechanical ventilation, it does not provide heating and/or cooling), then the equivalent zone in the notional building will be modelled with direct-fired multi-burner radiant heating, where the thermal efficiency is 92%, 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.

Table 9: Notional building water heating fuel, system type & heat generator efficiency

Actual building DHW fuel	Notional building DHW fuel & efficiency for centralised systems		DHW system type	
	Option 1	Option 2	High DHW demand	Low DHW demand
Bio-fuel	Natural gas (boiler) 93%	Natural gas (boiler) 93%	Centralised	Point-of-use (electric) 100%
Dual fuel (mineral + wood)				
Waste Heat				
Natural gas				
LPG				
Fuel oil				
Non-electric heat pump				
Electricity (direct)				
District Heating (see para 70)				
Electric (heat pump)	Electric (heat pump) 250%	Electric (heat pump) 270%		

68. The fuel and associated seasonal generator efficiency 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.

69. The fuel and associated seasonal generator efficiency for hot water generation in each zone of the Notional building is also linked to whether the activity in the space has ‘high’ or ‘low’ hot water demand. A space with ‘high’ hot water demand is taken as one whose activity in the NCM Activity Database has an annual HW demand (*i.e., the sum of the “HWS_#” fields from the “activity_sbem_D_ACU” table in the NCM Activity Database*) higher than 200 litres/m² per year. Otherwise, a space is considered to have ‘low’ hot water demand.

70. Where ‘high hot water demand’ is reported for an activity, the centralised solution applies, as noted in Table 9, hot water generation in the Notional building will have the following nominal storage and secondary circulation system:

c. Storage vessel size (litres) is the product of 0.8 and the floor area served by the HW system (m²). Vessel will have 50 mm of factory insulation.

d. Secondary circulation loop length (m) is the product of 4.0 and the square-root of the floor area served by the HW system.

e. Secondary circulation loss is 8 W/m of loop length.

f. Secondary circulation has no time switch, and its pump power (kW) is determined using the following equation:

Equation 3 *Pump power = ((0.25 x loop length) + 42) / 500*

71. For hot water, the energy demand must be taken as that required to raise the water temperature from 10 ^{0}C to 60 ^{0}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.

72. Where supply from a **district heating system is proposed** for space and/or water heating in the actual building, the notional building will apply a mains gas solution as noted in Table 9. The calculation for the actual building will follow the process set out in paragraph 107.

73. For bivalent heating systems (i.e. where more than one fuel is used in the actual building via separate heat generators to provide space and/or water heating), as all but one fuel solution is assigned against a natural gas notional building, a demand-weighted conversion factor will only be calculated for the notional building where one of the systems is an electric heat pump. 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, from Table 8 or Table 9.

Auxiliary energy

74. 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_#"*[21] *from the "activity_sbem_D1_ACU" table in the NCM Activity database*).

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

76. 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/m² where the HVAC system only provides heating, and 0.90 W/m² if it provides mechanical ventilation and/ or air-conditioning (i.e., equivalent to the Notional building benefitting from variable speed pumping with multiple pressure sensors in the system – see **Table 13**);

[21] *"SYS_ T_HOURS_#" if the system provides both heating and cooling.*

- 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.

77. For zones where the ventilation system also provides heating and/ or cooling, the fan power density in the Notional building is determined for each zone using the following equations:

Equation 4 *Fan power density = Lesser of* (FPS_1, FPS_2)

Equation 5 $FPS_1 = (FAR_{max} \times SFP_{central}) + (SCR \times SFP_{terminal})$

Equation 6 $FPS_2 = \text{Greater of } (FAR_{max}, SCR) \times SFP_{central}$

Where $SFP_{central}$ = 1.80 W per l/s and $SFP_{terminal}$ = 0.30 W per l/s
"FAR_{max}" is the peak fresh air supply rate (l/s/m²) that is set by the activity type in the NCM Activity database, while "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 7 $SCR = \text{Greater of } (PSH, PSC) / (\rho \times C_p \times \Delta T)$

Where ρ =1.2 kg/m³, C_p =1.018 kJ/kgK, and ΔT =8K

"PSH" is the peak space heating load, and "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 ^{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.

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

79. For zones where the ventilation system does not provide heating or cooling (but can include heat recovery), the fan power density for the notional building 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.

80. For zones with local mechanical exhaust where the fan is within the zone, the fan power density is the product of the user-defined (for the Actual building) 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 (for the Actual building) 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.

81. In zones with mechanical ventilation, the notional building benefits from demand control of ventilation through variable fan speed control based on CO_2 sensors.

82. Energy for other ancillary services in the building, such as secondary hot water circulation pump, where relevant, will be an addition to the fan and pump energy of the Notional building.

83. 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 2021 Non-Domestic Technical Handbook apply).

