National Calculation Methodology (NCM) modelling guide (for buildings other than dwellings in England)

2021 Edition

September 2022

Main Changes in the 2021 Edition

This NCM Modelling Guide comes into force on 15th June 2022 in support of the 2021 Edition of the Approved Document L - Conservation of fuel and power, Volume 2: Buildings other than dwellings. The main changes in the technical requirements of software since the issue of the previous NCM Modelling Guide are as follows:

1. The 2021 compliance target is for both CO_2 emissions and primary energy.
2. New specifications of the Notional building for the 2021 edition, which are used to determine the CO_2 emissions and primary energy targets, have been defined to deliver a 27% reduction in CO_2 emissions on average across the new non-domestic building mix relative to Part L 2013.
3. New classification of high and low hot water demand activities to determine the specifications for the Notional building's water heating system.
4. On-site electricity generation by PV in the Notional building.
5. 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. Also provided is a set of fuel factors specifically for district heating networks.
6. 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.
7. Revised approach for accounting for primary energy due to electricity generated on-site by renewables.
8. Upgrade to the 2016 CIBSE TRY weather data sets.
9. Updated options for HVAC systems in the Actual building and calculation of the corresponding fan energy.
10. Revised approach for calculating the fan energy associated with demand control of ventilation.
11. September 2022: Amended glass properties for solar gains check glazing benchmark type 3 (Table 21).

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INTRODUCTION

1. This document, which takes effect on 15th June 2022, gives guidance on the use of the government's Simplified Building Energy Model (SBEM) and other approved software tools comprising the National Calculation Methodology (NCM) when:

a. Demonstrating compliance with the carbon dioxide (CO_2) emissions and primary energy requirements of the Building Regulations[1] for England in respect of buildings other than dwellings.
b. Calculating the asset ratings as part of preparing Energy Performance Certificates (EPCs) for buildings other than dwellings.

2. It is expected that separate guidance will be produced by accreditation bodies regarding the forward transmission of the results of these calculations for the purposes of lodgement on the National Register and the formal issue of EPCs and Recommendation Reports to building owners.

3. It is expected that separate guidance will be published for the application of the methodology when using approved tools to demonstrate compliance with the applicable regulations in Wales, Scotland, and Northern Ireland.

4. This document is under continuous review and will be updated as and when the need for additional clarification is identified. This regular updating will help improve the consistency of application of the various tools to the Building Regulations compliance and energy certification processes.

Notice of approval

5. The Notice of Approval sets out:

a. The methodology approved by the Secretary of State for calculating the energy performance of buildings (including methods for calculating the Asset Rating and Operational Rating of buildings); and
b. The approved ways of expressing the energy performance of buildings.

6. Associated with the Notice of Approval are tables showing when individual software tools have been approved. This document gives guidance on how those approved software tools should be used:

a. For demonstrating compliance with regulation 26 of the Building Regulations; and
b. For calculating the Asset Rating as part of the production of an EPC.

7. To be approved, the software tool must satisfy the criteria as published by the Department for Levelling Up, Housing, and Communities (DLUHC). These requirements are updated from time to time and cover a number of generic issues as follows:

[1] Building Regulations 2010 (SI 2010/2214), as amended.

a. The software tool has to demonstrate that the calculations are technically robust, and that they cover a necessary minimum set of energy flows.
b. The software tool has to demonstrate that it follows the procedures for compliance and certification as defined in this document, including the use of the NCM Databases, the definitions of Notional and Reference buildings, and other issues as defined from time to time.
c. The software tool has to demonstrate that it reports a minimum set of output parameters, and that these parameters can be passed appropriately to standard modules for:
    i. Compliance checking
    ii. Producing an EPC
    iii. Deriving a set of recommendations for energy efficiency improvements.

8. In addition to ensuring that the software tools are compatible in terms of technical scope, the approval process also checks 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 both the Notional and Reference buildings 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. All software is expected to be developed in accordance with ISO 90003:2004 – 'Guidelines for the application of ISO 9001:2000 to computer software'.

Version policy

12. All software tools, including SBEM and approved Dynamic Simulation Models (DSMs), evolve with time as improvements are made to 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 following rules define the procedures approved by the Secretary of State:

13. For certifying compliance with Building Regulations:

a. The earliest version of a software tool (i.e., software and NCM Databases) that can be used in any initial notification is the latest approved version, as listed in the relevant notice of approval which applies to the building work, available 12 months prior to application to Building Control.
b. Developers can subsequently elect at various key points in the process the version of the tool that they will use for compliance and certification purposes. These key points are:
    i. CO_2 emission and primary energy rates calculation before commencement of work, and
    ii. CO_2 emission and primary energy rates calculation after completion.

c. At either (or both) of these stages, developers can elect to adopt a more recently approved version of the tool, but having elected to use a later version, developers cannot subsequently revert to using a previous one.

14. For producing EPCs, the most recently approved version of the adopted software tool should be used, unless the latest version has been released less than one calendar month prior to the assessment date. In such cases, the immediately previous version of the tool may be used. For newly constructed buildings, the version used to demonstrate compliance with Building Regulations may also be used to produce the EPC.

15. To facilitate this process, part of the procedures for approving a software tool is that a new version must be backwards compatible with all previous versions, i.e., it can either read the data files of previous versions, or a file conversion utility must be provided.

Choosing a software tool

16. All calculation methods involve a degree of simplification, and two classes of software tool are available for use for Building Regulations compliance or EPC generation for buildings other than dwellings:

a. SBEM, the Simplified Building Energy Model developed by the Department for Levelling Up, Housing, and Communities (DLUHC). This can be applied to any building (irrespective of size) although there are some cases, as described in paragraphs 18 to 21, where representation of certain building features will require some approximation.
b. Approved Dynamic Simulation Models (DSMs). These will be applicable for any building unless an individual DSM's approval specifically excludes certain classes 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 (as opposed to carrying out compliance and certification calculations).

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

SBEM constraints

18. 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. This problem is not insurmountable and is most likely to arise where buildings and their systems have features that have properties which vary non-linearly over periods of the order of an hour.

19. 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

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

21. 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 205), 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, i.e., it will *not* run on computers with 32-bit Windows operating systems. However, there is an optional 32-bit version of the SBEM engine which can be used on computers running 32-bit Windows operating systems. NB: Memory limitations might affect the maximum number of zones/objects which can be modelled on 32-bit Windows operating systems.

COMPLIANCE WITH BUILDING REGULATIONS

22. This section of the guide defines the basis for setting the 2021 Target Emission Rate (TER) and Target Primary Energy Rate (TPER). The Building Regulations require that all new buildings must achieve or better both of these targets. The TER and TPER are both based on the performance of the Notional building (see below), and the following procedure must be followed in order to establish the TER and TPER. The procedure converts calculated building loads into energy (and hence CO_2 emissions and primary energy) using seasonal efficiency parameters. *This approach is adopted to avoid the need to define system models appropriate to each type of building. It also ensures a consistent approach to the target setting process.*

THE NOTIONAL BUILDING

23. 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 guidance starting at paragraph 215).

24. Each space must contain the same activity (and, therefore, the same activity parameter values) as proposed for the equivalent space in the Actual building. The activity in each space must be selected from the list of activities as defined in the NCM Activity Database (see paragraph 190).

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

26. Whatever building services type (heating, ventilation, cooling) is specified in a zone in the Actual building must also be provided 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, and then both buildings must heat those spaces to the heating set-point specified for the zone type in the NCM Activity Database. A similar approach applies with regards to the provision of cooling.

27. Any building services system not covered by the energy performance requirements in the Building Regulations[1] must be ignored in both the Actual and Notional buildings.

Activity glazing class

28. 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 class assigned to each NCM activity is determined in the “activity” table from the NCM Activity Database in the “DRIVER2A” field (*0 for activity with no daylight, i.e., unlit, 1 for side-lit activity, and 2 for top-lit activity*).

Building fabric

29. The U-values in the Notional building must be as specified in **Table 1**. All U-values must be calculated following the guidance in BR443[2]. The reference constructions conforming to these U-values are provided in Appendix A of this document. In addition, the general guidance beginning at paragraph 195 must be followed.

[2] BR 443: Conventions for U-value calculations, BRE, 2019 Edition.

Table 1 Construction elements U-value and thermal capacity for the Notional building			
Element	**U-value (W/m²K)**		**Thermal capacity[3] (kJ/m²K)**
	Side-lit and unlit activities	**Top-lit activities**	
Roofs[4] (irrespective of pitch)	0.15	0.18	88.3 (1.40 if metal-clad)
Exposed walls	0.18	0.26	21.8 (1.40 if metal-clad)
Exposed floors and ground floors (subject to paragraph 36)	0.15	0.22	77.7
Windows*	1.4	-	-
Roof-lights*	-	2.1	-
Vehicle access and similar large doors	1.3		2.1
Pedestrian doors and high usage entrance doors	1.9		54.6
Internal walls	1.8		8.8
Internal floors/ceilings	1.0		71.8 from above / 66.6 from below
*This is the overall U-value of the complete unit, including the frame and edge effects, and it relates to the performance of the unit in the vertical plane for windows (and roof windows), and in the horizontal plane (i.e., already adjusted for flat roofs) for roof-lights (BR443[2]) so, where applicable, the U-value must be adjusted (from the vertical plane) for the slope of the roof by +0.3 W/m²K if the roof is flat, and +0.2 W/m²K if the roof is pitched. 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.			

30. 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 2** 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*).

31. For SBEM, the thermal capacity of the construction elements must be as defined in **Table 1**. For DSM software, the construction details in Appendix A provide the necessary technical parameters to account for the effect of thermal capacity. The thermal mass of windows should be ignored.

32. The Notional building does not have curtain walling, even if there is curtain walling in the Actual building.

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[3] Thermal capacity calculation in EN ISO 13790:2004

[4] Any part of a roof having a pitch greater than 70º is considered a wall.

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

34. 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 (and be consistently applied to both Actual and Notional buildings), or by adding 10% to the standard U-values of the Notional building (see paragraph 90 for the Actual building). Note that the U-values as given in **Table 1** DO NOT include this allowance so the calculation tool must make the adjustment explicitly.

35. Where a 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 2**.

Table 2 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

36. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made[5]:

a. If the calculated value is greater than 0.15 W/m²K, the value of 0.15 W/m²K must be used in the Notional building.
b. If the calculated value is less than 0.15 W/m²K with no added insulation, this lower value must be used in the Notional building.

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

38. Zones in the Notional building will use the air permeability values from **Table 3**, provided that zones whose activity types are flagged as involving metal cladding in the NCM Activity Database (see paragraph 30) will use the values in the 'Top-lit' column of **Table 3**. The calculation method used to predict the infiltration rate must use the air permeability as the parameter defining the envelope

[5] This follows the guidance given in CIBSE Guide A (2021)

leakage. For compliance and certification, the same method must be used in both the Actual and Notional buildings. Acceptable methods include:

a. The method specified in the SBEM Technical Manual[6], which is taken from EN 15242[7].
b. Other methods that use a relationship between infiltration rate and air permeability and are set out in national or international standards or recognised UK professional guidance documents which relate average infiltration rate to envelope permeability. An example of the latter would be tables 4.16 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 3 Air permeability for the Notional building (m^3/h per m^2 of envelope area at 50 Pa)

Side-lit and unlit activities	Top-lit activities
3	5

Areas of windows, doors, and roof-lights

39. The areas of windows, doors, and roof-lights 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 the guidance beginning at paragraph 215.

