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

2013 Edition

November 2015

Main Changes in the 2013 Edition

This NCM Modelling Guide comes into force on 6 April 2014 in support of the 2013 Edition of the Approved Document L2A: Conservation of fuel and power in new building 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. New specifications of the Notional building for the 2013 edition, which are used to determine the carbon dioxide (CO_2) target, have been defined to deliver a 9% CO_2 savings across the new non-domestic building mix relative to Part L 2010.
2. The 'side-lit' class of zones in the Notional building has been split into those with and without artificial cooling in place in order to widen the set of zones classes based on their access to daylight: unlit, side-lit (heated only), side-lit (heated and cooled), and top-lit.
3. The Notional building's air permeability has been further sub-divided by size.
4. The 2013 target emission rate is the 2013 Notional building emission rate (i.e., no additional improvement factors). If the actual building is constructed entirely to the notional building specifications, it will meet the target emission rate and the limiting values for individual fabric elements and building services. Developers are, however, free to vary the specifications, provided the target emission rate is achieved or bettered.
5. A new set of fuel emission factors and primary energy factors for non-domestic buildings is provided in this document.
6. November 2015: Revised policy regarding software version to be used for producing EPCs. Addition of some further guidance and clarifications, for e.g., regarding flags in the NCM Activity Database.

* This NCM modelling guide gives guidance for compliance with the Building Regulations for England. It also applies to new buildings other than dwellings that are excepted energy buildings in Wales as defined in the Welsh Ministers (Transfer of Functions) (No.2) Order 2009 and to new

buildings other than dwellings that are buildings of statutory undertakers and of the Crown or Crown authorities in both England and Wales.

CONTENTS

INTRODUCTION

1. This document, which takes effect on 6 April 2014, 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) emission 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 of Communities and Local Government (DCLG). These requirements are updated from time to time and cover a number of generic issues as follows:

a. The software tool has to demonstrate that the calculations are technically robust, and that they cover a necessary minimum set of energy flows.

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

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 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 rate calculation before commencement of work, and
    ii. CO_2 emission rate 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 of Communities and Local Government (DCLG). 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 and merging of all contiguous similar areas (see paragraph 188), in order to generally avoid creating more than 100-150 zones in SBEM.

COMPLIANCE WITH BUILDING REGULATIONS

22. This section of the guide defines the basis for setting the 2013 Target Emission Rate (TER). Regulation 26 requires that all new buildings must achieve or better this target. The TER is based on the performance of the Notional building (see below), and the following procedure must be followed in order to establish the TER. The procedure converts calculated building loads into energy (and hence CO_2 emissions) 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 197).

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 172).

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 system 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 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.

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.

28. The energy performance standards of the Notional building are based on a concurrent specification that delivers a 9% reduction in CO_2 emissions relative to the 2010 standard based on an assumed build mix. This means that some buildings will be required to improve by more than 9%, others by less, but all should achieve the improvement at a similar cost of carbon mitigation (see the Part L Impact Assessment[2] for details of the derivation).

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[2] Changes to Part L of the Building Regulations 2013 - Impact Assessment

Activity glazing class

29. 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*).

30. One change from 2010 is that an additional class for zones in the Notional building has been defined. This has the effect of splitting the 'side-lit' class activities into those with and without artificial cooling in place. There are, therefore, 4 classes for the Notional building, applicable to each defined zone in the Actual building and based on the source of daylight (if any) and servicing strategy:

a. Side-lit, heated only
b. Side-lit, heated and cooled
c. Top-lit
d. Unlit

Building fabric

31. The U-values must be as specified in **Table 1**. All U-values must be calculated following the guidance in BR443[3]. The reference constructions conforming to these U-values are provided in Appendix A of this document. In addition, the general guidance beginning at paragraph 177 must be followed.

Table 1 Construction element U-values and thermal capacity for the Notional building

Exposed element	U-value (W/m²K)	Thermal capacity[4] (kJ/m²K)
Roofs[5] (irrespective of pitch)	0.18	21.8 (1.40 if metal-clad)
Walls	0.26	88.3 (1.40 if metal-clad)
Exposed floors and ground floors (subject to paragraph 33)	0.22	77.7
Windows*	1.60	-
Roof windows and roof-lights*	1.80	-

[3] Conventions for U-value calculations, BRE, 2006.

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

[5] Any part of a roof having a pitch greater or equal to 70º is considered as a wall.

Vehicle access and similar large doors	1.50	2.1
Pedestrian doors and high usage entrance doors	2.20	54.6
Internal wall	1.80	8.8
Internal floor/ceiling	1.00	71.8 from above / 66.6 from below
*This is the overall U-value including the frame and edge effects, and it relates to the performance of the unit in the vertical plane so, for roof-lights, it must be adjusted for the slope of the roof (BR443[3]). 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 (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, and its U-value adjustment is taken as +0.3 W/m^{2}K if the roof is flat and +0.2 W/m^{2}K if the roof is pitched.		

32. 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*).

33. 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.

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

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

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

37. 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

38. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made[6]:

a. If the calculated value is greater than 0.22 W/m²K, the value of 0.22 W/m²K must be used in the Notional building.
b. If the calculated value is less than 0.22 W/m²K with no added insulation, this lower value must be used in the Notional building.

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

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

a. The method specified in the SBEM Technical Manual[7], which is taken from EN 15242[8].
b. Other methods that use a relationship between infiltration rate and air permeability and are set out in national or international standards or recognised UK professional guidance documents which relate average infiltration rate to envelope permeability. An example of the latter would be tables 4.13 to 4.20 of CIBSE Guide A (2006).

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.

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[6] This follows the guidance given in CIBSE Guide A (2006)

[7] SBEM Technical Manual will be available at http://www.ncm.bre.co.uk

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

Table 3 Air permeability for the Notional building (m³/h per m² of envelope area at 50 Pa)			
Gross internal area of the building	**Side-lit or unlit (where HVAC specification is heating only)**	**Side-lit or unlit (where HVAC specification includes cooling)**	**Top-lit**
Less than or equal 250 m^2	5	5	7
Greater than 250 m^2 and less than 3,500 m^2	3	3	7
Greater than or equal to 3500 m^2 and less than 10,000 m^2	3	3	5
Greater than or equal 10,000 m^2	3	3	3

Areas of windows, doors, and roof-lights

41. 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 197.

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 1.1m. 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**.

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

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	40%	10%	71%
Top-lit	12% of exposed roof area will be made up of roof-lights*	55%	15%	60%
Unlit	No windows or roof-lights	n/a		

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

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

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.

43. 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 side-lit glazing

	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 top-lit glazing

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.580	0.186	0.227	0.665	0.254	0.285	0.837	0.209
Cavity	12mm	Argon gas fill							
Inner pane	6mm	0.783	0.072	0.072	0.889	0.081	0.081	0.837	0.837

44. 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 1.1m sill height rule would not need to be followed), with zero glazing for the below ground part.

HVAC system

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

a. unheated
b. heated only with natural ventilation
c. heated 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.

46. 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 Notional and Actual buildings.

47. 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[9], 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[10] by 1ºK. 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.*

48. Humidity control is ignored in the Actual, Notional, and Reference buildings.

49. The system performance definitions follow the practice set out in EN 15243[11]:

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[12].
b. Heating Seasonal Coefficient of Performance (SCoP) is the ratio of the sum of the heating consumption of all spaces served by a system to the energy content of the fuels (or electricity) supplied to the boiler or other heat generator of the system. The SCoP includes boiler efficiency, heat losses in pipework, and duct leakage. It does not include energy used by fans and pumps (but does include the proportion of that energy which reappears as heat

[9] 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.