Lighting power density

84. The general lighting in the notional building is based on lighting with efficacy of 125 luminaire lumens per circuit-watt 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 8 *Power density per 100 lux* = $(0.93 + (0.003 \times R) + (0.030 \times R^2)) / MF$

Where R is the ratio of the total wall area[22] *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 in the next paragraph, 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.*

85. The illuminance level used for the general lighting in the Notional building is determined by the illuminance values for the activity type in the NCM Activity Database and the design illuminance for the Actual building (if input by the user) so that:

- The Notional building will use the same design illuminance input by the user for the zone in the Actual building provided the design illuminance is equal to or greater than the activity's NCM minimum lighting level (*specified in the "LIGHTING_LUX_MIN" field of the "activity" table in the database*) and does not exceed the activity's NCM maximum lighting level (*specified in the "LIGHTING_LUX_MAX" field of the "activity" table in the database*).
- Where the user does not define the design illuminance for the zone in the Actual building, or the design illuminance input for the zone in the Actual building is less than the activity's NCM minimum lighting level, the Notional building will use the activity's NCM minimum lighting level.
- Where the design illuminance defined for the zone in the Actual building is greater than the activity's NCM maximum lighting level, the Notional building will use the activity's NCM maximum lighting level.

[22] 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.

86. 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[23]), without back-sensor control.

87. 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 [22]) 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. Whether or not the activity is appropriate to have local manual control is determined in the "activity" table from the NCM Activity Database in the "BR_CHECK02" field *(1 for activity that is not appropriate to have local manual control, and 0 otherwise).*

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

89. 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). Whether or not the activity is appropriate to have local manual control is determined in the "activity" table from the NCM Activity Database using the "BR_CHECK02" field, as described in paragraph 87.

90. All zones in the Notional building with either photoelectric dimming or occupancy sensing light controls, or both, will have a continuous (i.e. always on) parasitic power density of 0.1 W/m².

91. The display lighting, where applicable, in the Notional building is based on the display lighting with luminous efficacy of 95 lamp lumens per circuit-watt so the display lighting power density in the Notional zone will be from the NCM Activity Database multiplied by 0.158 (i.e. adjustment between lamp efficacy of 95 and 15 lumens per circuit-watt). Daylight harvesting and local manual switching do not apply to display lighting in the notional building (i.e. only affects general lighting).

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

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

On-site generation of electricity

94. The Notional Building includes an assignment for low and zero carbon technologies represented, as a proxy, by the inclusion of roof mounted photovoltaic panels. The

[23] SBEM Technical Manual (for SBEM version 6) available at https://www.uk-ncm.org.uk/

notional building therefore includes on-site electrical generation equal to the lesser of Equation 9 or Equation 10 below:

Equation 9 *Notional onsite electrical generation = 13% x GIA x 150 kWh/m²*

Equation 10 *Notional onsite electrical generation = 50% x roof area x 150 kWh/m²*

95. Equation 9 models an area of photovoltaic panels equivalent to 13% of the actual building's gross internal area assuming photovoltaic panels with an output of *150 kWh/m²* Equation 10 ensures that the area of photovoltaic assigned in the notional building is never larger than 50% of the building's roof area.

96. The Notional building's PV array is defined as having south orientation, 30° pitch from the horizontal, 'no or very little over-shading', and 'strongly ventilated or forced ventilated modules'.

97. If any HVAC system in the Actual building provides space heating using a heat pump, then the area of the PV array in the Notional building calculated in Equation 9 is reduced pro-rata by the proportion of the building's space heating demand which is met by a heat pump in relation to the building's total space heating demand.

For example, if a heat pump meets 30% of the space heating demand in the Actual building, then the area of the PV array in the Notional building will be reduced by 30% from the value calculated in Equation 9 / 10. Therefore, if a heat pump meets 100% of the space heating demand of the Actual building, then the Notional building will have no PV system.

98. A further limiter is applied to the assignment of energy generated on-site within the notional and actual building calculation – see paragraph 100 & 142.

Target Emission Rate (TER) and Target Primary Energy Rate (TPER)

99. The TER is the CO_2 emission rate of the 2021 Notional building reported in kg.CO_{2e} per square metre of the building's total floor area. Similarly, the TPER is the primary energy rate of the Notional building reported in kWh_{pe}/m^2.

100. The following approach is applied when calculating the two target rates for the Notional building. **Noting that this has the effect of excluding any predicted export component of on-site generation from both the emissions and the PE calculation.**

a. Calculate the total monthly demands for energy from all regulated sources within the calculation which consume electricity.

b. The calculated monthly total for equipment load within SBEM is assigned to represent 'plug-in' electrical load.

c. Calculate the monthly totals for on-site generation from assignment of PV to the notional building.

d. Determine total 'useful generation', which is the lesser of (a+b) or c.

e. Calculate monthly emissions and PE for electrical demand (a) only, applying the factors from **Table 19b**.

f. Calculate monthly emissions and PE for useful electrical generation only (d), applying the relevant factors for PV (**Table 19c**). Noting that where generation includes other than by PV, this should be counted before PV (e.g. prioritise the 'same' factors).

g. Calculate the monthly emissions and PE for energy totals from all other fuels consumed using, applying the factors from **Table 19a**.

h. Calculate the net monthly total for emissions and PE as, in both cases, e–f+g.