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 4**, the balance must be made up of windows or roof-lights as appropriate.
d. If the total area of the copied elements exceeds the allowance for glazing from **Table 4**, the copied areas must be retained but no windows or roof-lights 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 4**.

40. Display windows in the Actual building are not copied across into the Notional building.

[6] SBEM Technical Manual will be available at http://www.uk-ncm.org.uk

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

Table 4 Glazing in the Notional building				
Activity glazing class	**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: 1.5m high × full facade width OR 40% of exposed facade area	29%	10%	60%
Top-lit	12% of exposed roof area will be made up of roof-lights*	40%	15%	71%
Unlit	No windows or roof-lights	n/a		

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

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

The number of roof-lights 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.

41. DSM software are required to use the glass data provided in **Table 5** and **Table 6** to model the glazing specification required in **Table 4**, 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 5 Glass properties for top-lit glazing in the Notional building

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.409	0.289	0.414	0.798	0.051	0.040	0.837	0.042
Cavity	12mm	Argon gas fill							
Inner pane	6mm	0.783	0.072	0.072	0.889	0.081	0.081	0.837	0.837

Table 6 Glass properties for side-lit glazing in the Notional building

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

42. 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 4** 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.

HVAC and HW systems

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

44. A space is only considered as having air-conditioning if the system serving that space includes refrigeration. 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. 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 the Notional and Actual buildings.

45. 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[8], 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 whenever the space temperature exceeds the heating set-point[9] by 1°K. This enhanced ventilation must cease immediately the space temperature falls below the heating set-point. *By maintaining the increased natural ventilation until internal temperatures fall to the (high) heating set-point, the temperatures at start-up next day will be neither artificially high nor low.*

46. Humidity control is ignored in both the Actual and Notional buildings.

47. The system performance definitions follow the practice set out in EN 15243[10]:

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[8] 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.

[9] 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.

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

a. Auxiliary energy is the energy used by controls, pumps, and fans associated with the HVAC systems. It is the term described as "fans, pumps, controls" in Energy Consumption Guides such as ECG019[11].

b. The Seasonal System Coefficient of Performance (SCoP) for heating 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) 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[6]. Heating energy consumption is, therefore, calculated from the following expression:

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

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, inter alia, 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[6]. Cooling energy consumption is, therefore, calculated from the following expression:

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

48. 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 (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.

49. The Notional building has heat recovery with sensible seasonal 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).

[11] Energy use in offices, Energy Consumption Guide 19, Action Energy, 2003

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

51. In air-conditioning mode, the Notional building will have a cooling SSEER of 4.4, which already takes account of 20% distribution losses and fan energy associated with heat rejection.

52. In mixed-mode operation, the Notional building will have a cooling SSEER[12] of 2.7 with a cooling set-point of 27°C.

53. 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 7**. Note that the SCoP values already take account of distribution losses of 10% (where applicable).

54. 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 generation in the equivalent zone in the Actual building, based on the values provided in **Table 8** to **Table 10**.

55. 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 biomass for hot water generation, then the equivalent zone in the Notional building will use electric heat pumps for space heating and biomass for hot water generation.

[12] 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.

Table 7 Space heating system SCoP and fuel type in the Notional building

Fuel in the Actual building	SCoP in the Notional building		Fuel in the Notional building
	Heated-only top-lit activities*	All other top-lit, side-lit, and unlit activities	
Dual fuel (mineral + wood)	86% thermal and 65% radiant*	81.9%	Dual fuel (mineral + wood)
Natural gas, LPG, fuel oil, manufactured smokeless fuel, coal, or anthracite		86%	Natural gas
Waste heat	63%		Waste heat
Bio-fuel (i.e., biogas or biomass)			The particular bio-fuel
Electricity (heat pump)	264%		Grid electricity (heat pump)
Non-electric heat pump	126%		Natural gas (heat pump)
Electricity (direct)	100% - in modular/portable buildings[13] with a planned time of use in a single location ≤ 2 years		Grid electricity (direct)
	134% - in all other buildings		Grid electricity (heat pump/direct electric hybrid system)

*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 86%, and 65% of the thermal output is radiant (i.e., radiant component of 0.65). Zones with top-lit activities tend to be large/tall spaces where direct radiant heating allows a lower air temperature for a given level of thermal comfort, and this reduces ventilation losses. The SBEM Technical Manual[6] 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.

56. 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, as provided in **Table 8** to **Table 10**, respectively. 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/m^2 per year. Otherwise, a space is considered to have 'low' hot water demand.

57. For hot water, the energy demand in the Actual and Notional buildings must be taken as that required to raise the water temperature from 10°C to 60°C based on the demands specified in the NCM Activity Database. The Activity Database defines a daily total figure, in l/m^2 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.

58. Where indicated in **Table 8** to **Table 10**, hot water generation in the Notional building will have the following nominal storage and secondary circulation system:

[13] With a total planned service life of > 2 years.

a. Storage vessel size (litres) is the product of 0.8 and the floor area served by the HW system (m^2). The vessel will have 50 mm of factory insulation.

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

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

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

Equation 3

$$Pump\ power = \left((0.25 \times loop\ length) + 42\right) / 500$$

Table 8 Water heating seasonal generator efficiency and fuel type in the Notional building for high HW demand activities

Fuel in the Actual building	Seasonal generator efficiency in the Notional building	Fuel in the Notional building	Storage & secondary circulation in the Notional building
Natural gas, LPG, fuel oil, manufactured smokeless fuel, coal, or anthracite	93%	Natural gas	Yes
Electric heat pump	286%	Grid electricity (heat pump)	
Non-electric heat pump	140%	Natural gas (heat pump)	
Waste heat	Table 10		
Bio-fuel (i.e., biogas or biomass)			
Dual fuel (mineral + wood)			
Electricity (direct)			

Table 9 Water heating seasonal generator efficiency and fuel type in the Notional building for low HW demand activities

Fuel in the Actual building	Seasonal generator efficiency in the Notional building	Fuel in the Notional building	Storage & secondary circulation in the Notional building
Natural gas, LPG, fuel oil, manufactured smokeless fuel, coal, or anthracite	100%	Grid electricity (point-of-use)	No
Electric heat pump	286%	Grid electricity (heat pump)	
Non-electric heat pump	140%	Natural gas (heat pump)	
Waste heat	Table 10		
Bio-fuel (i.e., biogas or biomass)			
Dual fuel (mineral + wood)			

Electricity (direct)	

Table 10 Water heating seasonal generator efficiency and fuel type in the Notional building for both high and low HW demand activities

Fuel in the Actual building	Seasonal generator efficiency in the Notional building	Fuel in the Notional building	Storage & secondary circulation in the Notional building
Waste heat	70%	Waste heat	Yes
Bio-fuel (i.e., biogas or biomass)		The particular bio-fuel	
Dual fuel (mineral + wood)	91%	Dual fuel (mineral + wood)	
Electricity (direct)	100%	Grid electricity (point-of-use)	No

59. For bivalent heating systems (i.e., where more than one fuel is used in the Actual building to provide space and/or water heating, such as a biomass boiler supplemented by a natural gas boiler), a demand-weighted conversion factor will be calculated for the Notional building that is based on the proportion of heating demand met by each fuel type in the Actual building. This calculation is determined at zone level, where for each fuel type, the proportion of heating demand is multiplied by the appropriate fuel emission factor and then divided by the associated SCoP from **Table 7** and **Table 8** to **Table 10**. This is repeated for each fuel type and then summed to determine the demand-weighted conversion factor.

For example, if a zone with a side-lit activity in the Actual building meets 70% of its space heating demand with biomass and the rest with natural gas, then the equivalent zone in the Notional building would use a demand-weighted conversion factor of ((0.7×0.029/0.630)+(0.3×0.210/0.86))=0.105 for the CO_2 emission rate, and the equivalent for primary energy. Note that the demand-weighted conversion factor already takes into account both the fuel emission factor and the SCoP.

60. For bivalent water heating systems in the Actual building, the size of the storage vessel calculated in paragraph 58.a, if applicable, for the corresponding Notional water heating system will be pro-rated based on the proportion of the hot water demand met by the fuel type which corresponds to "storage" in **Table 8** to **Table 10**. If applicable, the loop length of the secondary circulation calculated in paragraph 58.b for the Notional building will be similarly pro-rated.

For example, if a zone with a low hot water demand activity in the Actual building meets 70% of its water heating demand with biomass and the rest with natural gas, then the Notional water heating system, which serves the equivalent zone in the Notional building, would have a storage vessel whose size is based on 70% of the zone's floor area.

61. Where a district heating system is used for space and/or water heating in the Actual building (see paragraph 208 and **Table 32**), district heating will be used for space and/or water heating in the Notional building with the following provisions:

- If the Actual building is connected to an *existing*[14] district heating network, the Notional building will use the same emission and primary energy factors of heat delivered as defined by the user for the Actual building.
- If the Actual building is connected to a *new*[14] district heating network, the Notional building will use 0.23 $kgCO_2/kWh$ and 1.05 kWh_{PE}/kWh as the emission and primary energy factors of heat delivered[15], respectively.
- A district heating hot water system in the Notional building will have the nominal storage and secondary circulation described in paragraph 58 where it serves activities with high hot water demand, and no storage or secondary circulation where it serves activities with low hot water demand (as defined in paragraph 56).

Auxiliary energy

62. 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_#"*[16] *fields from the "activity_sbem_D1_ACU" table in the NCM Activity Database*).

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

64. The pump power density for the Notional building will depend on the HVAC system's configuration in the Actual building so that:

- If the Actual building's HVAC system 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 also provides air-conditioning (i.e., equivalent to the Notional building benefitting from variable speed pumping with multiple pressure sensors in the system – see **Table 14**).
- 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.

65. For zones where the ventilation system also provides heating or heating and 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 $$FPS_2 = Greater\ of\ (FAR_{max}, SCR) \times SFP_{central}$$

where:

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[14] ADL volume 2 defines an "existing" district heat network as one that is either in operation or is under construction on 15 June 2022. For these purposes, under construction means any of the following: (a) the building to house the energy centre has been constructed, (b) there is a heat offtake agreement signed between the heat network and a third party, or (c) excavation for pipework has been completed.

[15] These conversion factors represent a district heating network supplied by a gas-fired CHP with an electrical efficiency of 30% and a heat efficiency of 50%, supplying 80% of the heating load, with the remaining 20% assumed to be supplied by an electric heat pump with an efficiency of 264% (and a 15% uplift applied to the CO_2 and primary energy content of heat to account for network heat losses).

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

$\boldsymbol{SFP_{central}}$ = 1.80 W per l/s[17] (supply & extract), and $\boldsymbol{SFP_{terminal}}$= 0.30 W per l/s,
"FAR_{max}" is the peak fresh air supply rate (l/s per 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 per m²), and is calculated as follows:

Equation 7 $$\boldsymbol{SCR = Greater\ of\ (PSH, PSC) / (\rho \times C_p \times \Delta T)}$$

where:

$\boldsymbol{\rho}$ =1.2 kg/m³, $\boldsymbol{C_p}$ =1.018 kJ/kgK, and $\Delta\boldsymbol{T}$ = 8°K,

"$\boldsymbol{PSH}$" is the peak space heating load, and "$\boldsymbol{PSC}$" 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 air losses (infiltration/ventilation load) based on an external ambient of 0°C. The peak space cooling load is the sum of the individual peaks for occupancy, equipment, general lighting, display lighting, and solar. For SBEM, the peak solar gain is calculated using the solar data for September from Table 2.30 of CIBSE Guide A (2006) (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.

66. 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[17] (supply & extract).