[10] 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.

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

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

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[7]. Heating energy consumption is, therefore, calculated from the following expression:

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

c. The Seasonal System Energy Efficiency Ratio for cooling (SSEER) is the ratio of the sum of the sensible cooling consumption of all spaces served by a system to the energy content of the electricity (or fuel) supplied to the chillers or other cold generator of the system. The SSEER includes, 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[7]. Cooling energy consumption is therefore calculated from the following expression:

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

50. 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.

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

52. The cooling and auxiliary energy must be taken to be powered by grid-supplied electricity.

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

54. In mixed-mode operation, the Notional building will have a cooling SSEER of 2.7 with cooling set-point of 27ºC (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).

55. The fuel and associated Seasonal Coefficient of Performance (SCoP) for space heating and hot water generation in each zone of the Notional building is linked to the type of fuel used for space heating and hot water in the equivalent zone in the Actual building, based on the values provided in **Table 7** and **Table 8**. Space heating and hot water generation are considered independently. For example, if a zone in the Actual building uses electric heat pumps for space heating and natural gas for hot water generation, then the equivalent zone in the Notional building will use electric heat pumps for space heating and natural gas for hot water generation. Note that the SCoP values already take account of distribution losses of 10% for space heating and 5% for hot water (i.e., generator efficiency is 91%).

Table 7 Heating system SCoP and emission factors for side-lit (whether HVAC specification is heating only or heating and cooling) and unlit activities in the Notional building

Heating fuel used in the Actual building	Space heating	Hot water	Heating fuel emission factor in the Notional building ($kgCO_2/kWh$)
Bio-fuels (i.e., whose emission factor < emission factor of natural gas)	63.0%	66.5%	The factor for the particular bio-fuel
Natural gas	81.9%	86.45%	0.216
LPG			0.241
Dual fuel (Mineral + Wood)			0.226
Fuel oil			0.319
Electric heat pump	243.0%	256.5%	0.519
Non-electric heat pump	126.0%	133.0%	The factor for the particular fuel
Electricity (direct)	81.9%	86.45%	0.319
Other fuels (i.e., whose emission factor > emission factor of fuel oil)			

Table 8 Heating system SCoP and emission factors for top-lit activities in the Notional building

Heating fuel used in the Actual building	Space heating	Hot water	Heating fuel emission factor in the Notional building ($kgCO_2/kWh$)
Bio-fuels (i.e., whose emission factor < emission factor of natural gas)	63.0%	66.5%	The factor for the particular bio-fuel
Natural gas	86% for radiant heating*; otherwise 81.9%	86.45%	0.216
LPG			0.241
Dual fuel (Mineral + Wood)			0.226
Fuel oil			0.319
Electric heat pump	243.0%	256.5%	0.519

<table>
<tr><td>Non-electric heat pump</td><td>126.0%</td><td>133.0%</td><td>The factor for the particular fuel</td></tr>
<tr><td>Electricity (direct)</td><td rowspan="2">86% for radiant heating*; otherwise 81.9%</td><td rowspan="2">86.45%</td><td rowspan="2">0.319</td></tr>
<tr><td>Other fuels (i.e., whose emission factor > emission factor of fuel oil)</td></tr>
<tr><td colspan="4">*Where a 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[7] 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.</td></tr>
</table>

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

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

- Where the emission factor of heat supplied in the Actual building is less than or equal to 0.15 $kgCO_2/kWh$, the Notional building will have an emission factor of heat supplied of 0.15 $kgCO_2/kWh$ (and primary energy factor of 0.85 kWh/kWh[13]).
- Where the emission factor of heat supplied in the Actual building is greater than 0.15 $kgCO_2/kWh$ and less than 0.4 $kgCO_2/kWh$, the Notional building will have the same emission factor of heat supplied as the Actual building.
- Where the emission factor of heat supplied in the Actual building is greater than or equal to 0.4 $kgCO_2/kWh$, the Notional building will have an emission factor of heat supplied of 0.4 $kgCO_2/kWh$ (and primary energy factor of 1.34 kWh/kWh), i.e., the Notional building's emission factor is capped at 0.4 $kgCO_2/kWh$.

The heating fuel emission factor of 0.15 $kgCO_2/kWh$ represents a typical, though not exceptional, district heating system supplied by a gas-fired CHP with an electrical efficiency of 30% and a heat efficiency of 50%, supplying 70% of the heating load. In this way, district heating systems offering improved performance are incentivised.

[13] kWh of primary energy per kWh of delivered energy.

58. For bivalent heating systems (i.e., where more than one fuel is used in the Actual building to provide space and/or water heating, such as a biomass boiler supplemented by a natural gas boiler), a demand-weighted conversion factor will be calculated for the Notional building that is based on the proportion of heating demand met by each fuel type in the Actual building. This calculation is determined at zone level, where for each fuel type, the proportion of heating demand is multiplied by the appropriate fuel emission factor and then divided by the associated SCoP, both from **Table 7** or **Table 8**. 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 ((0.7×0.031/0.630)+(0.3×0.216/0.819))=0.114*. Note that the demand-weighted conversion factor already takes into account both the fuel emission factor and the* SCoP*.*

Auxiliary energy

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

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

61. The pump power density for the Notional building will be zero in zones with top-lit activities satisfying the conditions in the footnote in **Table 8**. In all other cases, 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 provides air-conditioning;
- If the HVAC system in the Actual building is based on a dry system (e.g., split system), then the Notional building will have zero pump power.

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

Equation 3 $\text{Fan power density} = \text{Lesser of } (FPS_1, FPS_2)$

Equation 4 $FPS_1 = FAR_{max} \times SFP_{central} + SCR \times SFP_{terminal}$

Equation 5 $FPS_2 = \text{Greater of } (FAR_{max}, SCR) \times SFP_{central}$

Where $SFP_{central} = 1.80$ *W per l/s*[14] *(supply & extract)*, *and* $SFP_{terminal} = 0.30$ *W per l/s*

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

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

Equation 6 $SCR = \text{Greater of } (PSH, PSC) / (\rho \times C_p \times \Delta T)$

Where $\rho = 1.2$ kg/m³, $C_p = 1.018$ kJ/kgK, and $\Delta T = 8K$

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

63. The Notional building benefits from variable speed pumping with multiple pressure sensors in the system.

64. For zones where the ventilation system does not provide heating or cooling (but can include heat recovery), the fan power density is the product of the fresh air supply rate for the activity type from the NCM Activity database and a specific fan power of 0.90 W per l/s[14] (supply & extract).

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

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

67. 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 ADL2A (2013) Table 1 apply).

Lighting power density

68. The general lighting in the Notional building is based on lighting with efficacy of 60 luminaire lumens per circuit-watt, and the resulting power density (W/m²) will vary as a function of the geometry of each zone modelled, which will be determined using the following equation:

Equation 7 $\text{Power density per 100 lux} = (1.93 + 0.007 \times R + 0.063 \times R^2)/MF$

Where R is the ratio of the total wall area[15] to the total floor area, where the maximum value for R is 8, and MF is the maintenance factor which, for the Notional building, is taken as 0.8. The power density per 100 lux is then multiplied by the illuminance level for the activity type, which is determined by the NCM Activity database, and divided by 100. This equation was derived using regression analysis of parametric results produced using lighting design software for a range of space geometries and lighting systems.

69. 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 photo-electric dimming (as defined in the SBEM Technical Manual[7]), without back-sensor control and with continuous (i.e., always on) parasitic power that is the lesser of either: 3% of the installed lighting load or 0.3 W/m².