101. The annual sum of the net monthly totals for emissions and primary energy, once divided by the total floor area of the building are presented as the Target Emission Rate and the Target Primary Energy Rate. If, for either Rate, this is calculated to be less than zero, the value shall be set to zero.

THE ACTUAL BUILDING

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

Building fabric

103. 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).

104. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be allowed for by a method that satisfies BS EN ISO 14683 or by adding 25% to the standard area-weighted average U-values, of the Notional Building. Whichever method is applied must be applied to both Notional and Actual building calculations (see paragraph 43 for the former).

105. 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[24] following the guidance set out in BR497[25].

Table 10: Default Psi values for the actual building (W/mK)

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

Space and water heating

106. Space and water heating for the actual building are calculated based upon the solution specified. For the purpose of demonstrating compliance, there is one exception to this.

107. Where supply from a **district heating system is proposed** for space and/or water heating in the actual building, the notional building will apply a mains gas solution as noted in Table 9. Calculation of the emissions and primary energy totals for the actual building shall be undertaken by applying the emissions and primary energy factors from grid-supplied electricity to the calculated delivered energy totals for the actual building to calculate BER and BPER rather than default or declared values for the district heating system in question.

This comparative performance scenario (asserting 100% utilisation of delivered heat) is intended to provide assurance that the specification for building fabric, secondary services and effective offsetting via on-site generation will be as effective in limiting delivered energy to a building where heat demand is met from a network connection as for a building-based heat solutions that utilises grid-supplied electricity to provide direct heating. The EPC calculation is unaffected and will still apply the requisite factors for the heat network in question

Note that this assignment of annual factors for grid electricity to supplied heat demand applies only to the calculation for compliance with standard 6.1.

[24] Further information available in the Introduction to the Accredited Construction Details (Scotland) 2015.
[25] BR497 Conventions for calculating linear thermal transmittance and temperature factors, BRE, 2016.

Lighting

108. 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 minimum NCM lighting level for the activity in the Activity database.

109. Where the design illuminance is less than the minimum NCM activity lighting level, the general power density will be automatically pro-rated to the minimum NCM activity lighting level. For example, an office with installed lighting load density of 6 W/m^2 that delivers 200 lux illuminance (i.e. 3 W/m^2 per 100 lux) would be adjusted to 9 W/m^2 for the purpose of compliance because the NCM activity assumes 300 lux illuminance.

110. For building regulations compliance, the general lighting can be defined explicitly, by calculating and inputting the design/installed circuit power[26], 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.

111. 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:

- **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 125 luminaire lumens per circuit-watt*) defined by Equation 8 to infer a power density for the general lighting in the Actual building. 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 106 above, if applicable.
- **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 125 luminaire lumens per circuit-watt*) defined by Equation 8 to infer a power density for the general lighting in the Actual building. 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 106 above, if applicable.

[26] The luminous efficacy can be derived for reporting by working backwards using Equation 8, the circuit power, and inference method 1 from paragraph 111.

Table 11: Lamp inference data		
Lamp type	**Luminaire lumens per circuit-watt**	
	Side-lit and unlit activities	**Top-lit activity**
LED	50.0	50.0
Tungsten and Halogen	7.5	9.0
Fluorescent - compact	22.5	27.0
T12 Fluorescent - halophosphate - low frequency ballast	25.0	30.0
T8 Fluorescent - halophosphate - low frequency ballast	27.5	33.0
T8 Fluorescent - halophosphate - high frequency ballast	32.5	39.0
T8 Fluorescent - triphosphor - high frequency ballast	36.3	43.5
Metal Halide	25.0	39.0
High Pressure Mercury	22.5	27.0
High Pressure Sodium	35.0	42.0
T5 Fluorescent - triphosphor-coated - high frequency ballast	37.5	45.0
Fluorescent (no details)	22.5	27.0

112. 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 modelling constant illuminance control (as defined in BS EN 15193:2007[27]) by reducing the general lighting power density by 10%, if applicable.

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

114. 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.

115. 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%.

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

[27] BS EN 15193:2007 - Energy performance of buildings - Energy requirements for Lighting.

Auxiliary energy

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

118. 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.).

119. 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*).