67. For zones with local mechanical exhaust where the fan is within the zone, the fan power density for the Notional building 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 for the Notional building 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 & extract ventilation. Note that the user-defined exhaust rate is not considered in the air load calculations.

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

69. 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.

70. 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 from ADL volume 2[18] Table 2.1 apply).

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[17] If the activity in the space requires the use of higher levels of filtration, e.g., high efficiency particulate air (HEPA) filters, then the specific fan power is increased by 1.0 W per l/s to account for the increased pressure drop.

[18] https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l

Lighting

71. The general lighting in the Notional building is based on lighting with efficacy of 95 luminaire lumens per circuit-watt, and the resulting power density (W/m^2) will vary as a function of the geometry of each zone modelled, which will be determined using the following equation:

Equation 8 $$\textit{Power density per 100 lux} = \left(1.22 + (0.005 \times R) + (0.04 \times R^2)\right) / MF$$

Where $\boldsymbol{R}$ *is the ratio of the total wall area*[19] *to the total floor area, where the maximum value for* $\boldsymbol{R}$ *is 8, and* $\boldsymbol{MF}$ *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 zone, which is determined following paragraph 72, 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.*

72. 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.

73. All zones in the Notional building which receive natural daylight directly (i.e., through glazing in the zone's own external envelopes) will be modelled with photoelectric dimming (as defined in the SBEM Technical Manual[6]), without back-sensor control.

74. Zones in the Notional building which do not receive natural daylight directly (i.e., through glazing in the zone's own external envelopes), but are flagged in the NCM Activity Database as appropriate to have local manual light control, will be modelled with local manual switching (as described in the SBEM Technical Manual[6]), provided the floor area of the zone is less than 30 m^2. 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 lighting

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[19] 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.

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*).

75. Zones in the Notional building do not benefit from constant illuminance control[28].

76. All zones in the Notional building will be modelled with occupancy sensing (as defined in the SBEM Technical Manual[6]), if appropriate (i.e., if the activity is flagged in the NCM Activity Database as appropriate to have local manual light control), 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 light control is determined in the "activity" table from the NCM Activity Database using the "BR_CHECK02" field, as described in paragraph 74.

77. 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/m^2.

78. The display lighting, where applicable, in the Notional building is based on the display lighting with luminous efficacy of 95 light source 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 light source efficacy of 95 and 15[20] lumens per circuit-watt). Daylight harvesting, occupancy sensing, and local manual switching do not apply to display lighting in the Notional building (i.e., only affect general lighting).

79. The display lighting in the Notional building does not benefit from automatic time switch control.

80. 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 electricity generation

81. The Notional building will have a roof-mounted PV array whose peak power (kW$_p$) is the product of 0.2 kW$_p$/m^2 and an array area (m^2) calculated using the following equation:

Equation 9

$$A_{PV} = \left(A_{foundation} \times 20\% \times A_{side-lit\&unlit} \,/\, A_{total}\right) + \left(A_{foundation} \times 40\% \times A_{top-lit} \,/\, A_{total}\right)$$

where:

A_{PV} = area of PV array, $A_{foundation}$ = area of building's foundation (as input by user), $A_{side-lit\&unlit}$ = total area of side-lit and unlit zones, $A_{top-lit}$ = total area of top-lit zones, and A_{total} = total area of all zones in the building.

82. The area of building's foundation is calculated using the following equation:

Equation 10

$$A_{foundation} = A_{conditioned} \,/\, N_{storeys}$$

[20] The light source luminous efficacy value on which the display lighting power density values in the NCM Activity Database had been based.

where:

$\boldsymbol{A_{conditioned}}$ = *the total floor area of all the spaces in the modelled building which are conditioned or intended to be conditioned, e.g., after fit-out, by a space heating or space cooling system (i.e., areas of permanently unconditioned[21] spaces are excluded), and* $\boldsymbol{N_{storeys}}$ = *the total number of storeys in the entire structure that encases the modelled building, including partial storeys and storeys containing dwellings and buildings other than dwellings (whether or not they are part of the building being assessed, i.e., represented in the software model).*

83. 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.

Therefore, if a heat pump meets 100% of the space heating demand in the Actual building, then the Notional building will have no PV system.

84. The Notional building's PV array will have a south orientation, a 30° pitch from the horizontal, 'no or very little over-shading', and 'strongly ventilated or forced ventilated modules'.

Target emission rate (TER) and target primary energy rate (TPER)

85. The TER is the CO_2 emission rate of the 2021 Notional building (i.e., no additional improvement factors), in kg/m^2 of the building's total floor area. Similarly, the TPER is the primary energy rate of the Notional building in kWh/m^2.

If the Actual building is constructed entirely to the Notional building specifications, it will meet the target emission rate and target primary energy rate. Developers are, however, free to vary the specifications, provided the target emission rate and target primary energy rate are each achieved or bettered.

86. The following approach must be followed when calculating the CO_2 emission rate of the Notional building.

a. Calculate the monthly electrical energy used by the Notional building irrespective of source of supply. Multiply that energy use by the monthly CO_2 emission factors for grid-supplied electricity from **Table 30** and sum the monthly values to produce the annual figure.
b. Calculate the annual energy associated with any other fuels used in the Notional building and multiply the energy use by the respective CO_2 emission factors for the fuels from **Table 29**.

[21] Permanently unconditioned spaces are those which are not served, or intended to be served e.g., after fit-out, by a space heating or space cooling system.

c. Calculate the monthly electricity generated by the on-site PV system, if applicable, multiply that by the monthly CO_2 emission factors for grid-displaced electricity by PV from **Table 31** (irrespective of the proportion of electricity that is used on site and how much is exported), and sum the monthly values to produce the annual figure.
d. The net figure of 'a *plus* b *minus* c' above is the annual CO_2 emissions used to establish the TER. If 'a *plus* b *minus* c' is a negative value, then the TER is set to 0.

87. The net primary energy of the Notional building and the TPER are calculated using the same approach described in paragraph 86 but substituting the primary energy factors from **Table 29** to **Table 31** for the CO_2 emission factors.

THE ACTUAL BUILDING

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

Building fabric

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

90. 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 (and be consistently applied to both Actual and Notional buildings), or by adding 25% to the standard U-values of the Actual building (see paragraph 34 for the Notional building).

91. Where a method that satisfies BS EN ISO 14683 is used to take account of non-repeating thermal bridges in the Actual building, the user will have the option of either directly entering the relevant Psi values or using defaults as specified in **Table 11** (based on BRE IP 1/06[22] values degraded by the greater of 0.04 W/mK or 50%). Where the user directly enters the Psi values, these values must have been calculated by a person with suitable expertise and experience[23] following the guidance set out in BR497[24] and following a process flow sequence that has been provided to Building Control, indicating the way in which the detail should be constructed.

Table 11 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

92. The U-value typically quoted for a window, roof window, or roof-light is the overall U-value of the complete unit, including the frame and edge effects, and it relates to the performance of the

[22] IP 1/06 Assessing the effects of thermal bridging at junctions and around openings in the external elements of buildings, BRE, 2006.

[23] ADL volume 2.

[24] BR497 Conventions for calculating linear thermal transmittance and temperature factors, BRE, 2007.

unit in the vertical plane for windows and roof windows, and in the horizontal plane (i.e., already adjusted for flat roofs) for roof-lights (BR443[2]) so, where applicable, the U-value must be adjusted (from the vertical plane) for the slope of the roof by +0.3 W/m^{2}K if the roof is flat, and +0.2 W/m^{2}K if the roof is pitched.

Lighting

93. 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 activity's NCM minimum lighting level in the Activity Database. Where the design illuminance is less than the activity's NCM minimum lighting level, the general power density will be automatically pro-rated (up) to the activity's NCM minimum lighting level. *For example, an office with installed lighting load density of 6 W/m² that delivers 200 lux illuminance (i.e., 3 W/m² per 100 lux) would be adjusted to 9 W/m² for the purpose of the calculation because the NCM assumes a minimum illuminance of level 300 lux for this activity.* If the user does not set the design illuminance for the zone, the activity's NCM minimum lighting level will be used for calculating the general power density in the Actual building.

94. For building regulations compliance, the general lighting can be defined explicitly by calculating and inputting the design/installed circuit power[25], or by inference. 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.

95. For general lighting, the following inference methods can be used in addition to the explicit method for Building Regulations compliance to define the general lighting:

- **Inference method 1** - User sets the light source 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 95 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 93, if applicable.
- **Inference method 2** - User assigns a lamp type to each zone based on **Table 12**, where the luminaire efficacy can be pro-rated against the Notional lighting curve (*which is based on 95 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 93, if applicable.

[25] The luminous efficacy can be derived for reporting by working backwards using Equation 8, the circuit power, and inference method 1 from paragraph 95.

Table 12 Lamp inference data				
Lamp type	Luminaire lumens per circuit-watt			
	For all buildings except those specified in the next column[26]		For modular or portable "distress purchase" buildings with a planned time of use in a single location ≤ 2 years	
	Side-lit and unlit activities	Top-lit activity	Side-lit and unlit activities	Top-lit activity
LED	50.0	50.0	55.0	55.0
Tungsten and Halogen	7.5	9.0	7.5	9.0
Fluorescent - compact	22.5	27.0	22.5	27.0
T12 Fluorescent - halophosphate - low frequency ballast	25.0	30.0	25.0	30.0
T8 Fluorescent - halophosphate - low frequency ballast	27.5	33.0	55.0	55.0
T8 Fluorescent - halophosphate - high frequency ballast	32.5	39.0	55.0	58.5
T8 Fluorescent - triphosphor - high frequency ballast	36.3	43.5	55.0	65.3
Metal Halide	25.0	39.0	25.0	39.0
High Pressure Mercury	22.5	27.0	22.5	27.0
High Pressure Sodium	35.0	42.0	35.0	42.0
T5 Fluorescent - triphosphor-coated - high frequency ballast	37.5	45.0	56.3	67.5
Fluorescent (no details)	22.5	27.0	22.5	27.0

96. The general lighting in the Actual building will include the capability of modelling daylight harvesting, local manual switching, where appropriate[27], and occupancy sensor control (as defined in the SBEM Technical Manual[6]), where appropriate. It will also include the capability of modelling constant illuminance control (as defined in BS EN 15193:2007[28]) by reducing the general lighting power density by 10%, if applicable.

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

98. Display lighting will be defined in terms of the average display lighting light source efficacy for each zone, which will be pro-rated against an efficacy of 15 light source lumens per circuit-watt to adjust the NCM display lighting power density value associated with the activity in the NCM Activity Database.

[26] Luminous efficacy values were derived using a light output ratio of 0.5 for side-lit and unlit activities and 0.6 for top-lit activities, except in the case of LED, where a light output ratio of 1.0 was used for all activity classes.

[27] 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 74.

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

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

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

Auxiliary energy

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

102. 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.).

103. 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_#"*[16] *fields from the "activity_sbem_D1_ACU" table in the NCM Activity Database*).

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

105. 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 13** 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 14** gives the pump power densities for constant speed pumping as well as variable speed pumping.

Table 13 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
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
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 14 Pump power density for Actual building (W/m²)

Pump configuration	LTHW only	Both LTHW and 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

106. For zones where the ventilation system also provides heating or heating and cooling, the fan power density is determined for each zone using one of the following equations as determined by **Table 15**:

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

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

Equation 13 $$FPS_3 = Greater\ of\ \left((SCR/5), FAR_{max}\right) \times SFP_{central}$$

Equation 14 $$FPS_4 = FAR_{max} \times SFP_{central}$$

Equation 15 $$FPS_5 = 0.85 \times FAR_{max} \times SFP_{central}$$

where:

"FAR_{max}" is the peak fresh air supply rate (l/s per 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 per m²) and is calculated as follows:

Equation 16 $$SCR = Greater\ of\ (PSH, PSC) \,/\, \left(\rho \times C_p \times \Delta T\right)$$

where:

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

"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 air losses (infiltration/ventilation 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 (2006) (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.

