Non-domestic Energy Assessment Procedure (NEAP) Modelling Guide &

SBEM Technical Manual version 3.5.a

For calculating and rating the energy performance of new and existing non-domestic buildings in the Republic of Ireland

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

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This manual and the adaptation of the software tools described in it for the Republic of Ireland Building Regulations were developed by the BRE for Sustainable Energy Authority of Ireland (SEAI). This manual is a version specifically adapted for the Republic of Ireland from the combination of the UK's *National Calculation Methodology (NCM) Modelling Guide for Buildings Other than Dwellings in England and Wales* and the original *SBEM Technical Manual* which, together with the software tools described in it, were developed by the BRE for the UK's Department for Communities and Local Government (CLG), under a contract managed for CLG by AECOM (formerly Faber Maunsell).

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Summary

This document consists of two volumes:

Volume 1: **Non-domestic Energy Assessment Procedure (NEAP) Modelling Guide**

This volume describes the official Irish methodology for demonstrating compliance with specific aspects of Part L of Building Regulations 2008 and generating Building Energy Rating (BER) certificates for new and existing non-domestic buildings in the Republic of Ireland.

Volume 2: **SBEM Technical Manual version 3.5.a**

This volume describes the various calculation procedures adopted within the Simplified Building Energy Model (SBEM).

1. Background

This document looks at the requirements for a calculation methodology for the Republic of Ireland that complies with Article 3 of the EPBD, and which has developed into the Non-domestic Energy Assessment Procedure (NEAP). It describes how one particular implementation (SBEM) has been designed to satisfy these requirements.

1.1. Requirements of the EPBD

The Energy Performance of Buildings Directive (EPBD) 2002/91/EC of the European Parliament and Council (dated 16 December 2002) calls on each EU Member State to promote the improvement of energy efficiency of buildings, by laying down standards, assessing performance on a consistent basis, and providing certificates for the majority of buildings so that this performance is communicated effectively.

In more detail, the EPBD calls on Member States to:

- develop a methodology of calculation of the integrated energy performance of buildings (Article 3)
- set minimum requirements for the energy performance of new and existing buildings (Article 4)
- ensure that those requirements for the energy performance are met in new buildings, and that the feasibility of certain alternative energy systems is checked for new buildings (Article 5)
- ensure that those requirements for the energy performance are met in existing buildings that are subject to major renovation or extension (Article 6)
- develop energy certification of buildings (Article 7)
- set up regular inspection of boilers and of air-conditioning systems, and of the whole heating system where the boilers are more than 15 years old (Articles 8 & 9)
- ensure that certification and inspections required by articles 7, 8 & 9 are carried out by qualified and/or accredited experts (Article 10)

Later in this document, it is explained how the relevant parts of Articles 3, 4, 5, 6 & 7 led to the National Calculation Methodology (NCM) and thence to SBEM for new construction, extensions, major refurbishment and existing buildings. The issues addressed by EPBD Articles 8 – 10, which deal with inspection and the accreditation of experts, are not considered here.

1.2. Need for methodology

Article 3 of the EPBD calls for a methodology for calculating the energy performance of buildings to be applied at a national or regional level. The Republic of Ireland's response to this has been to develop the Non-domestic Energy Assessment Procedure (NEAP), which draws heavily on the UK's National Calculation Methodology (NCM). SBEM is one implementation of this methodology.

An annex to the EPBD states that the calculation must be based on a general framework, which includes at least the following factors:

- Thermal characteristics of the building (shell and internal partitions, etc.); this may include air tightness
- Heating installation and hot water supply, including their thermal characteristics
- Air-conditioning installation

- Natural and mechanical ventilation
- Built-in lighting installation (mainly in the non-residential sector)
- Position and orientation of buildings, including outdoor climate
- Passive solar systems and solar protection
- Indoor climatic conditions, including the designed indoor climate

The calculation should also deal with the influence of the following aspects of energy performance, where relevant:

- Active solar systems, and other heating and electricity systems based on renewable energy sources
- Electricity produced by combined heat and power
- District or block heating or cooling systems
- Natural lighting

Buildings should be classified into different categories for the purposes of the calculation. Article 3 of the EPBD calls for the calculation to be transparent, that is, the way it works should be explained. This manual is part of that explanation.