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

121. 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 12: Assigning pump power to HVAC systems

HVAC system type	Pump power	Variable speed pumping allowed
Central heating using water: radiators	LTHW only	Yes
Central heating using water: convectors	LTHW only	Yes
Central heating using water: floor heating	LTHW only	Yes
Central heating with air distribution	None	No
Other local room heater - fanned	None	No
Other local room heater - unfanned	None	No
Unflued radiant heater	None	No
Flued radiant heater	None	No
Multiburner radiant heaters	None	No
Flued forced-convection air heaters	None	No
Unflued forced-convection air heaters	None	No
Single-duct VAV	Both LTHW and CHW	No

Table 12: Assigning pump power to HVAC systems		
HVAC system type	**Pump power**	**Variable speed pumping allowed**
Dual-duct VAV	Both LTHW and CHW	No
Indoor packaged cabinet (VAV)	Both LTHW and CHW	Yes
Fan coil systems	Both LTHW and CHW	Yes
Induction system	Both LTHW and CHW	Yes
Constant volume system (fixed fresh air rate)	Both LTHW and CHW	No
Constant volume system (variable fresh air rate)	Both LTHW and CHW	No
Multizone (hot deck/cold deck)	Both LTHW and CHW	No
Terminal reheat (constant volume)	Both LTHW and CHW	No
Dual duct (constant volume)	Both LTHW and CHW	No
Chilled ceilings or passive chilled beams and displacement ventilation	Both LTHW and CHW	Yes
Active chilled beams	Both LTHW and CHW	Yes
Water loop heat pump	Both LTHW and CHW	No
Split or multi-split system	None	No
Single room cooling system	None	No
Variable refrigerant flow	None	No
Chilled ceilings or passive chilled beams and displacement ventilation	Both LTHW and CHW	Yes
Chilled ceilings or passive chilled beams and mixing ventilation	Both LTHW and CHW	Yes

Table 13: Pump power density for Actual building (W/m²)		
Pump configuration	**LTHW only**	**Both LTHW & CHW**
Constant speed pumping	0.6	1.8
Variable speed pumping with differential sensor across pump	0.5	1.5
Variable speed pumping with differential sensor in the system	0.4	1.1
Variable speed pumping with multiple pressure sensors in the system	0.3	0.9

122. 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 11 $FPS_1 = (FAR_{max} \times SFP_{central}) + (SCR \times SFP_{terminal})$

Equation 12 $FPS_2 = \text{Greater of } (FAR_{max}, SCR) \times SFP_{central}$

Equation 3 $FPS_3 = \text{Greater of } (SCR/5, FAR_{max}) \times SFP_{central}$

Equation 4 $FPS_4 = FAR_{max} \times SFP_{central}$

Equation 5 $FPS_5 = 0.85 \times FAR_{max} \times SFP_{central}$

"FAR_{max}" is the peak fresh air supply rate (l/s/m²) that is set by the activity type in the NCM Activity database, while "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 $SCR = \text{Greater of } (PSH, PSC) / (\rho \times C_p \times \Delta T)$

Where:

ρ =1.2 kg/m³, C_p =1.018 kJ/kgK, and ΔT =8K

"PSH" is the peak space heating load, and "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.

123. The fan power density equations are assigned to HVAC systems based on Table 14.

Table 14: Assigning fan power equations to HVAC systems

HVAC system type	SBEM ID	Fan power density
Fan coil systems	4	Equation 11
Indoor packaged cabinet (VAV)	32	
Central heating using air distribution	2	Equation 12
Constant volume system (fixed fresh air rate)	5	
Constant volume system (variable fresh air rate)	6	
Single-duct VAV	7	
Water loop heat pump	13	

Table 14: Assigning fan power equations to HVAC systems		
Dual duct (constant volume)	15	
Multi-zone (hot deck/cold deck)	16	
Terminal reheat (constant volume)	17	
Dual-duct VAV	31	
Active chilled beams	12	Equation 3
Induction system	14	
Variable refrigerant flow	10	Equation 3
Chilled ceilings or passive chilled beams and mixing ventilation	35	
Chilled ceilings or passive chilled beams and displacement ventilation[28]	11	Equation 4

124. 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.

125. 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.

126. 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 14a: Additional fan power for specific HVAC systems

HVAC system type	SBEM ID
Central heating using water; convectors (but only in cases where the system utilises fanned convectors)	24
Other local room heaters (fanned)	3

127. Energy for other ancillary services in the building, such as secondary hot water circulation pump, 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

128. 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

[28] Displacement ventilation is assumed to reduce the required airflow by 15% compared to mixing ventilation.

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.

129. 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

130. For zones with natural ventilation, the following options will be available to the user:

a. No demand-controlled ventilation *(default option)*
b. Enhanced ventilation

131. 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 7 $FAR_{dc} = C_{dc} \times FAR_{lower} + (1 - C_{dc}) \times FAR_{max}$

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). C_{dc} = is a demand control coefficient and is determined based on the data in Table 15 and FAR_{lower} is the greater of either: FAR_{min} or 0.6 × FAR_{max}.