107. The fan power density equations are assigned to HVAC systems based on **Table 15**.

Table 15 Assigning fan power equations to HVAC systems

HVAC system type	iSBEM 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	
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 13
Induction system	14	
Variable refrigerant flow	10	Equation 14
Chilled ceilings or passive chilled beams and mixing ventilation	35	
Chilled ceilings or passive chilled beams and displacement ventilation[29]	11	Equation 15

108. 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.

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

110. For zones served by the HVAC systems listed in **Table 16**, 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 16 Additional fan power for specific HVAC systems

HVAC system type	iSBEM ID
Central heating using water: convectors (*but only in case the system utilises fanned convectors)*	24
Other local room heater - fanned	3

111. 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

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

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

113. 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

114. 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

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

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

116. 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 as follows:

Equation 17 $$FAR_{dc} = (C_{dc} \times FAR_{lower}) + \left((1 - C_{dc}) \times FAR_{max}\right)$$

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 per m²), C_{dc} is a demand control coefficient which is determined based on the data in **Table 17***,* and FAR_{lower} is calculated as follows:

Equation 18 $$FAR_{lower} = Greater\ of\ \left(FAR_{min}, (0.6 \times FAR_{max})\right)$$

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), in l/s per m².

Table 17 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

117. 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 18**, 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 18 Proportion of maximum fan power in case of demand control of ventilation[30]

FAR_{dc}/FAR_{max}	0	0.2	0.4	0.6	0.8	1
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 & core

118. For shell and core buildings, users need to identify which services are assumed at the 'as built' stage. Assumed services should be defined at zone level by means of differentiating 'shell' from 'core' zones (approved software tools must allow for this selection).

119. If calculation is performed at the 'as built' stage, the proportion of energy associated to HVAC, lighting, and HW systems serving 'shell' zones would not be accounted for in the total energy consumption of the building, as well as the associated floor area. Note that those systems are fully operational and calculated so that the expected service is provided, designated temperatures are maintained, lighting and hot water provided in all zones, both 'shell' and 'core'. That means the boundary conditions between the shell and core areas are considered, but no energy is used by the plants or lighting systems when serving 'shell' zones. In all other cases, e.g., analysis performed at 'as designed' stage or for 'core' zones, energy would be accounted for as usual. This is applicable to all modelled buildings: Actual and Notional.

120. Energy produced by renewable energy sources must be apportioned in an area-weighted basis when the analysis is done at the 'as built' stage. Only the proportion for 'core' zone areas is accounted for at this stage.

121. The energy associated with combined heat and power (CHP) systems would only apply to the 'core' areas.

122. These procedures only apply to Building Regulations compliance ('as built' stage); EPC generation will still include both 'shell' and 'core'.

Modular and portable buildings

123. For modular and portable buildings with a planned service life of more than two years, reasonable provision to demonstrate compliance with Building Regulations could be subject to certain corrections to the TER and TPER as specified in Tables 2.2 and 2.3 of ADL volume 2[18]. Approved tools must allow users to specify the necessary information to apply such adjustments. Users are expected to follow guidance in Approved Documents to correctly populate these fields.

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[30] Adapted from BS EN 15241:2007 - Ventilation for buildings.

Low energy demand non-exempt buildings, and parts of buildings

124. In non-exempt buildings defined in ADL volume 2[18] as of 'low energy demand', as specified in paragraph 2.26, the zones should be modelled in the approved software as 'unconditioned', i.e., not served by a space heating or space cooling system, for the purpose of demonstrating compliance with Building Regulations. Other fixed building services, such as lighting, water heating, local mechanical exhaust, etc., should be modelled as normal.

Building emission rate (BER) and building primary energy rate (BPER)

125. The following approach must be followed when calculating the CO_2 emission rate of the Actual building, in kg/m^2 of the building's total floor area.

a. Calculate the monthly electrical energy used by the Actual building irrespective of source of supply. Multiply that energy use by the monthly CO_2 emission factors for grid-supplied electricity from **Table 30** and sum the monthly values to produce the annual figure.
b. Calculate the annual energy associated with any other fuels used in the Actual building, including any fuel used in generating the electricity (e.g., in a CHP generator), and multiply the energy use by the respective CO_2 emission factors for the fuels from **Table 29**.
c. Calculate the monthly electricity generated by any on-site PV systems, multiply that by the monthly CO_2 emission factors for grid-displaced electricity by PV from **Table 31** (irrespective of the proportion of electricity that is used on site and how much is exported), and sum the monthly values to produce the annual figure.
d. Calculate the monthly electricity generated by any on-site systems other than PV, for e.g., wind or CHP generators, multiply that by the monthly electricity CO_2 emission factors from **Table 30** (irrespective of the proportion of electricity that is used on site and how much is exported), and sum the monthly values to produce the annual figure.
e. The net figure of 'a *plus* b *minus* c *minus* d' above is the annual CO_2 emissions used to establish the BER.

126. The net primary energy of the Actual building and the BPER are calculated using the same approach described in paragraph 125 but substituting the primary energy factors from **Table 29** to **Table 31** for the CO_2 emission factors.

Alternative energy systems

127. 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 Regulation 25A of the Building Regulations (renewable energy systems, CHP, district heating/cooling, or heat pumps), and to confirm that there is documentary evidence of the feasibility assessment. They should also be asked if they have included any such systems in the proposed design solution. The answers to these questions will be reported in the BRUKL (compliance output document) summary.

LIMITING SOLAR GAINS

128. This section describes how the solar gain limit (described in ADL volume 2[18]) should be checked in the Actual building.

129. The solar gain check will include any zone in the Actual building that is either mechanically-cooled 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)*.

130. 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.

131. The contribution of solar gain from display windows will be included in the solar gain limit check for zones that apply.

132. The solar gain limit is based on the solar gains through benchmark glazing types described in **Table 19**, and selected according to paragraph 136, aggregated over the period from April to September, and using the same CIBSE TRY weather data used for the CO_2 emissions and primary energy calculations.

Table 19 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 1 m 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 10% 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.

133. 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 (**Figure 1** and **Figure 2**) that meets the requirements of **Table 19**. 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/m^2, respectively). This means that each DSM will have 3 values for benchmark aggregated solar flux for each CIBSE TRY weather data set.

134. 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 20** and **Table 21** (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).

135. During validation, DSM software will be required to declare the benchmark aggregated solar flux values. Once approved by DLUHC, the declared benchmark aggregated solar flux values cannot be changed unless re-validation is carried out.

136. 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), the limiting solar gain will be the aggregated solar flux for benchmark glazing type 2 multiplied by the exposed roof area.

b. For zones with top-lit activities:
   - For each zone where the height[31] is less than 6 m, 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[31] is greater than or equal to 6 m, 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).

137. The total solar gain aggregated over the period from April to September for each zone in the Actual building, where this criterion 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).

138. 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 20 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	6mm	0.489	0.319	0.217	0.791	0.045	0.071	0.045	0.302
Cavity	16mm	Argon gas fill							
Inner pane	6mm	0.895	0.079	0.079	0.908	0.082	0.082	0.840	0.840

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

Table 21 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	6mm	0.430	0.269	0.298	0.664	0.169	0.070	0.840	0.072
Cavity	16mm	Argon gas fill							
Inner pane	6mm	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

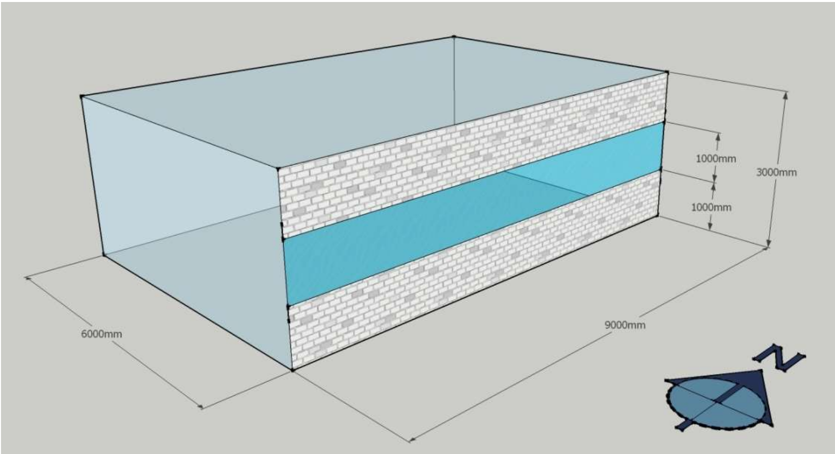
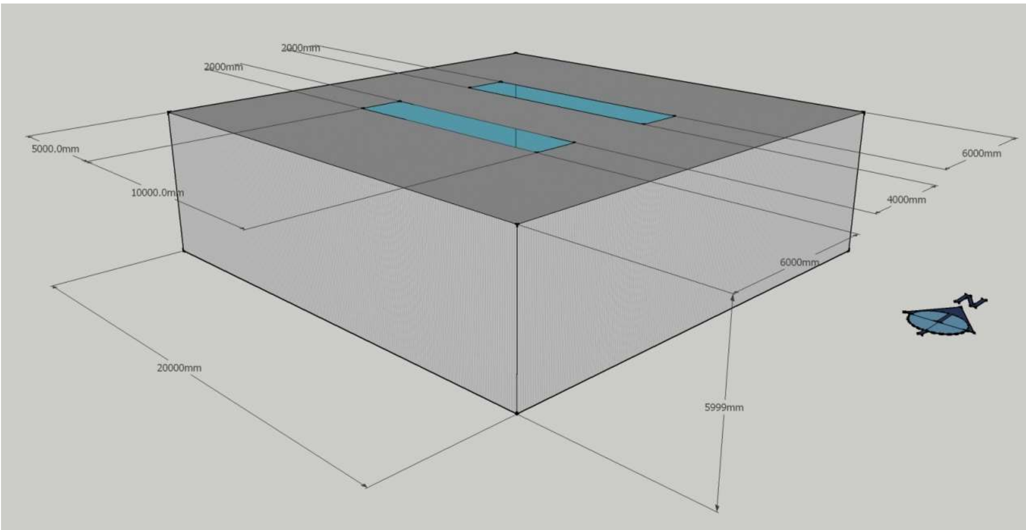


Figure 2 Isometric view of standard test-space for benchmark glazing types 2 and 3