70. 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 control, will be modelled with local manual switching (as described in the SBEM Technical Manual[7]), provided the floor area of the zone is less than 30 m². Otherwise, the general lighting is switched centrally based on the occupancy hours for the activity in the NCM Activity database. Whether or not the activity is appropriate to have local manual control is determined in the "activity" table from the NCM Activity database in the "BR_CHECK02" field (*1 for activity that is not appropriate to have local manual control, and 0 otherwise*).

71. Zones in the Notional building do not benefit from constant illuminance control.

72. All zones in the Notional building will be modelled with occupancy sensing (as defined in the SBEM Technical Manual[7]), if appropriate (i.e., if activity is flagged in the NCM Activity database as appropriate to have local manual 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) with a continuous (i.e., always on) parasitic power density of 0.3 W/m². 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 70.

73. The display lighting in the Notional building is based on the display lighting power density from the NCM Activity database multiplied by 0.682 (i.e., adjustment between lamp efficacy of 22 and 15). Daylight harvesting and local manual switching do not apply to display lighting in the Notional building (i.e., only affects general lighting).

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

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

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[15] 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.

The target emission rate (TER)

76. The TER is the CO_2 emission rate of the 2013 Notional building (i.e., no additional improvement factors).

THE ACTUAL BUILDING

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

Building fabric

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

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

80. 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 use defaults as specified in **Table 9** (*based on BRE IP 1/06*[16] *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[17] following the guidance set out in BR497[18] and following a process flow sequence that has been provided to Building Control, indicating the way in which the detail should be constructed.

Table 9 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

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

[17] ADL2A (2013).

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

81. The U-value typically quoted for a window, roof window, or roof-light is the overall U-value including the frame and edge effects, and it relates to the performance of the unit in the vertical plane so, for roof-lights, it must be adjusted for the slope of the roof (BR443[3]) 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

82. 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 lighting level in the Activity database. Where the design illuminance is less than the NCM activity lighting level, the general power density will be automatically pro-rated to the NCM activity lighting level. For example, an office with installed lighting load density of 6 W/m^2 that delivers 300 lux illuminance (i.e., 2 W/m^2 per 100 lux) would be adjusted to 8 W/m^2 for the purpose of compliance because the NCM activity assumes 400 lux illuminance. However, in the case of modular and portable buildings where the date of manufacture of 70% of the modules making up the external envelope is prior to 6 April 2014, the calculated power density will always be pro-rated to the NCM activity lighting level if the design illluminance is different, i.e., whether it is greater or less.

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

84. 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 lamp efficacy in lumens per circuit-watt and the light output ratio of the luminaire, to determine the efficacy of the lighting system in terms of luminaire lumens per circuit-watt, which can be pro-rated against the Notional lighting curve (*which is based on 60 luminaire lumens per circuit-watt*) defined by Equation 7 to infer a power density for the general lighting. The user can also input the design illuminance in the zone, if known, and the power density will then be subject to be pro-rated following paragraph 82.

Inference method 2 - User assigns a lamp type to each zone based on **Table 10**, where the luminaire efficacy can be pro-rated against the Notional lighting curve (*which is based on 60 luminaire lumens per circuit-watt*) defined by Equation 7 to infer a power density for the general lighting. The user can also input the design illuminance in the zone, if known, and the power density will then be subject to be pro-rated following paragraph 82.

Table 10 Lamp inference data				
Lamp type	Luminaire lumens per circuit-watt			
	For all buildings except those specified in the next column[19]		For modular or portable "distress purchase" buildings with a planned service life less than 2 years	
	Side-lit and unlit activities	Top-lit activity	Side-lit and unlit activities	Top-lit activity
LED	27.5	33.0	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

85. The general lighting in the Actual building will include the capability of modelling daylight harvesting, local manual switching (where appropriate[20]), and occupancy sensor control (as defined in the SBEM Technical Manual[7]). It will also include the capability of modelling constant illuminance control (as defined in BS EN 15193:2007[21]) by reducing the general lighting power density by 10%, if applicable.

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

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

88. For Building Regulations compliance, any zone where the display lighting has efficacy less than 22 lamp lumens per circuit-watt will be reported in the BRUKL (compliance output document) summary as not meeting the standards of Criterion 2.

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[19] 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.

[20] 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 70.

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

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

90. 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

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

92. 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.).

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

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

95. 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 11** 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 12** gives the pump power densities for constant speed pumping as well as variable speed pumping.

Table 11 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
Chilled ceilings or passive chilled beams and displacement ventilation	Both LTHW and CHW	Yes
Active chilled beams	Both LTHW and CHW	Yes
Water loop heat pump	Both LTHW and CHW	No
Split or multi-split system	None	No
Single room cooling system	None	No

Table 12 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

96. For zones where the ventilation system also provides heating and/or cooling, the fan power density is determined for each zone using one of the following equations as determined by **Table 13**:

Equation 8 $FPS_1 = FAR_{max} \times SFP_{central} + SCR \times SFP_{terminal}$

Equation 9 $FPS_2 = Greater\ of\ (FAR_{max}, SCR) \times SFP_{central}$

Equation 10 $FPS_3 = \text{Greater of } (SCR/5, FAR_{max}) \times SFP_{central}$

Equation 11 $FPS_4 = FAR_{max} \times SFP_{central}$

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

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

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

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

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

97. The fan power density equations are assigned to HVAC systems based on **Table 13**.

Table 13 Assigning fan power equations to HVAC systems

HVAC system type	SBEM ID	Fan power density
Fan coil systems	4	Equation 8
Indoor packaged cabinet (VAV)	32	
Central heating using air distribution	2	Equation 9
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 10
Induction system	14	
Chilled ceilings or passive chilled beams and displacement ventilation	11	Equation 11

98. 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.

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

100. Energy for other ancillary services in the building, such as secondary hot water circulation, de-stratification fans, forced circulation for solar water heating systems, etc., will be an addition to the fan and pump energy.

DEMAND CONTROL OF VENTILATION

101. The Actual building will include the ability to model demand control of ventilation for zones with mechanical ventilation (but excluding exhaust-only systems) while for naturally ventilated zones, there will be the option of enhanced ventilation control (this refers to natural ventilation with BMS control, i.e., modifying the ventilation flow rate provided by natural means in the space based on some form of control). The details for implementing demand-controlled ventilation (as defined in the SBEM Technical Manual[7]) are outlined below.

102. 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

103. 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

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

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

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

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

where:

FAR_{max} is the ventilation rate per person from the NCM Activity database multiplied by the peak occupancy density during the occupied period (i.e., l/s/m²).

FAR_{min} is the ventilation rate per person from the NCM Activity database multiplied by the minimum occupancy density during the occupied period (i.e., this can be zero for some activities).

FAR_{lower} is the greater of either: FAR_{min} or $0.6 \times FAR_{max}$.

C_{dc} = is a demand control coefficient and is determined based on the data in **Table 14**.

Table 14 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

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

Shell & core

107. 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).

108. If calculation is performed at '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 design' stage or for 'core' zones, energy would be accounted for as usual. This is applicable to all modelled buildings: Actual and Notional.

109. 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.

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

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

Modular and portable buildings

112. 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 as specified in Table 2 of ADL2A (2013). 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.

CRITERION 3: LIMITING SOLAR GAINS

113. This section describes how the solar gain limit (i.e., Criterion 3 of ADL2A (2013)) should be checked in the Actual building.

114. 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)*.

115. 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.

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

117. The solar gain limit is based on the solar gains through benchmark glazing types described in **Table 15**, and selected according to paragraph 121, aggregated over the period from April to September, and using the same CIBSE TRY weather data used for the Criterion 1 CO_2 emission calculations.