Equation 8 $FAR_{lower} = \text{Greater of } (FAR_{min}\ (0.6 \times FAR_{max}))$

where:

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).

Table 15: Values for demand control coefficient

Type of demand control	Demand control coefficient (C_{dc})
None	0
Control based on occupancy density	0.85
Control based on gas sensor	0.95
Enhanced natural ventilation	0.50

132. 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 there is demand control of ventilation, the auxiliary energy calculation will use FAR_{max} pro-rated by a value obtained from Table 15a, depending on the type of control for air regulation and the ratio of modified fresh air rate to maximum fresh air rate (i.e. FAR_{dc}/FAR_{max}).

Table 15a: Proportion of maximum fan power in case of demand control of ventilation

FAR_{dc}/FAR_{max}	0	0.2	0.4	0.6	0.8	1.0
Air flow regulation type						
Damper control*	0	0.525	0.65	0.8	1	1
Speed control	0	0.1	0.18	0.35	0.65	1

*Average of forward and backward blades.
Use linear interpolation for intermediate values of FAR_{dc}/FAR_{max}.

Shell buildings

133. 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.

134. Shell buildings are subject to the compliance check against the TER & TPER under the conditions specified in clause 6.1.10 of Section 6.

135. Assessment under standard 6.1 is required both for the shell building warrant and also for the subsequent fit-out works, via the imposition of a continuing requirement in this respect on 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[29]). Assessment of the fit-out work should be made using the category 'other buildings' under 'S6 type of building'.

136. 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

[29] https://www.gov.scot/publications/procedural-handbook/

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'.

137. 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.

138. Where these procedures apply to compliance with standard 6.1, EPC generation required under standard 6.9 should be deferred until the fit-out stage of such a building by inclusion in the continuing requirement. This deferral is on the basis that a shell building is incomplete and cannot be occupied and will ensure that the lodged EPC represents the building as fitted out.

Modular and portable buildings

139. For modular and portable buildings with an intended life on site of less than five years, the TER & TPER must be adjusted as described in Annex 6.C of Section 6.

140. 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

141. 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 demonstrate compliance with the carbon dioxide emissions standard 6.1.

142. 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.

Building Emission Rate (BER) and Building Primary Energy Rate (BPER)

143. The BER is the CO_2 emission rate of the Actual building reported in kg.CO_{2e} per square metre of the building's total floor area. Similarly, the BPER is the primary energy rate of the Actual building reported in kWh_{pe}/m^2.

144. The following approach is applied when calculating the two building rates for the Actual building. Noting that this has the effect of excluding any predicted export component of on-site generation from both the emissions and the PE calculation.

a. Calculate the total monthly demand for energy from all regulated source within the building which consumes electricity.

b. The calculated monthly total for equipment load within SBEM is assigned to represent ‘plug-in’ electrical load.

c. Calculate the monthly total for on-site generation, for PV and separately for any other source. Determine the sum of all sources.

d. Determine total ‘useful generation’, which is the lesser of (a+b) or c. *Note: If c is greater than (a+b), the software tool should notify this to the user so that they are aware that the calculated useful generation capacity is exceeded.*

e. Calculate monthly emissions and PE for electrical demand (a) only, applying the factors from **Table 19b**.

f. Calculate monthly emissions and PE for useful electrical generation only (d), applying the relevant factors for PV or another source (**Tables 19b & 19c**). Noting that where generation includes other than by PV, this should be counted before PV (e.g. prioritise the ‘same’ factors).

g. Calculate the monthly emissions and PE for energy totals from all other fuels consumed using, applying the factors from **Table 19a**.

h. Calculate the net monthly total for emissions and PE as, in both cases, e–f+g.

145. Noting that, as with the Notional Building, this has the effect of excluding any predicted export component of on-site generation from both the emissions and the PE calculation. The intent of this is to avoid over-specification of generation as part of building solutions where this does not contribute to the reduction of the delivered energy total for the building.

146. The annual sum of the net monthly totals for emissions and primary energy, once divided by the total floor area of the building are presented as the Building Emission Rate and the Building Primary Energy Rate. Compliance is achieved where neither the Building Emission Rate nor the Building Primary Energy Rate exceed their respective Target rating, the Target Emission Rate and the Target Primary Energy Rate.

CHECKING SOLAR GAINS

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

148. 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)*.

149. 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.

150. The contribution of solar gain from display windows will be checked for zones where the solar gain check applies.

151. The solar gain check is based on the solar gains through the benchmark glazing types described in Table 16, and selected according to paragraph 153, aggregated over the period from April to September, and using the same CIBSE TRY weather data used for the emissions and primary energy calculations (standard 6.1).