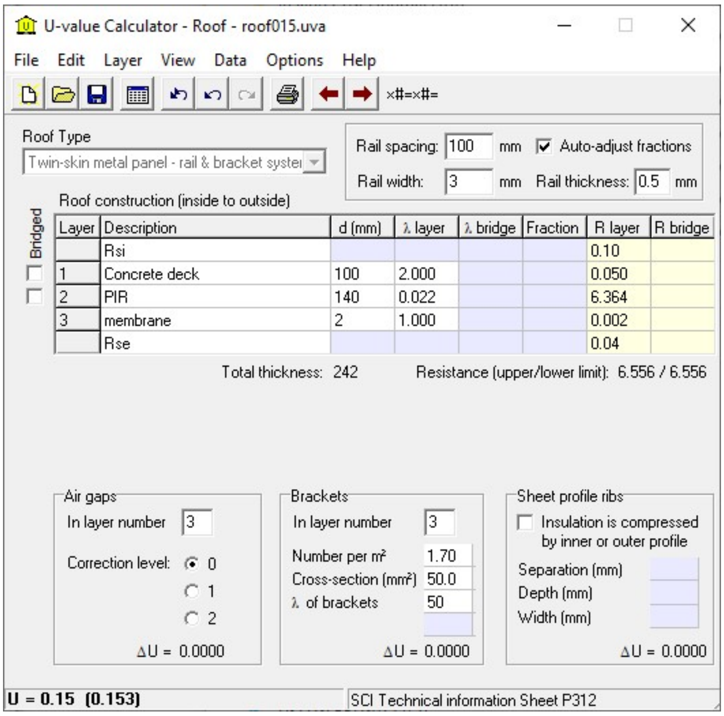


APPENDIX A – CONSTRUCTION DETAILS FOR 2021 NOTIONAL BUILDING

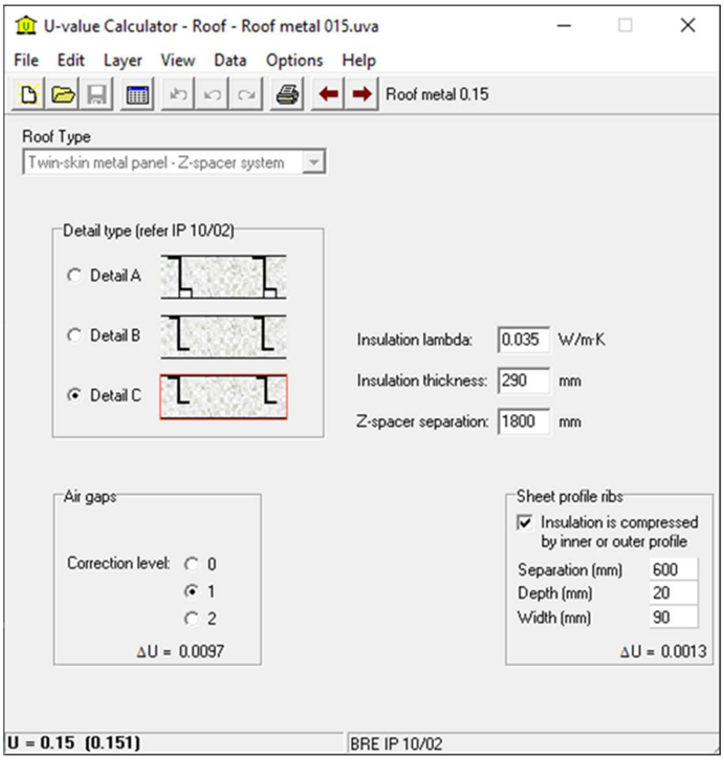
139. This section includes screen grabs from the BRE U-value calculator (version 2.02) that show the construction details used as the basis for the data for thermal capacity values in **Table 1**. These construction details are for use by DSM software to account for the effect of thermal capacity.

140. 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**.

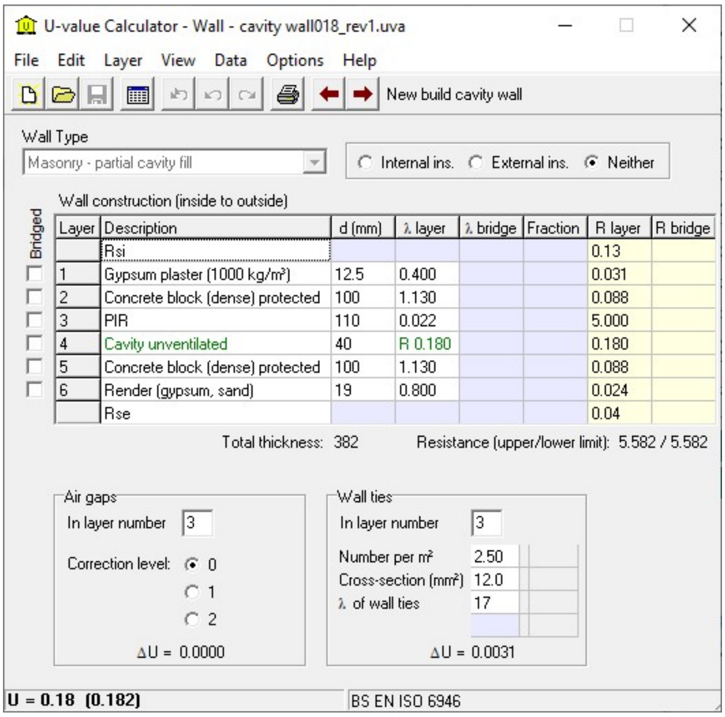
141. Roof construction details for the 2021 Notional building (not involving metal cladding).



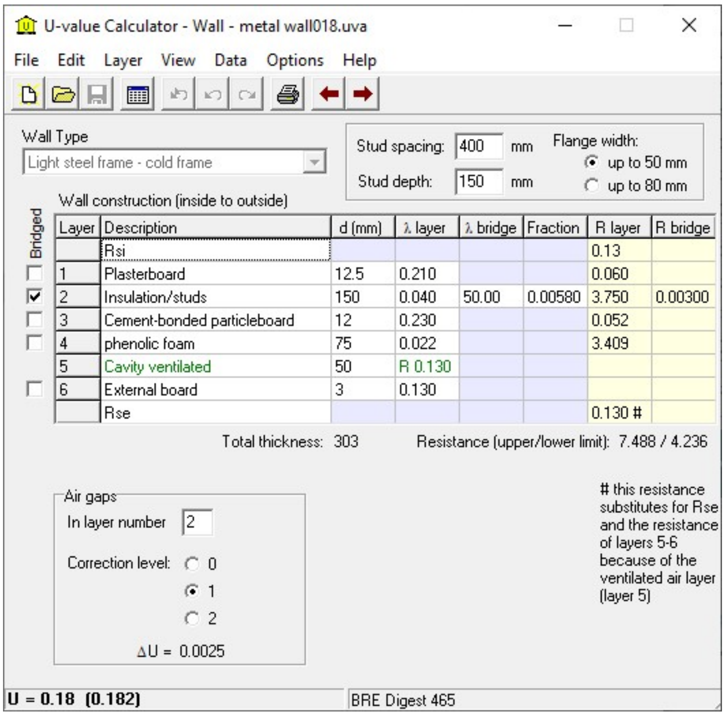
142. Roof construction details for the 2021 Notional building (involving metal cladding).



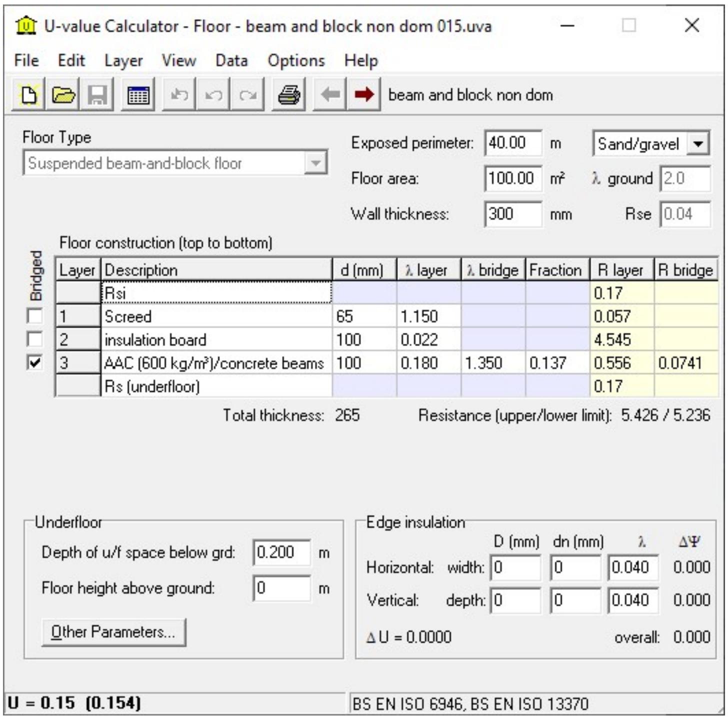
143. External wall construction details for the 2021 Notional building (not involving metal cladding).



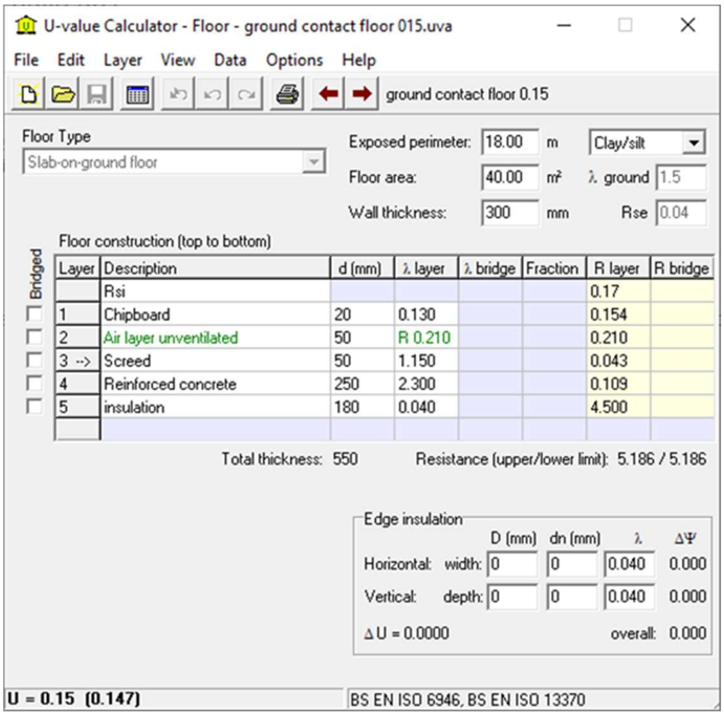
144. External wall construction details for the 2021 Notional building (involving metal cladding).