The definition of “energy performance” in Article 2 of the EPBD refers to the estimation of energy needed for the “standardised use” of the building. This estimation is intended to enable comparisons made between buildings to be on the basis of their intrinsic properties rather than being dependent on the user’s choice of operating patterns which might exist in practice.

The NEAP has been developed to provide the calculation of the energy performance of buildings, as called for by the EPBD. Later in this document is an explanation of the calculation methodologies and compliance checking procedures that form the NEAP.

1.3. Comparison rather than absolute values

At the core of the Non-domestic Energy Assessment Procedure (NEAP), the calculation process compares the primary energy consumption and carbon dioxide emissions of the proposed building with those of a “reference building” for building regulations compliance purposes (new buildings) and with those of a “notional building” for Building Energy Rating purposes.

This approach, which is based on comparisons rather than absolute values, minimises arguments about how well the absolute primary energy consumption and carbon dioxide emissions are predicted by NEAP-compliant methods because the proposed, reference and notional buildings are subject to the same calculation approach. Instead it concentrates on improved energy efficiency and the use of renewable energy where appropriate.

1.4. NEAP requirements

In the NEAP, buildings for evaluation should be defined in terms of:

- the zones in which identifiable, standardised activities take place
- the geometry of each zone, i.e., its floor area, the areas of the building fabric elements which surround it, and their location with respect to the exterior or other interior conditioned zones
- the thermal performance characteristics of the building fabric elements surrounding each zone
- the building services systems which serve each zone (or groups of zones)
- weather location

The NEAP also requires the use of standard databases or information sources for:

- Environmental conditions and operating/occupation patterns in each part of each building
- Weather data

The reason for this is to encourage consistency between repeated evaluations of the proposals. These databases are described in more detail in Section 11.3 in Volume 2 of this document.

The NEAP requires that specific construction elements in the proposed building are checked for compliance with minimum performance standards specified in *Technical Guidance Document L: Conservation of Fuel and Energy - Buildings other than Dwellings, Building Regulations 2008*. It also requires that the output report adopts a standard format, so that building control officers will not have to interpret the way different tools present the results. These requirements are effectively provided by a compliance checking module (BRIRL) which is incorporated into all implementations of the NEAP, such as SBEM.

1.5. Basis for calculation methodology

The requirements of the EPBD are most readily achieved by demonstrating that the calculation method complies with the CEN standard umbrella document PG-N37, which lists standards relevant to the implementation of the EPBD. In particular, EN ISO 13790 deals with *Energy Performance of Buildings – Calculation of Energy Use for Space Heating and Cooling.*

Some necessary parts of the calculation are not dealt with explicitly or completely by these CEN standards or draft prEN standards. Acceptable calculation methodologies used in SBEM to deal with the areas not covered by the standards are explained in Volume 2 of this document.

Volume

1

Non-domestic Energy Assessment Procedure (NEAP) Modelling Guide

2. Introduction to the Non-domestic Energy Assessment Procedure (NEAP)

1. This volume gives guidance on the use of SBEM and other approved software tools comprising the Non-domestic Energy Assessment Procedure (NEAP) when:
    a. Demonstrating compliance with the primary energy consumption and carbon dioxide emission requirements of the building regulations for the Republic of Ireland in respect of buildings other than dwellings.
    b. Calculating Building Energy Ratings (BER) as part of preparing BER certificates for buildings other than dwellings in the Republic of Ireland.
2. SEAI has issued separate guidance on the submission and publication of assessments on the non-domestic national administration system and the formal issue of BER certificates and advisory reports to building owners.
3. 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 Part L compliance and energy certification processes.