Table 16: General description of benchmark glazing for setting solar gain limit

Benchmark glazing type	Description	Glazing dimensions/ area
1	Vertical glazing facing east with 10% frame factor and g-value of 0.48	Height of 1m and width equal to the total exposed facade* width of the zone being checked
2	Horizontal glazing with 25% frame factor and g-value of 0.48	Area equal to 10% of either the projected floor area or the exposed roof area** (whichever is greater)
3	Horizontal glazing with 15% frame factor and g-value of 0.42	Area equal to 20% of either the projected floor area or the exposed roof area** (whichever is greater)

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

** The exposed roof area is determined from inside the space looking out.

152. 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.

153. 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).

154. 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.

155. 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[30] 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[30] 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).

156. 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).

157. 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 0.48

Thickness		T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6 mm	0.489	0.319	0.217	0.791	0.045	0.071	0.0.045	0.302
Cavity	16 mm	Argon gas fill							
Inner pane	6 mm	0.895	0.079	0.079	0.908	0.082	0.082	0.840	0.840

[30] For zones with pitch roofs, use the average height.

Table 18: Glass properties to achieve g-value of 0.42									
Thickness		T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	4 mm	0.895	0.079	0.079	0.908	0.082	0.082	0.840	0.840
Cavity	16 mm	Argon gas fill							
Inner pane	4 mm	0.895	0.079	0.079	0.908	0.082	0.082	0.840	0.840

Figure 1 Isometric view of standard test-space for benchmark glazing type 1

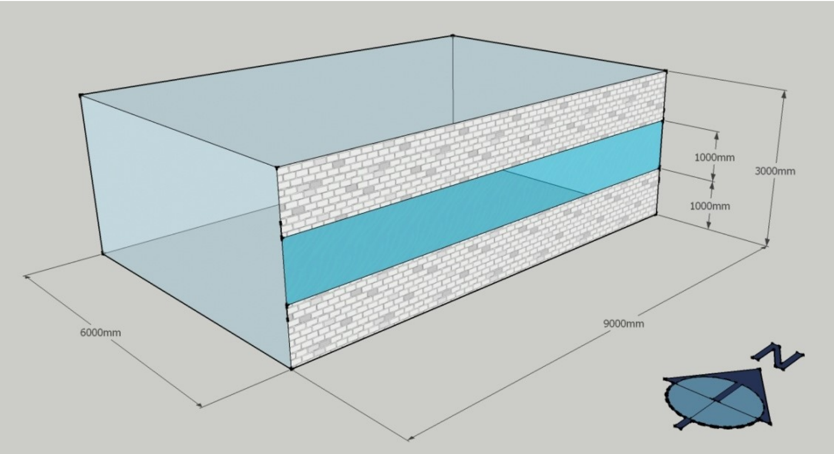


Figure 2 Isometric view of standard test-space for benchmark glazing type 2

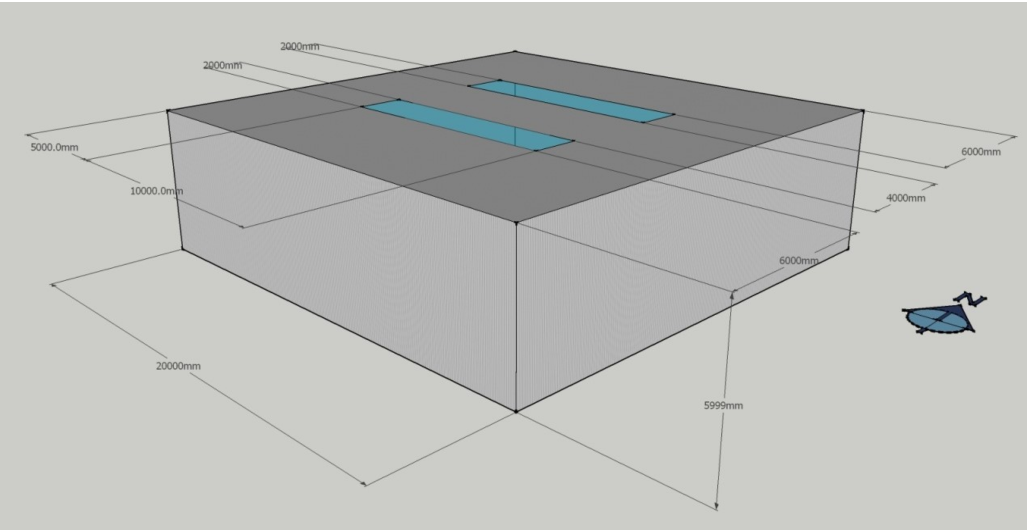
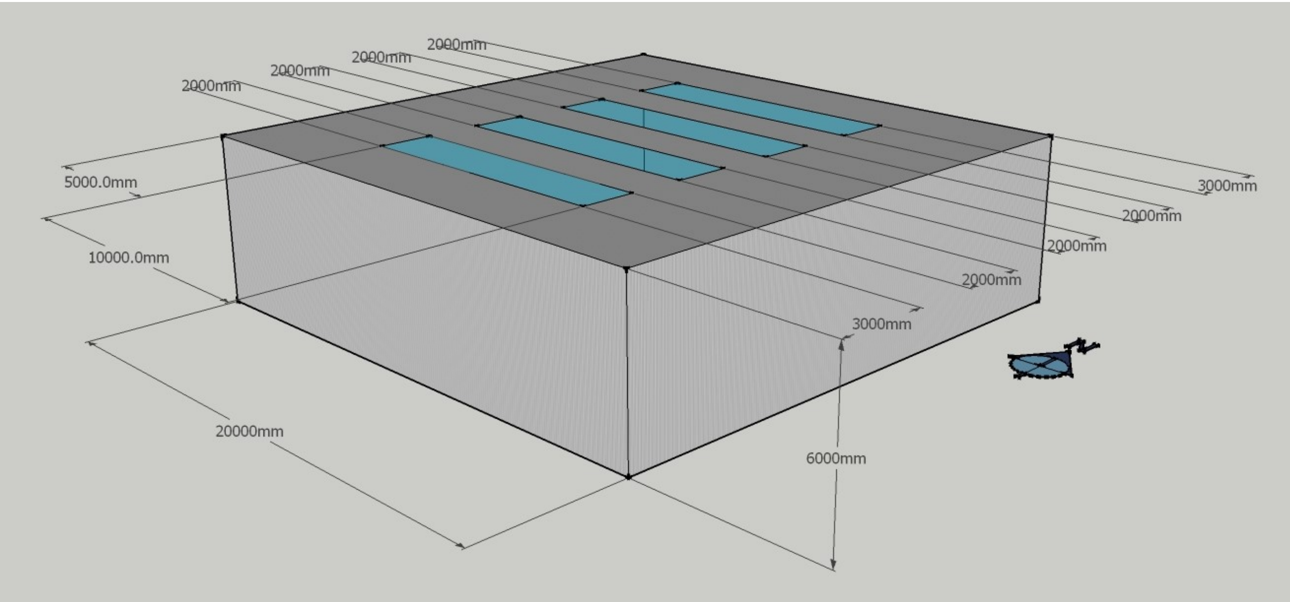