145. Exposed floor construction details for the 2021 Notional building.



146. Ground floor construction details for the 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).



U-value Calculator - Floor - ground contact floor 015.uva

File Edit Layer View Data Options Help

ground contact floor 0.15

Floor Type: Slab-on-ground floor

Exposed perimeter: 18.00 m — Clay/silt

Floor area: 40.00 m² — λ ground 1.5

Wall thickness: 300 mm — Rse 0.04

Floor construction (top to bottom)

Layer	Description	d (mm)	λ layer	λ bridge	Fraction	R layer	R bridge
	Rsi					0.17	
1	Chipboard	20	0.130			0.154	
2	Air layer unventilated	50	R 0.210			0.210	
3 -->	Screed	50	1.150			0.043	
4	Reinforced concrete	250	2.300			0.109	
5	insulation	180	0.040			4.500	

Total thickness: 550 Resistance (upper/lower limit): 5.186 / 5.186

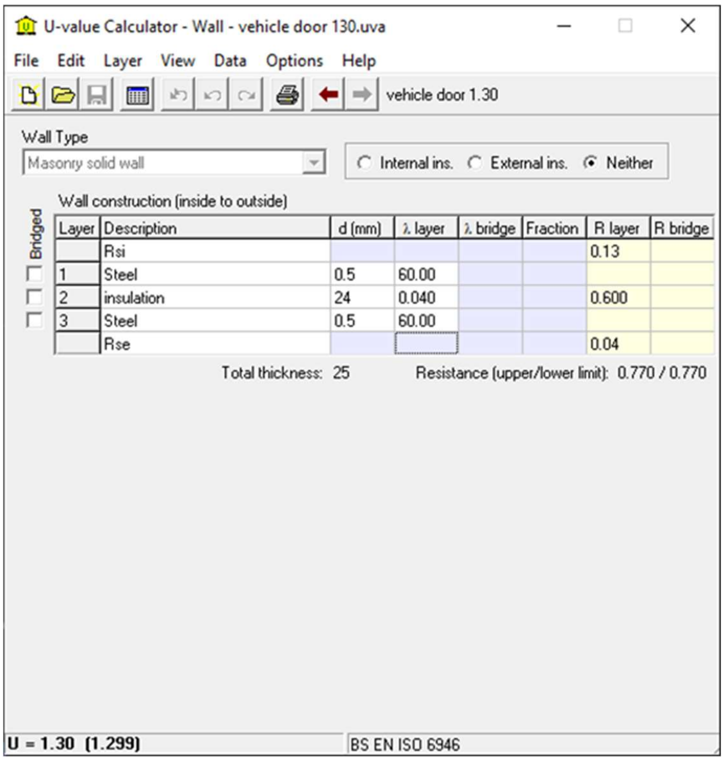
Edge insulation

		D (mm)	dn (mm)	λ	ΔΨ
Horizontal:	width:	0	0	0.040	0.000
Vertical:	depth:	0	0	0.040	0.000

ΔU = 0.0000 overall: 0.000

U = 0.15 (0.147) BS EN ISO 6946, BS EN ISO 13370

147. Vehicle access and similar large door construction details for the 2021 Notional building.



U-value Calculator - Wall - vehicle door 130.uva

File Edit Layer View Data Options Help

vehicle door 1.30

Wall Type: Masonry solid wall — Internal ins. External ins. Neither

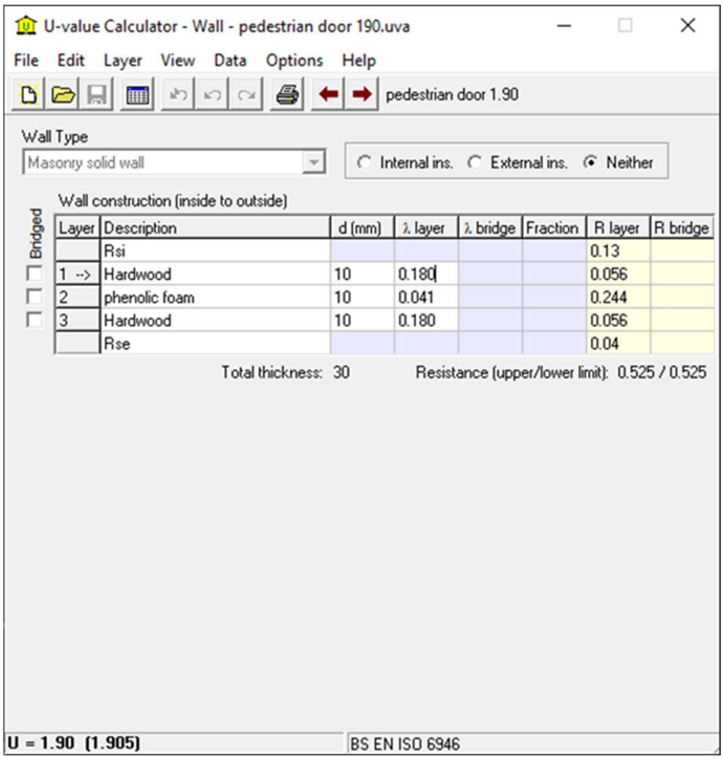
Wall construction (inside to outside)

Layer	Description	d (mm)	λ layer	λ bridge	Fraction	R layer	R bridge
	Rsi					0.13	
1	Steel	0.5	60.00				
2	insulation	24	0.040			0.600	
3	Steel	0.5	60.00				
	Rse					0.04	

Total thickness: 25 Resistance (upper/lower limit): 0.770 / 0.770

U = 1.30 (1.299) BS EN ISO 6946

148. Pedestrian doors and high usage entrance doors construction details for the 2021 Notional building.



U-value Calculator - Wall - pedestrian door 190.uva

File Edit Layer View Data Options Help

pedestrian door 1.90

Wall Type: Masonry solid wall (Internal ins. / External ins. / • Neither)

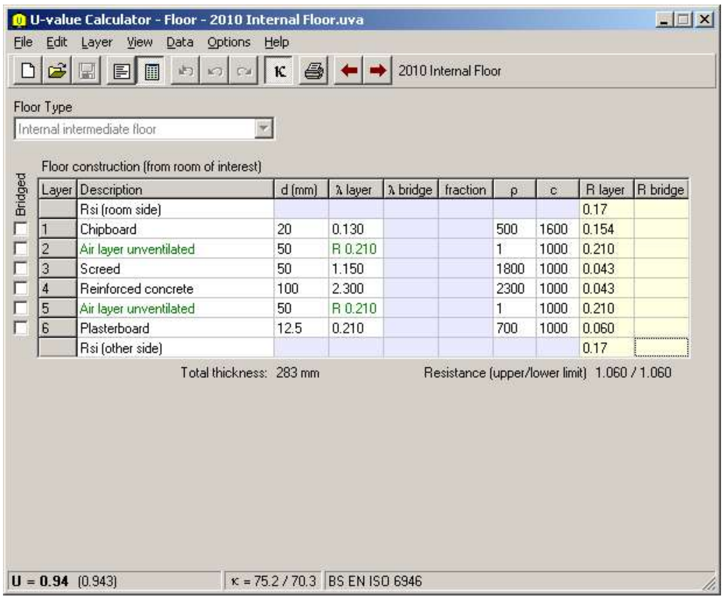
Wall construction (inside to outside)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	Fraction	R layer	R bridge
		Rsi					0.13	
☐	1 -->	Hardwood	10	0.180			0.056	
☐	2	phenolic foam	10	0.041			0.244	
☐	3	Hardwood	10	0.180			0.056	
		Rse					0.04	

Total thickness: 30 Resistance (upper/lower limit): 0.525 / 0.525

U = 1.90 (1.905) BS EN ISO 6946

149. Internal floor/ceiling construction details for the 2021 Notional building.



U-value Calculator - Floor - 2010 Internal Floor.uva

File Edit Layer View Data Options Help

2010 Internal Floor

Floor Type: Internal intermediate floor

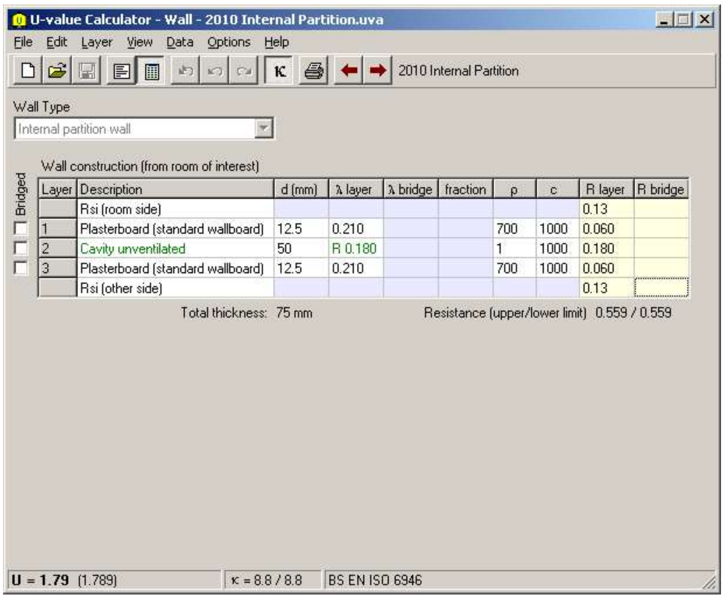
Floor construction (from room of interest)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
		Rsi (room side)							0.17	
☐	1	Chipboard	20	0.130			500	1600	0.154	
☐	2	Air layer unventilated	50	R 0.210			1	1000	0.210	
☐	3	Screed	50	1.150			1800	1000	0.043	
☐	4	Reinforced concrete	100	2.300			2300	1000	0.043	
☐	5	Air layer unventilated	50	R 0.210			1	1000	0.210	
☐	6	Plasterboard	12.5	0.210			700	1000	0.060	
		Rsi (other side)							0.17	

Total thickness: 283 mm Resistance (upper/lower limit) 1.060 / 1.060

U = 0.94 (0.943) κ = 75.2 / 70.3 BS EN ISO 6946

150. Internal partition construction details for the 2021 Notional building.



U-value Calculator - Wall - 2010 Internal Partition.uva

File Edit Layer View Data Options Help

2010 Internal Partition

Wall Type

Internal partition wall

Wall construction (from room of interest)

Bridged	Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
		Rsi (room side)							0.13	
☐	1	Plasterboard (standard wallboard)	12.5	0.210			700	1000	0.060	
☐	2	Cavity unventilated	50	R 0.180			1	1000	0.180	
☐	3	Plasterboard (standard wallboard)	12.5	0.210			700	1000	0.060	
		Rsi (other side)							0.13	

Total thickness: 75 mm

Resistance (upper/lower limit) 0.559 / 0.559

U = 1.79 (1.789) | κ = 8.8 / 8.8 | BS EN ISO 6946

APPENDIX B – THE REFERENCE BUILDING

151. This section of the guide defines the Reference building, which is the basis of setting the energy rating scale for Energy Performance Certificates (EPCs) for England (and Wales). The Asset Rating rates the CO_2 emissions from the Actual building in comparison to a Standard Emission Rate (SER). The Standard Emission Rate is determined by applying a fixed improvement factor to the emissions from a Reference building which is defined below.

152. EPCs are intended to send market signals about the relative performance of comparable buildings. In order to provide this consistency, the Reference building must be the same irrespective of:

a. Whether the Actual building is naturally-ventilated or air-conditioned[32].
b. The fuel choice in the Actual building.

153. The Reference building must have the same size, shape, and zoning arrangements as the Actual building, with the same conventions relating to the measurement of dimensions.

154. 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 (see paragraph 190).

155. The Reference and Actual buildings must be given the same orientation and be exposed to the same weather data. For DSM software, the Reference 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.

156. Any building services system not covered by the energy performance requirements in the Building Regulations[1] must be ignored in both the Actual and Reference buildings.

Building fabric

157. The U-values must be as specified in **Table 22**. All U-values must be calculated following the guidance in BR443[2]. The general guidance beginning at paragraph 195 must be followed.

Table 22 Construction elements U-value and thermal capacity for the Reference building

Element	U-value (W/m²K)	Thermal capacity[3] (kJ/m²K)
Roofs[4] (irrespective of pitch)	0.25	12.0
Exposed walls	0.35	11.7
Exposed and ground floors (subject to paragraph 160)	0.25	36.0
Windows, roof windows, roof-lights*, glazed doors, and curtain walling	2.20	-

[32] Spaces in the Reference building are all naturally-ventilated.

External pedestrian doors	2.20	-
Vehicle access and similar large doors	1.50	-
Internal walls	2.00	11.9
Internal windows	3.85	-
Internal floors/ceilings	1.24	8.6
*This is the overall U-value of the complete unit, including the frame and edge effects, and it relates to the performance of the unit in the vertical plane so, where applicable, it must be adjusted for the slope of the roof (BR443[2]) by +0.3 W/m^{2}K if the roof is flat and +0.2 W/m^{2}K if the roof is pitched. All the roof-lights in the Reference 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 (as opposed to 1.0 for flat ones), i.e., the area of the roof-light is 1.3 times the area of the opening in the roof.		