Table 15 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 0.68	Height of 1m and width equal to the total exposed facade* width of the zone being checked
2	Horizontal glazing with 25% frame factor and g-value of 0.68	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 0.46	Area equal to 20% of either the projected floor area or the exposed roof area (whichever is greater)

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

118. 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 to Figure 3) that meets the requirements of **Table 15**. This allows the pre-calculation of the benchmark aggregated solar gain as a function of facade length and exposed roof area (i.e., kWh/m and kWh/m² respectively). This means that each DSM will have 3 values for benchmark aggregated solar flux for each CIBSE TRY weather data set.

119. 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 16** and **Table 17** (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).

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

121. 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 either the projected floor area or the exposed roof area (whichever is greater).

b. For zones with top-lit activities:
   - For each zone where the height[22] is less than 6m, the solar gain limit will be the aggregated solar flux for benchmark glazing type 2 multiplied by either the projected floor area or the exposed roof area (whichever is greater).
   - For each zone where the height[22] is greater than or equal to 6m, the solar gain limit will be the aggregated solar flux for benchmark glazing type 3 multiplied by either the projected floor area or the exposed roof area (whichever is greater).

122. 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).

123. 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 16 Glass properties to achieve g-value of 0.68

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	6mm	0.783	0.072	0.072	0.889	0.081	0.081	0.837	0.837

22 For zones with pitch roofs, use the average height.

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 17 Glass properties to achieve g-value of 0.46

	Thickness	T_{solar}	R_{solar1}	R_{solar2}	$T_{visible}$	$R_{visible1}$	$R_{visible2}$	Emissivity 1	Emissivity 2
Outer pane	4mm	0.468	0.165	0.185	0.654	0.104	0.026	0.837	0.153
Cavity	12mm	Argon gas fill							
Inner pane	4mm	0.821	0.074	0.074	0.896	0.081	0.081	0.837	0.837

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

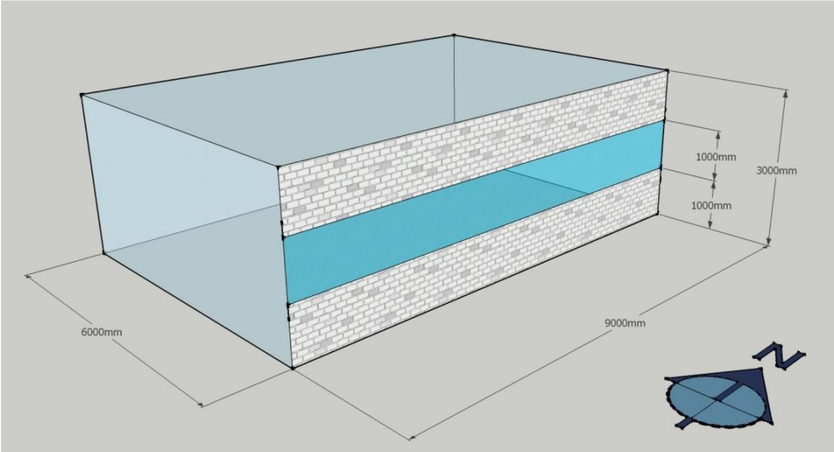


Figure 2 Isometric view of standard test-space for benchmark glazing type 2

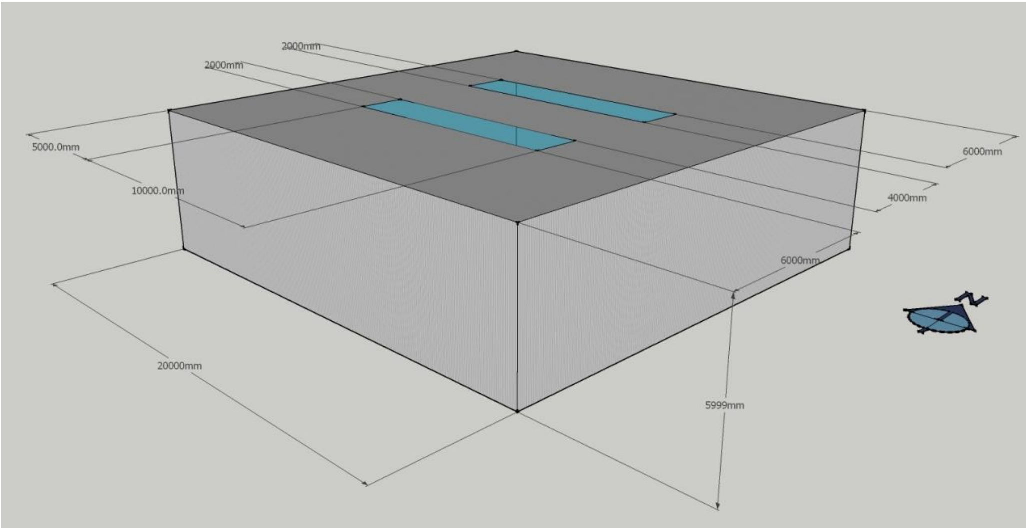
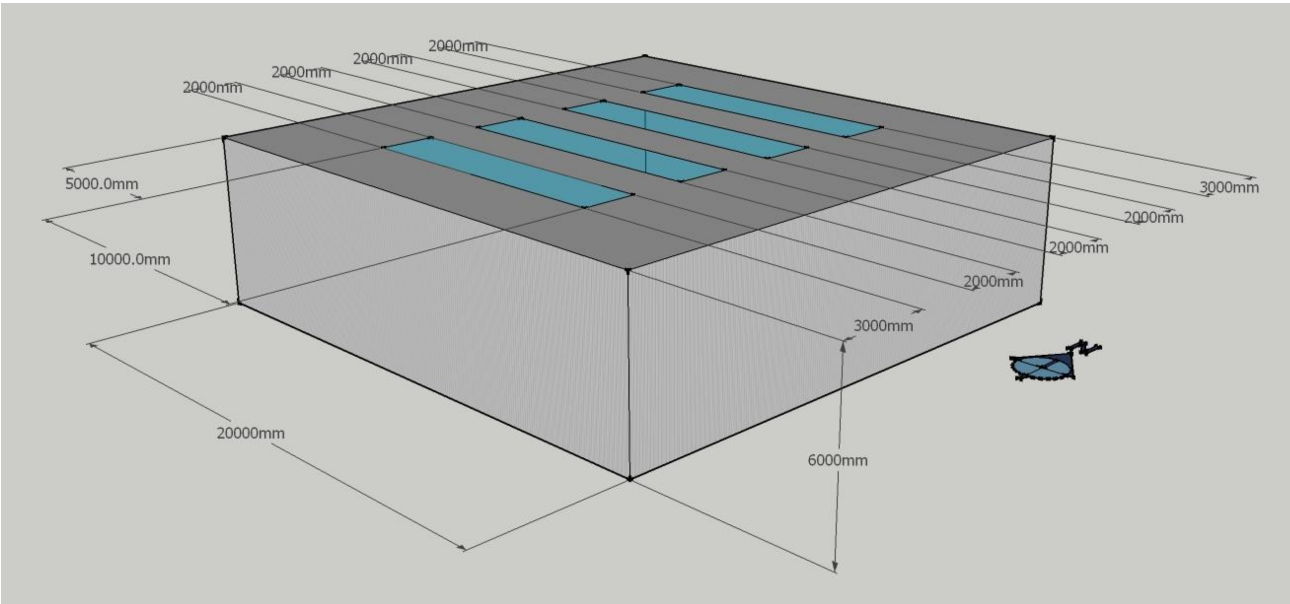