Figure 3 Isometric view of standard test-space for benchmark glazing type 3



ENERGY PERFORMANCE CERTIFICATES (EPCs)

NOTE: changes proposed in this document are offered for consultation in relation to the calculation of compliance with standard 6.1 in building regulations only.

Further review of EPC practice during 2021/22, in support of our draft Heat in Buildings Strategy, will determine whether and when aspects of the proposed changes are included in EPC calculations.

158. 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 CO_2 Emission Rate (BER) in kg per m^2 of floor area per year, rated on a seven band scale (see guidance to standard 6.9 in Section 6).

159. 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[31].

160. 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

The EPC Rating Scale

BER	≤	0.0	→	**A+** (net zero carbon or better)		
0.0	<	BER	≤	15.0	→	**A**
15.0	<	BER	≤	30.0	→	**B**
30.0	<	BER	≤	45.0	→	**C**
45.0	<	BER	≤	60.0	→	**D**
60.0	<	BER	≤	80.0	→	**E**
80.0	<	BER	≤	100.0	→	**F**
100.0	<	BER	→	**G**		

[31] https://www.gov.scot/policies/building-standards/energy-performance/

range of emissions ratings, with "A+ (net zero carbon or better)" being the most efficient (followed by "A") and "G" being the least efficient.

161. 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).

162. 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.

163. The impact of the recommendations on the CO_2 emission rate of the building and their estimated payback[32] is assessed based on the energy performance of the actual and notional buildings.

Other reference values

164. 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.

165. The EPC also displays other information such as, the approximate annual energy use of the building, in kWh/m² 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.

[32] 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/.

APPENDIX A - INPUT DATA TO APPROVED TOOLS

166. This section of the guide describes generally applicable approaches to data input and modelling 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

167. 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[33]. One of these standard activities must be assigned to each space in the building[34].

168. A 2021 version of the NCM Activity database has been updated from 2013/15 to accompany the 2021 version of the NCM Modelling Guide.

169. 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.

170. 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.

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33 The NCM databases (Activity, Construction, and Glazing) can be downloaded from https://www.uk-ncm.org.uk/.

34 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.

171. 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 NCM website[35] 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[36]. 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

172. 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[37]. 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 a method that satisfies BS EN ISO 14683 or by adding a specified percentage increase to the standard area-weighted average U-values (see paragraphs 43 & 104). Whichever method is applied must be applied to both Notional and Actual building calculations.

173. 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.

174. 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

[35] See https://www.uk-ncm.org.uk/.

[36] Clearly designers may wish to use alternative bespoke schedules for particular design assessments, but these exist outside the compliance/certification framework.

[37] https://www.bre.co.uk/filelibrary/pdf/rpts/BR_443_(2006_Edition).pdf

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.