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

159. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be allowed for in the Reference building by adding 10% to the standard U-values. Note that the U-values as given in **Table 22** DO NOT include this allowance, and so the calculation tool must make the adjustment explicitly.

160. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made[5]:

a. If the calculated value is greater than 0.25 W/m^{2}K, the value of 0.25 W/m^{2}K must be used in the Reference building.
b. If the calculated value is less than 0.25 W/m^{2}K with no added insulation, this lower value must be used in the Reference building.

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

162. The thermal capacity of the construction elements must be as defined in **Table 22**.

163. The air permeability of the Reference building must be 10 m^3/h per m^2 of envelope area at 50 Pa. The calculation method used to predict the infiltration rate must use the air permeability as the parameter defining the envelope leakage. For certification, the same method must be used in both the Actual and Reference buildings. Acceptable methods include:

a. The method specified in the SBEM Technical Manual[6], which is taken from EN 15242[7].
b. Other methods that use a relationship between the infiltration rate and air permeability and are set out in national or international standards or recognised UK professional guidance documents which relate the average infiltration rate to the envelope permeability. An example of the latter would be tables 4.16 to 4.23 of CIBSE Guide A (2021).

Areas of windows, doors, and roof-lights

164. In SBEM, the total solar energy transmittance (BS EN 410 g-value) and the light transmittance of glazing must be as given in **Table 23**. This data applies to windows, roof windows, and roof-lights. Appropriate values for intermediate orientations can be based on linear interpolation.

Table 23 Solar and light transmittances for glazing in the Reference building

Orientation of glazing	Solar transmittance	Light transmittance	Reference glazing type
North, North-East, South, North-West	0.72	0.76	1
East, South-East, South-West, West	0.58	0.61	2
Horizontal	0.43	0.46	3

165. DSM software are required to use the glass data provided in **Table 24** to **Table 26** to determine the EN ISO 410 g-value. T_{solar} is the direct solar transmittance, $T_{visible}$ is the direct visible light transmittance, R_{solar} is the solar reflectance, $R_{visible}$ is the visible light reflectance. The subscripts 1 and 2 refer to the outer and inner surfaces of each pane of glass respectively.

Table 24 Glass properties for Reference glazing type 1

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.821	0.074	0.074	0.913	0.082	0.082	0.837	0.837
Cavity	12mm	Argon gas fill							
Inner pane	6mm	0.664	0.111	0.092	0.822	0.109	0.098	0.170	0.837

Table 25 Glass properties for Reference glazing type 2

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.655	0.068	0.068	0.735	0.079	0.079	0.837	0.837
Cavity	12mm	Argon gas fill							
Inner pane	6mm	0.664	0.111	0.092	0.822	0.109	0.098	0.170	0.837

Table 26 Glass properties for Reference glazing type 3

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.437	0.052	0.055	0.551	0.060	0.063	0.837	0.837
Cavity	12mm	Argon gas fill							
Inner pane	6mm	0.664	0.111	0.092	0.822	0.109	0.098	0.170	0.837

166. The areas of windows, doors, and roof-lights in the Reference building must be determined as set out in the following sub-paragraphs and must also conform to the measurement conventions set out in the guidance beginning at paragraph 215.

a. Subject to the following criteria, all external walls must have windows, and all roofs must have roof-lights.
b. Copy the areas of pedestrian doors, vehicle access doors, and display windows that exist in the corresponding element of the Actual building.
c. If the total area of these elements is less than the appropriate allowance from **Table 27**, the balance must be made up of windows or roof-lights as appropriate.
d. If the total area of the copied elements exceeds the allowance from **Table 27**, the copied areas must be retained but no windows or roof-lights added.
e. The areas as defined in **Table 27** represent the areas of openings in the wall or roof and comprise the area of the glass plus frame. The windows must have a frame factor of 10% (i.e., 90% of the area of the opening is glazed) and roof-lights a frame factor of 30%.

167. The U-value of display windows must be taken as 5.7 W/m²K in the Reference building with solar transmittance of 0.77, light transmittance of 0.87, and 10% frame factor.

Table 27 Percentage opening areas in the Reference building

Building type[33]	**Windows (of exposed wall area)**	**Roof-lights (of exposed roof area)**
Residential buildings (where people temporarily or permanently reside)	30%	20%
Places of assembly, offices and shops	40%	20%
Industrial and storage buildings	15%	20%

168. In addition, the following rules apply:

a. The Reference building does not have any high usage entrance doors, even if these are present in the Actual building.
b. In the Reference building, pedestrian and vehicle access doors must be taken as being opaque (i.e., with zero glazing).
c. 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 **Table 27** percentages must apply to the above-ground part, with zero glazing for the below-ground part.

HVAC system

169. The space heating and hot water generation service is always met by natural gas irrespective of whether a fuel other than natural gas is used in the Actual building or natural gas is even available in the locality of the Actual building.

[33] Determined for each activity by the "BR_CHECK05" field in the "activity" table of the NCM Activity Database.

170. The Reference building has a fixed servicing strategy regardless of the strategy adopted in the Actual building. Therefore:

a. Each space is heated, as defined by the heating set-points defined in the NCM Activity Database, and naturally ventilated.
b. The space heating seasonal SCoP is 0.73.
c. The auxiliary energy is the product of 0.61 W/m² and the 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_#"[16] fields from the "activity_sbem_D1_ACU" table in the NCM Activity Database*).
d. Each space is cooled, based on the operating schedules defined by the NCM Activity Database, with the cooling set-point fixed at 27ºC (i.e., mixed-mode) irrespective of whether the particular space in the Actual building has cooling provision or not[34] . The cooling SSEER must be taken as 2.25 (this factor includes an allowance for fan energy when the system operates so no additional auxiliary energy need be determined).

A space that is not treated (i.e., has no heating and no cooling) in the Actual building will not be heated or cooled in the Reference building. This means that all potential levels of servicing are accommodated on a single scale. If a particular accommodation type does not need air-conditioning (e.g., warehouse), then the cooling demand will be zero, and no energy demand will be calculated. If a particular accommodation type always needs cooling (e.g., a dealer room), then a base-line level of cooling will be calculated. 27ºC has been chosen, rather than the usual comfort threshold of 28°C, because the calculations are based on the Test Reference Year (representing typical weather).

171. For zones with local mechanical exhaust where the fan is within the zone, the fan power density in the Reference building is the product of the user-defined (for the Actual building) exhaust rate and a specific fan power of 0.50 W per l/s. For zones where the mechanical exhaust fan is remote from the zone, the fan power density is the product of the user-defined exhaust rate and a specific fan power of 0.80 W per l/s. The exhaust fan energy will be an addition to the auxiliary energy from paragraph 170c.

172. In the Reference building:

a. No allowance should be made for heat recovery equipment.
b. No allowance should be made for demand control of ventilation.

173. The hot water system overall seasonal efficiency (including generation and distribution) in the Reference building must be taken as 45%. The energy demand in the Actual and Reference buildings must be taken as that required to raise the water temperature from 10°C to 60°C based on the demands specified in the NCM Activity Database. The Activity Database defines a daily total

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[34] If the space in the Actual building has a cooling system, then the calculation of the performance of the Actual building will be assessed by cooling the space to the cooling set-point temperature as defined in the NCM Activity Database. User-specified cooling set-points are not allowed.

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.

174. The Reference building must be assumed to have no power factor correction or automatic monitoring and targeting with alarms for out-of-range values.

175. Humidity control is ignored in both the Actual and Reference buildings.

Lighting

176. The Reference building will use an illuminance level for the space determined following a similar process to that described in paragraph 72 for the Notional building. For general lighting power density:

a. In office, storage, and industrial spaces, divide the illuminance level in the space by 100 and then multiply by 3.75 W/m² per 100 lux. This includes all spaces that accommodate predominantly office tasks, including classrooms, seminar rooms, and conference rooms, including those in schools.
b. For other spaces, divide the illuminance level in the space by 100 and then multiply by 5.2 W/m² per 100 lux.

Whether or not the activity is an office, storage, or industrial space is determined in the "activity" table from the NCM Activity Database in the "BR_CHECK01" field (*1 for activity that is an office, storage, or industrial space, and 0 for other spaces*).

177. Zones in the Reference building that are flagged in the NCM Activity Database as appropriate to receive local manual light control[35] will be modelled with local manual switching (as described in the SBEM Technical Manual[6]) provided the floor area for each 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. Note that local manual switching only applies to general lighting (i.e., does not apply to display lighting).

178. For display lighting, take the display lighting density appropriate to the activity from the NCM Activity Database.

179. The general lighting in the Reference building does not benefit from occupancy sensor control.

180. The display lighting in the Reference building does not benefit from automatic time-switch control.

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

[35] 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 74.

Calculating the asset rating

182. The CO_2 emission rate arising from the use of the fixed building services in the Reference building is calculated (the Reference Emission Rate or RER) and then adjusted, by the relevant improvement factor, to arrive at the CO_2 performance used to normalise the CO_2 emissions in the Actual building. This adjusted CO_2 emission rate is termed the Standard Emission Rate (SER). When making the adjustment, the improvement factor must be taken as 23.5%. In summary:

Equation 19 $$SER = RER \times 0.765$$

This is the overall improvement required for a heated and naturally-ventilated building, compared to 28% for a mechanically-ventilated or air-conditioned building as given in ADL2A (2006). The lower figure has been taken since, in most cases, the cooling energy demand will be small, and so the building most closely resembles a heated-only building. Furthermore, if the Actual building is air-conditioned to normal standards (i.e., typically 22-24°C), the Reference building is only cooled to 27°C, which gives the Reference building an advantage against the Notional building that will compensate (to some extent) for the smaller improvement factor compared to that required by Building Regulations.

183. It is not intended that the definition of the Reference building should change as Part L standards change since this would mean that the energy rating of a given building would also change, even if its energy efficiency had not been varied. Therefore, the Reference building is always as defined above.

184. The Asset Rating (AR) is the ratio of the CO_2 emission rate from the Actual building (i.e., the BER) to the Standard Emission Rate (i.e., SER), with the result normalised such that the SER is equivalent to an Asset Rating of 50, i.e.,

Equation 20 $$AR = 50 \times BER \,/\, SER$$

The calculated AR must be rounded to the nearest whole number, i.e., if the decimal part of the AR is less than 0.5, the AR must be rounded down; if it is 0.5 or greater, the AR must be rounded up.

185. The following approach must be followed when calculating the RER, in kg/m^2 of the building's total floor area.

a. Calculate the monthly electrical energy used by the Reference building, multiply that energy use by the monthly CO_2 emission factors for grid-supplied electricity from **Table 30**, and sum the monthly values to produce the annual figure.
b. Calculate the annual energy associated with the natural gas used in the Reference building and multiply the energy use by the corresponding CO_2 emission factor for natural gas from **Table 29**.
c. The total figure of 'a *plus* b' above is the annual CO_2 emissions used to establish the RER.

Constructing the rating scale

186. The A to G scale, in **Table 28**, is a linear scale based on two key points defined as follows:

a. The zero point on the scale is defined as the performance of the building that has zero net annual CO_2 emissions associated with the use of the fixed building services as defined in the Building Regulations. This is equivalent to a Building Emission Rate (BER) of zero.
b. The border between grade B and grade C is set at the Standard Emission rate (SER) and given an Asset Rating of 50[36]. Because the scale is linear, the boundary between grades D and grade E corresponds to a rating of 100.