Figure 3 Isometric view of standard test-space for benchmark glazing type 3

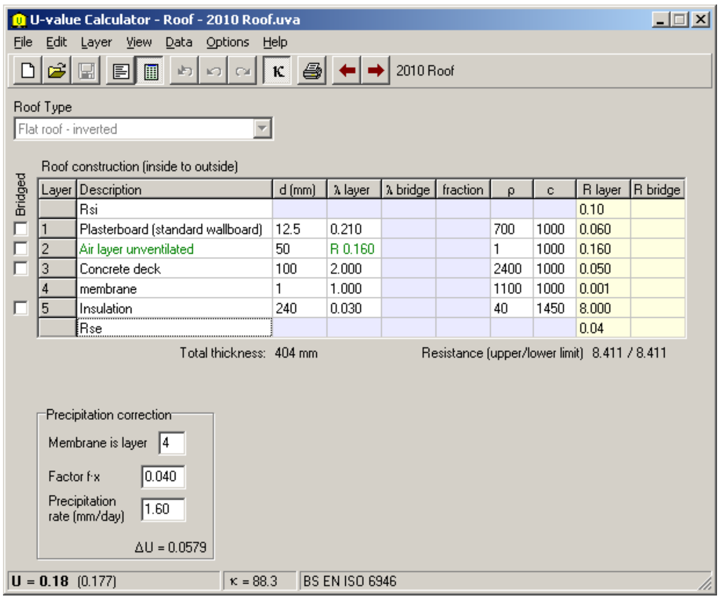


APPENDIX A – CONSTRUCTION DETAILS FOR 2013 NOTIONAL BUILDING

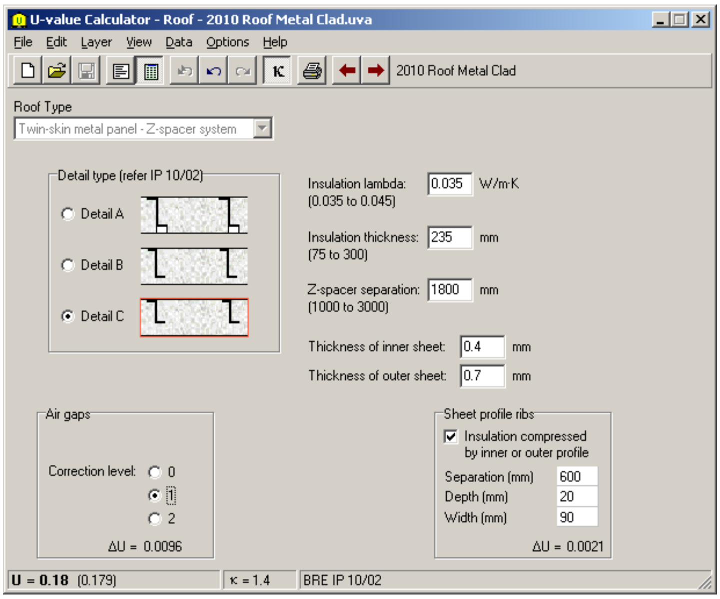
124. This section includes screen grabs from the BRE U-value calculator (version 2.02) that show the construction details used as the basis for the data for thermal capacity values in **Table 1**. These construction details are for use by DSM software to account for the effect of thermal capacity.

125. 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**.

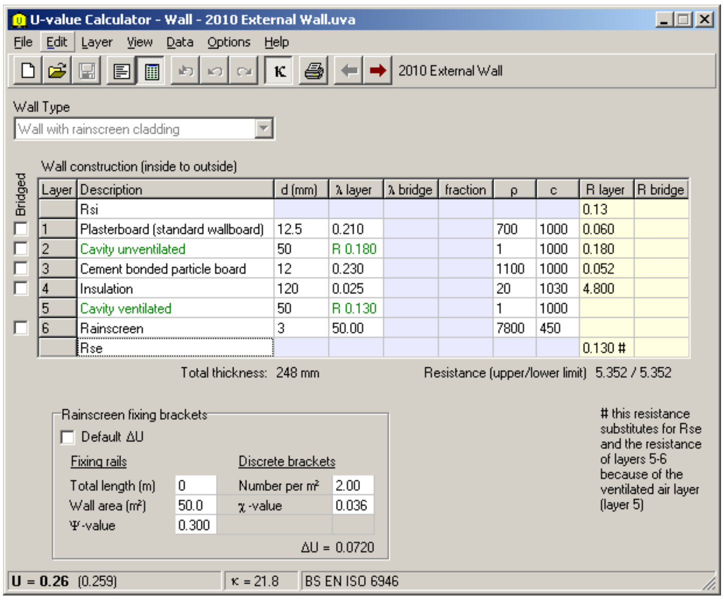
126. Roof construction details for the 2013 Notional building (not involving metal cladding).



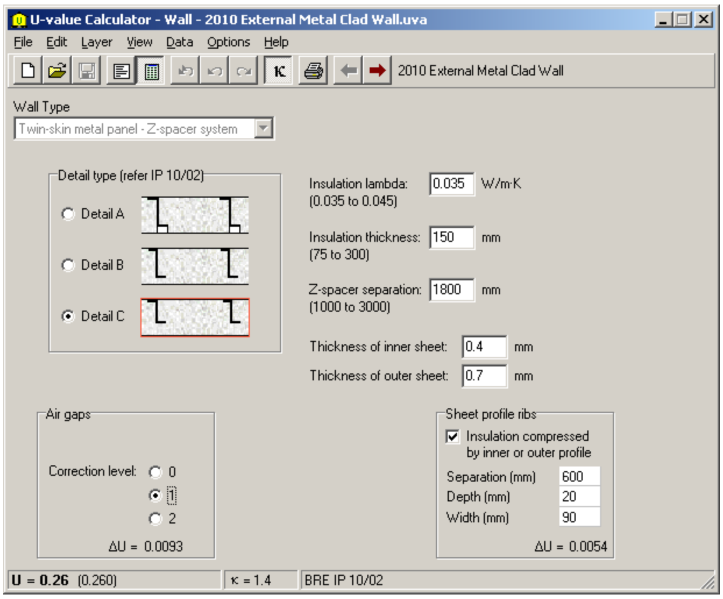
127. Roof construction details for the 2013 Notional building (involving metal cladding).



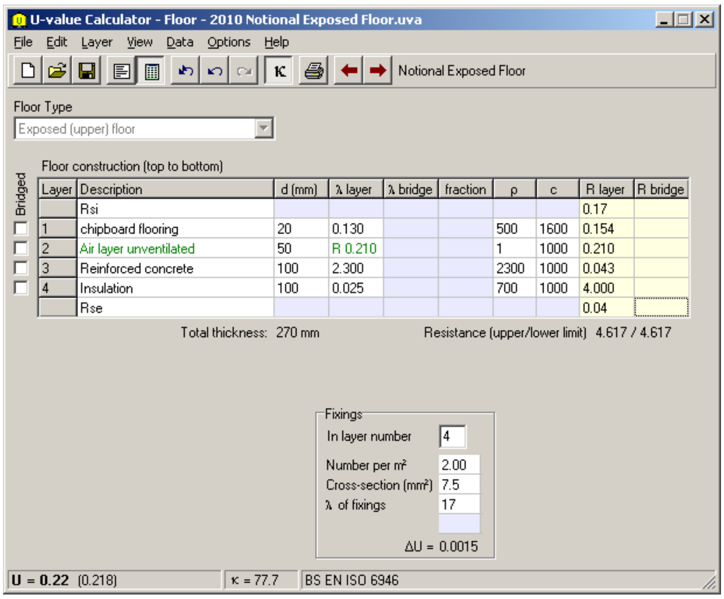
128. External wall construction details for the 2013 Notional building (not involving metal cladding).