Weather location

175. 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[38].

Zoning rules

176. 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.

177. 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 176 to 181); 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).

Zone types

178. 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

[38] 2016 CIBSE Test Reference Years (Glasgow). Weather Data provided by the Chartered Institution of Building Services Engineers (CIBSE). To discover more about weather data, the variables available, and Building Regulations Compliance, visit: www.cibse.org/weatherdata.

g. Where the output of each type of terminal device is controlled in a similar manner.

179. 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.

180. 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

181. Adjoining thermal zones (horizontally or vertically[39]) 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 176 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.

182. 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.

183. 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.

[39] If combining zones vertically, the zone height input should be that of a single zone, not the vertical sum of the zones’ heights.

Fuel emission factors (Draft)

184. Emissions factors and Primary Energy factors[40] for fuels are defined below.

Table 19a: Fuel emission & primary energy factors for non-domestic buildings

Fuel type	Emission Factor $kgCO_2$/ kWh	Primary Energy Factor kWh/ kWh
Natural gas	0.210	1.126
LPG	0.241	1.141
Biogas	0.024	1.286
Fuel oil	0.319	1.18
Coal	0.375	1.064
Anthracite	0.395	1.064
Manufactured smokeless fuel (inc. Coke)	0.366	1.261
Dual fuel (mineral + wood)	0.087	1.049
Biomass	0.029	1.037
Grid supplied electricity	See below	See below
Grid displaced electricity	See below	See below
Waste heat[41]	0.015	1.063

Table 19b: Fuel emission & primary energy factors - grid-supplied electricity and grid-displaced electricity EXCEPT that generated by PV systems

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kg.CO_2/kWh	0.163	0.160	0.153	0.143	0.132	0.120	0.111	0.112	0.122	0.136	0.151	0.163
kWh_{pe}/kWh	1.602	1.593	1.568	1.530	1.487	1.441	1.410	1.413	1.449	1.504	1.558	1.604

Table 19c: Fuel emission & primary energy factors - grid-displaced electricity from PV systems

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kg.CO_2/kWh	0.196	0.190	0.175	0.153	0.129	0.106	0.092	0.093	0.110	0.138	0.169	0.197
kWh_{pe}/kWh	1.715	1.697	1.645	1.567	1.478	1.389	1.330	1.336	1.405	1.513	1.623	1.718

HVAC

185. 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).

[40] The primary energy is considered to include the delivered energy plus an allowance for the energy 'overhead' incurred in extracting, processing, and transporting a fuel or other energy carrier to the building.

[41] This includes waste heat from industrial processes and power stations.

186. 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

187. Lighting calculations for ‘as designed’ compliance checks should assume a space maintenance factor of 0.8, which corresponds to a clean space that is maintained every 3 years (*EN 12464*).

188. 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).

189. 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

190. 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 CO_2 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

191. 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 20: Measurement and other conventions	
Parameter	**Definition**
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.*
Window Area	Area of the structural opening in the wall/roof; the area, therefore, includes the area of glass + frame.
HWS Dead-leg Length	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.
Flat Roof	Roof with pitch of 10º or less. If greater than 10º, the roof is a pitched roof.
Pitched Roof	Roof with pitch greater than 10º and less than or equal to 70º. If the pitch is greater than 70º, it must be considered a wall.
Glazed door	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.
Curtain walling	For curtain walling systems, the translucent and transparent areas should be modelled as glazing and the opaque parts as wall.

APPENDIX B – EPBD RECAST AND 2018 AMENDMENT

192. This section describes the added requirements of the amended Energy Performance of Buildings Directive (2018) retained and presented in the calculation methodology and output reports.

Primary energy consumption

193. Both a Target Primary Energy Rating (TPER) and a Building Primary Energy Rating (BPER) are calculated and reported, based on the predicted delivered energy consumption for each fuel and the corresponding primary energy factors, as defined in Table 19. These will be reported in the SBEM Specification Information summary.

Alternative energy systems

194. 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.

APPENDIX C – CONSTRUCTION FOR 2021 NOTIONAL BUILDING

NOTE: Appendix C will be updated post-consultation.

195. This section includes screen grabs from the BRE U-value calculator 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.

196. 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**.

197. Roof construction details - 2021 Notional building (not involving metal cladding).

198. Roof construction details - 2021 Notional building (involving metal cladding) –

199. External wall construction details - 2021 Notional building (not involving metal cladding) –

200. External wall construction details - 2021 Notional building (involving metal cladding) –

201. Exposed floor construction details - 2021 Notional building –

202. Ground floor construction details - 2021 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) –

203. Vehicle access and similar large door construction details - 2021 Notional building.

204. Pedestrian & high usage entrance doors construction details - 2021 Notional building.

205. Internal floor/ceiling construction details - 2021 Notional building.

206. Internal partition construction details - 2021 Notional building.