2.1. Software validation and approval

4. Non-domestic building energy calculation software packages, to demonstrate compliance with building regulations and calculate Building Energy Ratings, must be approved by Sustainable Energy Authority of Ireland (SEAI) before they can be available for commercial use in the Republic of Ireland. More information on the validation procedure and the approval scheme is available on SEAI's website at www.seai.ie/ber.
5. In brief, to be approved, the software tool must satisfy the requirements criteria published by SEAI. 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.
    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 National Calculation Methodology (NCM) databases, the definitions of the reference, notional, and typical 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 a Building Energy Rating (BER) certificate
        iii. Deriving a set of recommendations for energy efficiency improvements
6. 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.

7. All software tools (SEAI's Simplified Building Energy Model, SBEM, and commercial 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 rules and procedures are available on SEAI's website at www.seai.ie/ber.

8. 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.

2.2. Choosing a software tool

9. All calculation methods involve a degree of simplification. Two classes of software tools are available for use for Part L compliance or BER certificate generation:

   a. SBEM, the simplified building energy model developed for SEAI - This can be applied to any building (irrespective of size) although there are some cases, as described in paragraphs 11 and 12, where representation of certain building features will require some approximation, or mean that more accurate energy calculations may be obtained using more sophisticated calculation methods.

   b. Approved Dynamic Simulation Models (DSMs) - These will be applicable for any building unless an individual DSM 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 solely carrying out compliance and certification calculations).

10. 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.

2.3. SBEM constraints

11. It is difficult to give absolute rules about when SBEM can and cannot be used. As broad guidance, it is more likely to be difficult to use SBEM satisfactorily if the building and its systems have features that are (a) not already included in iSBEM and (b) have properties that vary non-linearly over periods of the order of an hour. However, this is not a universal rule. There is a balance between the time and effort required to carry out parametric studies to establish input values for SBEM and detailed explicit modelling of a particular building.

12. Features which cannot currently be represented in iSBEM include:

    a. Night ventilation strategy

    b. Ventilation with enhanced thermal coupling to structure

    c. Demand-controlled ventilation

    d. Automatic blind control

    e. Light transfer between highly glazed internal spaces such as atria or lightwells

3. Compliance with Building Regulations (Ireland) Part L

13. Compliance with the Technical Guidance Document L[1] of Building Regulations 2008 requires that all new buildings achieve or exceed certain criteria related to:

    a. Primary energy consumption and CO_2 emissions

    b. Building fabric

    c. Building services

14. The energy and CO_2 performance criteria are based on the relative values of the calculated primary energy consumption and CO_2 emissions of a building being assessed, and similar calculated values for a “reference building”. The criteria are determined as follows:

    a. The primary energy consumption and CO_2 emissions for both the actual building and the reference building are calculated

    b. The calculated primary energy consumption of the actual building is divided by that of the reference building (both in kWh/m^2.annum), the result being the *Energy Performance Coefficient* (EPC) of the actual building. To demonstrate that an acceptable primary energy consumption rate has been achieved, the calculated EPC of the building being assessed should be no greater than the *Maximum Permitted Energy Performance Coefficient* (MPEPC). The MPEPC is 1.0.

$$\frac{Primary\ EnergyUse_{actual}}{Primary\ EnergyUse_{reference}}\left[kWh/m^2.annum\right] = Energy\ Performance\ Coefficient\ (EPC)$$

    c. The calculated CO_2 emission rate of the actual building is divided by that of the reference building (both in kgCO$_2$/m^2.annum), the result being the *Carbon Performance Coefficient* (CPC) of the actual building. To demonstrate that an acceptable CO_2 emission rate has been achieved, the calculated CPC of the building being assessed should be no greater than the *Maximum Permitted Carbon Performance Coefficient* (MPCPC). The MPCPC is 1.0.

$$\frac{CO_2\ Emissions_{actual}}{CO_2\ Emissions_{reference}}\left[kgCO_2/m^2.annum\right] = Carbon\ Performance\ Coefficient\ (CPC)$$

    This approach is adopted to avoid the need to define different system models appropriate to each type of building. It also ensures a consistent approach to the target setting process.