Table 28 Rating scale and energy bands

Scale	Band
$AR < 0$	A+
$0 \leq AR \leq 25$	A
$25 < AR \leq 25$	B
$50 < AR \leq 75$	C
$75 < AR \leq 100$	D
$100 < AR \leq 125$	E
$125 < AR \leq 150$	F
$150 < AR$	G

Reference values and benchmarks

187. The Energy Performance Certificate must display reference values in addition to the Asset Rating. The Government has decided that the certificate should display two reference values as follows:

a. The rating of the Building Regulations standard (i.e., the TER). Note that this is based on the performance of the Notional building in comparison to that of the Reference building.
b. The rating of a “Typical” building, whose performance is assumed to be equal to approximately four[37] times the compliance target of 2021, i.e., it is equal to the energy performance of the 2021 Notional building multiplied by 4. If the TER is 0 (paragraph 86), then the emission rate of the Typical building is 4 times the emission rate of the Notional building *before* the emissions which are offset by the on-site PV system have been deducted.

Technical information

188. The Energy Performance Certificate must also display the following technical information about the Actual building:

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[36] This means that a gas-heated mixed-mode building that was just compliant with the 2006 Part L of the Building Regulations would have an Asset Rating of 50.

[37] The performance of the Typical building (approximately equivalent to the 1995 Part L standards) is assumed to be twice the compliance target of 2006, and the compliance target of 2021 is approximately half the compliance target of 2006 (0.75 x 0.91 x 0.73 = 0.498, where 0.75 represents the approximate improvement of 25% from the 2006 TER to the 2010 TER, 0.91 represents the approximate improvement of 9% from the 2010 TER to the 2013 TER, and 0.73 represents the approximate improvement of 27% from the 2013 TER to the 2021 TER).

a. ‘Main heating fuel’ which, for the purposes of the NCM, is taken as the fuel which delivers the greatest total thermal output for space or water heating.
b. ‘Building environment’ which is taken as the servicing strategy which contributes the largest proportion of the building’s CO_2 emissions.

APPENDIX C - INPUT DATA TO APPROVED TOOLS

189. This section of the guide describes generally-applicable approaches to data input and modelling strategies, and it applies equally to Building Regulations compliance and EPCs and also to the modelling of the Actual, Notional, and Reference buildings.

Defining internal gains and environmental conditions

190. 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[38] (which closely align with the Town and Country Planning (TCP) Use Classes[39] - although the class codes have now been removed from view in the software, in light of the recent amendments to the system of use classes). One of these standard activities must be assigned to each space in the building[40].

191. A 2021 version of the NCM Activity Database has been updated from 2013 to accompany the 2021 version of the NCM Modelling Guide.

192. The Activity Database provides standard occupancy, temperature set-points, outdoor air rates, and internal heat gain profiles for each type of space in the building so that buildings with the same mix of activities will differ only in terms of their geometry, construction, building services, and weather location. Thus, it is possible for the Building Regulation 26 compliance test and EPCs to compare buildings on the basis of their intrinsic potential performance, regardless of how they may actually be used in practice.

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

a. Occupancy times and density
b. Total metabolic rate and percentage which is latent (water vapour)
c. 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, Notional, and Reference buildings*
d. Set-back conditions for unoccupied periods
e. Sensible and latent heat gain from other sources
f. Outside/fresh air requirement
g. Level of illuminance for general lighting and the power density for display lighting
h. Hot water demand

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[38] The NCM Databases (Activity, Construction, and Glazing) can be downloaded from http://www.uk-ncm.org.uk

[39] Town and Country Planning (Use Classes) Order 1987 as amended. The Town and Country Planning (Use Classes) (Amendment) (England) Regulations 2020 came into force on 1st September 2020 and amended the Town and Country Planning (Use Classes) Order 1987. https://www.planningportal.co.uk/info/200130/common_projects/9/change_of_use.

[40] For example, 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.

i. Type of space for glazing, lighting, and ventilation classification within Building Regulations compliance
j. 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

194. If there is not an activity in the database that reasonably matches the intended use of a space, then this could be raised with the database managers (see UK-NCM website[38] 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[41]. If a special-use space is present in the Actual building, and no appropriate activity is available in the NCM Activity 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 Energy Assessor must select the closest match from the approved existing database. Because compliance and certification are both based on the performance of the Actual building in comparison to that of a Notional/Reference building, the impact of this approximation should be minimised.

Constructions

195. 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[2]. 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 bridges should be dealt with either by a method that satisfies BS EN ISO 14683 (and be consistently applied to the Actual and Notional buildings), or by adding the percentages specified in paragraphs 34 and 90, respectively, to the standard U-values of the Notional and Actual buildings.

196. Available on the UK-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 Building Regulations approval must declare this and demonstrate how the values were derived.

197. When using the software tool to generate an EPC, the performance parameters for some constructions may not be known. In such situations, the parameters must be inferred based on the data provided in the NCM Construction Database. This is an important aspect of ensuring consistency

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

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

198. 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. Standard weather sets have been adopted which must be used[42]. The available sites are:

- Belfast
- Birmingham
- Cardiff
- Edinburgh
- Glasgow
- Leeds
- London
- Manchester
- Newcastle
- Norwich
- Nottingham
- Plymouth
- Southampton
- Swindon

199. The chosen weather data file should, in most circumstances, be taken as the location from the above list which is closest in distance to the site of the proposed/Actual building. Where there are particular micro-climate issues that need to be taken into account, one of the other 13 weather data files may be used if the weather data is more appropriate. It is for this reason that although this methodology is for England, additional UK weather sites have been included since, in some cases, they may provide a better representation of the climate in the locality of the Actual building. For example, if the proposed building were on Dartmoor, the nearest weather site would be Plymouth, but this has a much milder climate than on the nearby moors. Therefore, a site with a climate that is more characteristic of an uplands site could be selected as being more appropriate. If the closest weather site is not used, the Regulation 26 compliance submission would need to justify the choice that has been made, but, in all cases, one of the above sites must be selected.

[42] 2016 CIBSE Test Reference Years. 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: cibse.org/weatherdata.

Zoning rules

200. 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 Building Regulations compliance or energy certification. The following procedure defines the approach to zoning for HVAC and lighting that must be followed.

201. The zoning arrangement must mimic the control strategy in the Actual building, and the same zoning arrangement must then be applied in the Notional and Reference buildings. 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 202 to 206); 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

202. A thermal zone is an area that:

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

203. 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 ~6 m from the perimeter.

204. 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

205. Adjoining thermal zones (horizontally or vertically[43]) 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 202 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.

206. 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.

Fuel emission and primary energy factors

207. The CO_2 emission factors[44] and primary energy factors[45] for the fuels used (and generated) in the Actual, Notional, and Reference buildings will be as defined in **Table 29** to **Table 31** (see paragraph 208 and **Table 32** for district heating in the Actual building and paragraph 61 for district heating in the Notional building).

Table 29 Fuel CO_2 emission and primary energy factors for buildings other than dwellings

Fuel type	$kgCO_2/kWh$	kWh_{PE}/kWh
Natural gas	0.210	1.126
LPG	0.241	1.141
Biogas	0.024	1.286
Fuel oil	0.319	1.180
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	**Table 30**	**Table 30**
Grid displaced electricity	**Table 31** for PV; **Table 30** otherwise	**Table 31** for PV; **Table 30** otherwise
Waste heat[46]	0.015	1.063
District heat networks	see **Table 32** and paragraph 61	

43 If combining zones vertically, the zone height input should be that of a single zone, not the vertical sum of the zones' heights.

44 These are CO_2 equivalent figures which include the global warming impact of CH_4 and N_2O as well as CO_2.

45 The primary energy (PE) 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.

46 This includes waste heat from industrial processes and power stations.

Table 30 CO_2 emission and primary energy factors for 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**
$kgCO_2/kWh$	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 31 CO_2 emission and primary energy factors for grid-displaced electricity by generation from PV systems												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
$kgCO_2/kWh$	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

208. The calculation (described in ADL volume 2[18]) of the CO_2 emission and primary energy factors for the heat delivered by a district heating network to the Actual building should be based on the specific factors from **Table 32** (see paragraph 61 for district heating in the Notional building).

Table 32 Fuel CO_2 emission and primary energy factors for district heat networks		
Fuel type	**$kgCO_2/kWh$**	**kWh_{PE}/kWh**
Heat from boilers that use mains gas	0.21	1.13
Heat from boilers that use LPG	0.241	1.141
Heat from boilers that use oil (assumes gas oil)	0.335	1.18
Heat from boilers that can use mineral oil or biodiesel	0.335	1.18
Heat from boilers that use HVO from used cooking oil	0.036	1.18
Heat from boilers that use FAME from animal/vegetable oils[a]	0.018	1.18
Heat from boilers that use B30D[b]	0.269	1.09
Heat from boilers that use coal	0.375	1.064
Heat from electric heat pump	0.136	1.501
Heat recovered from waste combustion	0.015[c]	0.063[c]
Heat from boilers that use biomass	0.029	1.037
Heat from boilers that use biogas (landfill or sewage gas)	0.024	1.286
Heat recovered from power stations	0.015[c]	0.063[c]
High grade heat recovered from process	0.011	0.051
Low grade heat recovered from process	0.136[d]	1.501[d]
Heat recovered from geothermal or other natural processes	0.011	0.051
Heat from CHP	as above according to fuel used	as above according to fuel used
Electricity for pumping in distribution network	0.136	1.501
Electricity generated by new CHP, export only	0.394	2.345
Electricity generated by new CHP, flexible operation	0.42	2.369
Electricity generated by new CHP, standard	0.311	2.107
Electricity generated by existing CHP (2015+), export only	0.394	2.345
Electricity generated by existing CHP (2015+), flexible operation	0.42	2.369

Electricity generated by existing CHP (2015+), standard	0.348	2.149
Electricity generated by existing CHP (pre-2015), export only	0.394	2.345
Electricity generated by existing CHP (pre-2015), flexible operation	0.42	2.369
Electricity generated by existing CHP (pre-2015), standard	0.374	2.23

- 'Export only' fuel factors should be used where a gas CHP exports all of its power to the grid (except for energy centre parasitic loads).
- 'Flexible operation' fuel factors should be used when a gas CHP unit runs only when the marginal generating plant on the grid is high carbon (i.e., gas CCGT).
- 'Standard' fuel factors should be used for all other operating regimes of gas CHP plants.

(a) For appliances that specifically use bio-liquid FAME to BS EN 14214 certified as wholly derived from waste animal fats/used cooking oil.
(b) For appliances that specifically use a blend of 30% bio-liquid FAME, and 70% kerosene (B30K) or 70% gas oil (B30D).
(c) Takes account of the reduction in electricity generation that occurs where heat is produced at a high enough temperature to supply a heat network.
(d) Figure assigned to energy used by heat pump to boost temperature.

HVAC

209. 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).

210. 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

211. 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*).

212. For Part L 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).

213. For Part L 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

214. 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 ADL volume 2[18] Table 2.1, the following approach should be followed if adjustments are applicable:

a. Apply the adjustment factor due to power factor correction to the CO_2 emissions and primary energy consumption which are attributed to grid-supplied electricity in the building.
b. Apply the adjustment factor due to automatic monitoring and targeting (M&T) 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

215. 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 33** below:

Table 33 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) = $h \times w$, 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 10° or less. If greater than 10°, the roof is a pitched roof.
Pitched Roof	Roof with pitch greater than 10° and less than or equal to 70°. If the pitch is greater than 70°, it must be considered a wall.
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	Fully-glazed curtain walling systems should be modelled as glazing, where the spandrel area (i.e., non-vision areas) can be accounted for in the frame factor parameter.