129. External wall construction details for the 2013 Notional building (involving metal cladding).

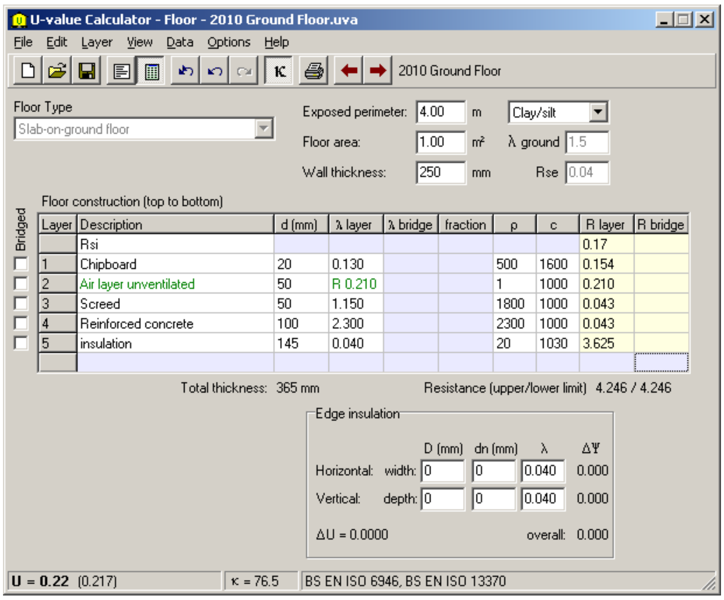


130. Exposed floor construction details for the 2013 Notional building.



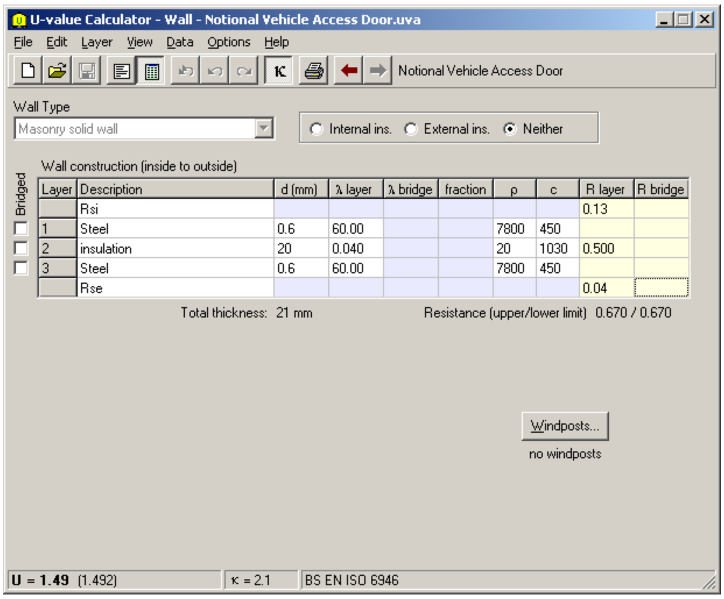
Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
	Rsi							0.17	
1	chipboard flooring	20	0.130			500	1600	0.154	
2	Air layer unventilated	50	R 0.210			1	1000	0.210	
3	Reinforced concrete	100	2.300			2300	1000	0.043	
4	Insulation	100	0.025			700	1000	4.000	
	Rse							0.04	

131. Ground floor construction details for the 2013 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).



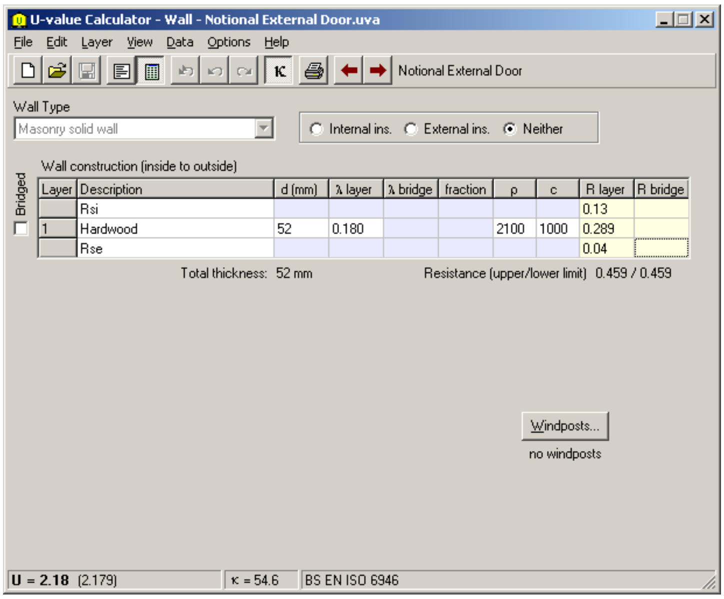
Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
	Rsi							0.17	
1	Chipboard	20	0.130			500	1600	0.154	
2	Air layer unventilated	50	R 0.210			1	1000	0.210	
3	Screed	50	1.150			1800	1000	0.043	
4	Reinforced concrete	100	2.300			2300	1000	0.043	
5	insulation	145	0.040			20	1030	3.625	

132. Vehicle access and similar large door construction details for the 2013 Notional building.



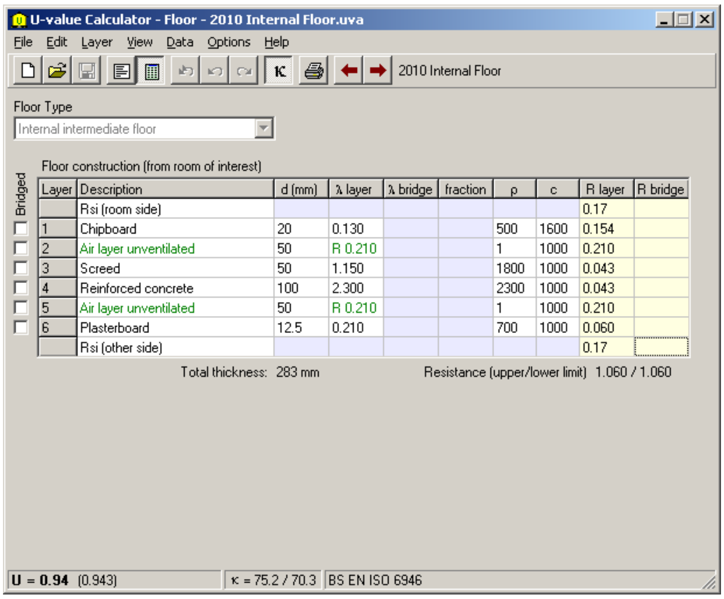
Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
	Rsi							0.13	
1	Steel	0.6	60.00			7800	450		
2	insulation	20	0.040			20	1030	0.500	
3	Steel	0.6	60.00			7800	450		
	Rse							0.04	