15. Potentially, the MPEPC the MPCPC could be decreased as future changes to the building regulations demand higher standards.

16. The methodology calculates the primary energy consumption for space heating and cooling, water heating, ventilation, and lighting, and the resulting CO_2 emissions, associated with a standardised use of a building. The primary energy consumption is expressed in terms of kWh per m^2 of floor area per year, and the CO_2 emissions are expressed in terms of kg of CO_2 per m^2 of floor area per year.

[1] Building Regulations 2008, Technical Guidance Document L, Conservation of Fuel and Energy – Buildings other than Dwellings.

3.1. Definition of the reference building

17. 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 (see Table 10).

18. Each space must contain the same activity (and therefore the same activity parameter values from the NCM Activity database) 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 27).

19. The reference and actual buildings must be given the same orientation and be exposed to the same weather. 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, if the software can model external shading (this does not apply to SBEM but might apply to DSMs).

20. Whatever servicing strategy (heating, ventilation, cooling) is specified in a zone in the actual building must also be provided in the reference 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 reference 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 reference building, and then both buildings must heat those spaces to the heating set-point specified for the zone type in the NCM Activity database.

21. Any building services system not covered by the energy performance requirements in the building regulations must be ignored in both the actual and reference buildings.

22. The energy performance standards of the reference building are specified to comply with the standards of reasonable provision described in Appendix C of the Technical Guidance Document L of Building Regulations 2008. Where that guidance document omitted to specify parameters, or did so in a way that is inconsistent with energy modelling data requirements, the nearest equivalent value has been used in the following data definition.

3.2. Building fabric of the reference building

23. Appendix C of Technical Guidance Document L specifies the U-values of the reference building as shown in Table 1. All U-values must be calculated following the guidance in BR443, excluding paragraph 3.10.2 which is currently not to be used, or the current editions of international standards to which Technical Guidance Document L refers. The NCM database constructions conforming to these U-values are identified in the table by their reference IDs. In addition, the general guidance beginning at paragraph 70 must be followed.

Exposed element - (Overall heat loss method)	U-value (W/m^2K)	Database reference IDs
Roofs (irrespective of pitch†)	0.16	390
Walls	0.27	374
Ground and other exposed floors	0.25	248
Windows, roof windows, rooflights, curtain walls, and glazed doors‡	2.2	See Table 3
External personnel doors	2.2	480
Vehicle access and similar large doors	1.5	261
Internal walls	2.0	307

Internal windows	3.85	481
Internal floors viewed from room above	1.25	355
Internal floors viewed from room below	1.23	315
† Any part of a roof with a pitch greater than or equal to 70° is considered a wall.		
‡ This U-value relates to the performance of the unit in the vertical plane. The U-value must be adjusted for slope as detailed in section 11.1 of BR443.		

Table 1: U-values of construction elements in the reference building

24. Further, the U-values of display windows in the reference building must be taken as 5.7 W/m^2K, with solar transmittance[2] of 0.77, light transmittance of 0.87, and frame factor of 0.1 (i.e., 10% of the area of the opening is the frame and 90% is glazed). Smoke vents and other ventilation openings, such as intake and discharge grilles, must be disregarded in both the reference and actual buildings, and their areas substituted by the relevant (i.e., immediately surrounding) opaque fabric (roof or wall).

25. Thermal bridge heat losses for each envelope element (including windows, etc.) must be allowed for in the reference building by adding 16% to the standard U-values, or by an equivalent method that satisfies BS EN ISO 14683. Note that the U-values as given in Table 1 and the construction elements in the database DO NOT include this allowance, and so the calculation tool must make the adjustment explicitly.

26. Special considerations apply to ground floors in the reference building, where the U-value is a function of the 'perimeter/area' ratio. The following adjustments[3] must be made:

    a. If the calculated value is greater than 0.25 W/m^2K, the value of 0.25 W/m^2K must be used in the reference building.