133. Pedestrian doors and high usage entrance doors construction details for the 2013 Notional building.



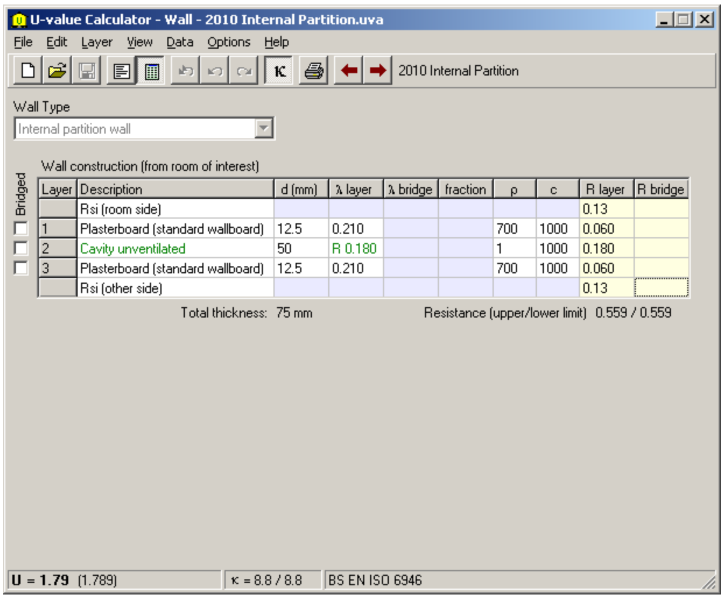
Layer	Description	d (mm)	λ layer	λ bridge	fraction	ρ	c	R layer	R bridge
	Rsi							0.13	
1	Hardwood	52	0.180			2100	1000	0.289	
	Rse							0.04	

134. Internal floor/ceiling construction details for the 2013 Notional building.



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	

135. Internal partition construction details for the 2013 Notional building.



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	

APPENDIX B – THE REFERENCE BUILDING

136. 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.

137. 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.
b. The fuel choice.

138. 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.

139. 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 174).

140. 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.

Building fabric

141. The U-values must be as specified in **Table 18**. All U-values must be calculated following the guidance in BR443[3]. The general guidance beginning at paragraph 177 must be followed.

Table 18 U-values for the Reference building

Exposed element	U-value (W/m²K)
Roofs[23] (irrespective of pitch)	0.25
Walls	0.35
Floors and ground floors (subject to paragraph 144)	0.25
Windows, roof windows, roof-lights*, and curtain walling	2.20
External pedestrian doors (including glazed doors)	2.20
Vehicle access and similar large doors	1.50

[23] Any part of a roof having a pitch greater or equal to 70º is considered as a wall.

Internal walls	2.00
Internal windows	3.85
Internal floors (viewed from room above)	1.40
Internal floors (viewed from room below)	1.23
*This is the overall U-value including the frame and edge effects, and it relates to the performance of the unit in the vertical plane so, for roof-lights, it must be adjusted for the slope of the roof (BR443[3]). 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, and its U-value adjustment is taken as +0.3 W/m²K if the roof is flat and +0.2 W/m²K if the roof is pitched.	

142. 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).

143. For SBEM and DSM software, the non-repeating thermal bridge heat losses for each element (including windows, etc.) must be allowed for by adding 10% to the standard U-values. Note that the U-values as given in **Table 18** DO NOT include this allowance, and so the calculation tool must make the adjustment explicitly.

144. Special considerations apply to ground floors, where the U-value is a function of the perimeter/area ratio. The following adjustments must be made[6]:

a. If the calculated value is greater than 0.25 W/m²K, the value of 0.25 W/m²K must be used in the Reference building.
b. If the calculated value is less than 0.25 W/m²K with no added insulation, this lower value must be used in the Reference building.

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

146. The thermal capacity of the construction elements must be as defined in **Table 19**.

Table 19 Thermal capacity of construction elements in the Reference building

Element	**Thermal capacity[4] (kJ/m²K)**
External wall	11.7
Roof	12.0
Ground floor	36.0
Internal wall	11.9
Internal floor (and ceiling)	8.6

147. 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 compliance and certification, the same method must be used in the Actual, Notional, and Reference buildings. Acceptable methods include:

a. The method specified in the SBEM Technical Manual[7], which is taken from EN 152428.
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 4.13 to 4.20 of CIBSE Guide A (2006).

Areas of windows, doors, and roof-lights

148. In SBEM, the total solar energy transmittance (BS EN 410 g-value) and the light transmittance of glazing must be as given in **Table 20**. This data applies to windows, roof windows, and roof-lights. Appropriate values for intermediate orientations can be based on linear interpolation.

Table 20 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

149. DSM software are required to use the glass data provided in **Table 21**, **Table 22**, and **Table 23** 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 21 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 22 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 23 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

150. 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 197.

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 24**, 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 24**, the copied areas must be retained but no windows or roof-lights added.
e. The areas as defined in **Table 24** 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%.

151. 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 24 Percentage opening areas in the Reference building

Building type[24]	**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%

24 Determined for each activity by the "BR_CHECK05" field in the "activity" table of the NCM Activity database.

152. 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 24** percentages must apply to the above-ground part, with zero glazing for the below ground part.

HVAC system

153. The space heating and hot water 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.

154. 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.
b. The heating 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_#" 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 27°C irrespective of whether the particular space in the Actual building has cooling provision or not[25] . 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., 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

[25] 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.

calculated. If a particular accommodation type always needs cooling (e.g., a dealer room), then a base-line level of cooling will be calculated. 27°C 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).

155. For zones with local mechanical exhaust where the fan is within the zone, the fan power density is the product of the user-defined exhaust rate and a specific fan power of 0.50 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 154c.

156. 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.

157. HWS overall system efficiency (including generation and distribution) must be taken as 45%. The energy demand must be taken as that required to raise the water temperature from 10°C to 60°C based on the demands specified in the NCM Activity database. The Activity database defines a daily total figure in l/(m².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.

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

159. 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 energy performance used to normalise the CO_2 emissions in the Actual building. This adjusted CO_2 emissions rate is termed the Standard Emission Rate (SER). When making the adjustment, the improvement factor must be taken as 23.5%. In summary:

Equation 14 $SER = RER \times 0.765$

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.

160. 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.

Lighting power density

161. For general lighting:

a. In office, storage, and industrial spaces, divide by 100 the illuminance defined for the space as given for the activity type in the NCM Activity database, 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 appropriate to the activity 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*).

162. Zones in the Reference building that are flagged in the NCM Activity database as appropriate to receive local manual control[26], will be modelled with local manual switching (as described in the SBEM Technical Manual[7]) 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).

163. For display lighting, take the display lighting density appropriate to the activity from the NCM Activity database.

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

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

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

Calculating the asset rating

167. The Asset Rating (AR) is the ratio of the CO_2 emissions 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 15 $$AR = 50 \times BER / SER$$

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.

[26] 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 70.

Constructing the rating scale

168. The A to G scale, in **Table 25**, 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 Emissions Rate (BER) of zero.

b. The border between grade B and grade C is set at the Standard Emissions rate (SER) and given an Asset Rating of 50[27]. Because the scale is linear, the boundary between grades D and grade E corresponds to a rating of 100.

Table 25 Rating scale and energy bands

Scale	Band
AR < 0.0	A+
0.0 ≤ AR ≤ 25.0	A
25.0 < AR ≤ 50.0	B
50.0 < AR ≤ 75.0	C
75.0 < AR ≤ 100.0	D
100.0 < AR ≤ 125.0	E
125.0 < AR ≤ 150.0	F
150.0 < AR	G

Reference values and benchmarks

169. 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 Building Regulations standard (i.e., the TER). Note this is based on the performance of the Notional building, not the Reference building.

b. The performance of the Typical building, where the emission rate is equal to the 2013 Notional building emission rate multiplied by 2 and divided by 0.6825 (*this is approximately twice the emission rate of the 2006 TER*).

(0.6825 = 0.75 x 0.91, where 0.75 is the approximate improvement from the 2006 TER to the 2010 TER, and 0.91 is the approximate improvement from the 2010 TER to the 2013 TER.)

Technical information

27 This means that a gas-heated mixed-mode building that is just compliant with Building Regulations (2006) would have an Asset Rating of 50.

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

a. ‘Main heating fuel’, which, for the purposes of this guide, 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

171. 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

172. 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[28] (which closely align with the Town and Country Planning (TCP) Use Classes[29]). One of these standard activities must be assigned to each space in the building[30].

173. A 2013 version of the NCM Activity database has been updated from 2010 to accompany the 2013 version of the NCM Modelling Guide.

174. The database provides standard occupancy, temperature set-points, outdoor air rates and heat gain profiles for each type of space in the building so that buildings 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.

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

a. Occupancy times and density; total metabolic rate and percentage which is latent (water vapour)
b. Set-point temperature and humidity in heating and cooling modes; *DSM software will use air temperature as the basis for temperature set-points for the Actual, Notional, and Reference buildings.*
c. Set-back conditions for unoccupied periods;
d. Sensible and latent heat gain from other sources;
e. Outside air requirement;
f. Level of illuminance for general lighting and the power density for display lighting;
g. Hot water demand;
h. Type of space for glazing, lighting, and ventilation classification within Building Regulations compliance;
i. A marker indicating whether the activity requires high efficiency filtration, thereby justifying an increased SFP allowance for that space to account for the increased pressure drop.

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[28] The NCM databases (Activity, Construction, and Glazing) can be downloaded from http://www.ncm.bre.co.uk

[29] Town and Country Planning (Use Classes) Order 1987 as amended.

[30] 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.

176. 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 NCM website[28] 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[31]. If a special-use space is present in the Actual building, and no appropriate activity is available in the database, it is accepted that time pressures may preclude waiting for the specific activity definition to be developed, peer reviewed, and approved. In such situations, the 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

177. 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[3]. 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 or by adding 10% to the standard area-weighted average U-values, and be consistently applied to both Actual and Notional buildings.

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

179. 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 in energy rating calculations, and so all software tools must adopt these procedures. This will be checked as part of the approval process.

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

Low and zero carbon systems

180. The following approach must be followed when calculating the impact of on-site electrical generation for both Building Regulation calculations and EPCs as applied to non-dwellings.

a. Calculate the annual electrical energy used by the building irrespective of source of supply. Multiply that energy use by the grid-supplied CO_2 emission factor.
b. Calculate the electricity generated by the on-site system and multiply that by the grid-displaced CO_2 emission factor, irrespective of the proportion of the electricity that is used on site and how much is exported.
c. The electricity-related CO_2 emissions used to establish the BER is the net figure i.e., 'a minus b' above.
d. Any fuel used in generating the electricity (e.g., in a CHP engine) is added (at its appropriate CO_2 emission factor) along with any other fuels used in the building (at their respective CO_2 emission factors) to arrive at the total building CO_2 emissions (i.e., the BER).

Weather location

181. 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[32]. The available sites are:

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

182. 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

[32] 2006 CIBSE Test Reference Years (see http://www.cibse.org)

this methodology is for England (& Wales up to 2010), 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.

Zoning rules

183. 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.

184. 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 185 to 189); 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

185. 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.

186. A lighting zone is an area that:

a. Has the same lighting requirement (levels and duration); and
b. Is served by the same type(s) of lamp/luminaire combination; and
c. Where the output of the lighting system is controlled in a similar manner; and

d. Has similar access to daylight, i.e., the zone is bounded with fenestration having similar glazing ratio, light transmittance, and orientation. This means that where benefit is being taken of daylight-linked controls (manual or automatic), a given lighting zone must not extend beyond ~6m from the perimeter.

187. 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

188. Adjoining thermal zones (horizontally or vertically[33]) 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 185 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.

189. 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

190. The CO_2 emission factors and primary energy factors[34] for fuels will be as defined in **Table 26**.

Table 26 Fuel CO_2 emission and primary energy factors for non-domestic buildings

Fuel type	**$kgCO_2/kWh$**	**kWh/kWh**
Natural gas	0.216	1.22
LPG	0.241	1.09
Biogas	0.098	1.10
Fuel oil	0.319	1.10
Coal	0.345	1.00
Anthracite	0.394	1.00
Manufactured smokeless fuel (inc. Coke)	0.433	1.21

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

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

Dual fuel (mineral + wood)	0.226	1.02
Biomass	0.031	1.01
Grid supplied electricity	0.519	3.07
Grid displaced electricity	0.519	3.07
Waste heat[35]	0.058	1.34

HVAC

191. 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).

192. 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

193. 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*).

194. 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).

195. 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

196. 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 ADL2A (2013) Table 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 electricity in the building.
b. Apply the adjustment factor due to automatic monitoring and targeting with alarms for out-of-range values to the energy consumption attributed to the lighting or HVAC system with the M&T feature.

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

Measurement and other conventions

197. 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 27** below:

Table 27 Measurement and other conventions

Parameter	Definition
Zone Area	Floor area of zone calculated using the internal horizontal dimensions between the internal surfaces of the external zone walls and half-way through the thickness of the internal zone walls. Used to multiply area-related parameters in databases. NB: If the zone has any virtual boundaries, e.g., no walls in certain orientations, the area of the zone is that delimited by the 'line' defining the virtual boundary.
Envelope Area	Area of vertical envelopes (walls) = h × w, where: h = floor to floor height, i.e., including floor void, ceiling void, and floor slab. For top floors, h is the height from the floor to the average height of the structural ceiling. w = horizontal dimension of wall. Limits for that horizontal dimension are defined by type of adjacent walls. If the adjacent wall is external, the limit will be the internal side of the adjacent wall. If the adjacent wall is internal, the limit will be half-way through its thickness. NB: Areas of floors, ceilings, and flat roofs are calculated in the same manner as the zone area. Area for an exposed pitched roof (i.e., without an internal horizontal ceiling) will be the inner pitched surface area of the roof.
Window Area	Area of the structural opening in the wall/roof; the area, therefore, includes the area of glass + frame.
HWS Dead-leg Length	Length of the draw-off pipe to the outlet in the space (only used for zones where the water is drawn off). Used to determine the additional volume of water to be heated because the cold water in the dead-leg has to be drawn off before hot water is obtained. Assumes that HWS circulation maintains hot water up to the boundary of the zone, or that the pipe runs from circulation or storage vessel within the zone.
Flat Roof	Roof with pitch of 10^{o} or less. If greater than 10^{o}, the roof is a pitched roof.
Pitched Roof	Roof with pitch greater than 10^{o} and less than or equal to 70^{o}. If the pitch is greater than 70^{o}, 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.

APPENDIX D – EPBD RECAST

198. This section describes the added requirements of the recast Energy Performance of Buildings Directive (EPBD2) with regards to the calculation methodology and output reports.

Primary energy consumption

199. A value for the total primary energy consumption by the Actual building will be calculated, based on the predicted delivered energy consumption for each fuel and the corresponding primary energy factors, as defined in **Table 26**, and will be reported in the BRUKL (compliance output document) summary.

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

a. Calculate the annual electrical energy used by the building irrespective of source of supply. Multiply that energy use by the grid-supplied primary energy factor.
b. Calculate the electricity generated by any on-site CHP system and multiply that by the grid-displaced primary energy factor, irrespective of the proportion of the electricity that is used on site and how much is exported.
c. The electricity-related primary energy of the building is the net figure i.e., 'a minus b' above.
d. Any fuel used in generating the electricity (e.g., in a CHP engine) is added (at its appropriate primary energy factor) along with any other fuels used in the building (at their respective primary energy factors) to arrive at the building's total primary energy consumption.

Alternative energy systems

201. Software tools will include additional questions for the user to confirm that the designers have considered, in the new building design, the technical, environmental, and economic feasibility of 'high-efficiency alternative systems', as defined in the recast EPBD2 (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.