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

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

28. The effective thermal capacity of the construction elements, κ (kappa value), in the reference building must be as shown in Table 2, as specified in Appendix C of Technical Guidance Document L. DSMs must use the construction elements whose reference IDs are given in Table 1. The information in the NCM Construction database includes the necessary technical parameters to evaluate the impact of thermal capacity.

Element	Effective thermal capacity** (kJ/m^2K)
Roofs	12
Walls	11.7
Floors	36
Internal wall	11.9
Internal floor (and ceiling)	8.6
** Effective thermal capacity, κ (kappa value), is defined in prEN ISO 13790	

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

29. The air permeability of the reference building must be defined as $10m^3/(h.m^2)$ 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

[2] BS EN 410 g-value.
[3] This follows the guidance given in CIBSE Guide A (2007).

purposes, the same method must be used in the reference, actual, notional, and typical buildings. Acceptable methods include:

a. The method specified in EN 15242[4].

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 in the Republic of Ireland or UK professional guidance documents, which relate the 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 reference building delivers the required permeability standard of 10m^3/(h.m^2) at 50 Pa.

3.3. Solar and daylight transmittance

30. The total solar energy transmittance (BS EN 410 g-value) and the daylight transmittance of glazing in the reference building must be as given in Table 3. These data apply to all windows, roof windows, and rooflights (refer to paragraph 24 for transmittance values of display windows). The data are based on a normal incidence value of 0.72 for solar transmittance and 0.76 for daylight transmittance (as specified in Appendix C of Technical Guidance Document L), which are further adjusted for certain orientations in order to limit overheating in the reference building. Appropriate values for intermediate orientations can be based on linear interpolation. DSMs must use the glazing element as identified by the reference IDs in the NCM Glazing database.

Orientation of glazing	Solar transmittance (BS EN 410 g-value)	Daylight transmittance	Database reference IDs
N	0.72	0.76	274
NE	0.72	0.76	276
E	0.58	0.61	277
SE	0.58	0.61	278
S	0.72	0.76	279
SW	0.58	0.61	280
W	0.58	0.61	281
NW	0.72	0.72	282
Horizontal	0.43	0.46	275

Table 3: Solar and daylight transmittances in the reference building

This variation in the solar and daylight transmittance with orientation is not an attempt to model varying daylight availability when using an overcast sky model. It is a pragmatic solution to achieving a building design that meets the heat loss requirements and avoiding solar overheating requirements, as specified in Technical Guidance Document L.

3.4. Areas of windows, doors, and rooflights

31. The areas of windows, doors, and rooflights 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 79.

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

a. Subject to the following criteria, all external walls must have windows, and all roofs must have rooflights.

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 4, the balance must be made up of windows or rooflights as appropriate.

d. If the total area of the copied elements exceeds the allowance from Table 4, the copied areas must be retained but no windows or rooflights added. As noted in paragraph 24, smoke vents and other ventilation openings must be ignored in both the reference and actual buildings.

e. The areas, as specified in Technical Guidance Document L and shown in Table 4, represent the areas of openings in the wall or roof, and comprise the area of the glass plus the frame. The windows must have a frame factor of 0.1 (i.e., 90% of the area of the opening is glazed) and rooflights a frame factor of 0.3 (refer to paragraph 24 for the frame factor of display windows).

Building type	**Windows and pedestrian doors as % of the area of exposed wall**	**Rooflights as % of the area of roof**
Residential buildings (where people temporarily or permanently reside)	30	20
Places of assembly, Offices, and shops	40	20
Industrial and storage buildings	15	20

Table 4: Opening areas in the reference building

32. 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 no 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 a part is above ground, the Table 4 percentages must apply to the above-ground part, with no glazing for the below-ground part.

3.5. HVAC system definition

33. Each space in the reference 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, i.e.:

a. unheated

b. heated only with natural ventilation

c. heated only with mechanical ventilation

d. air-conditioned

e. mixed-mode, where cooling operates only in peak season to prevent space temperatures exceeding a threshold temperature higher than that normally provided by an air-conditioning system.

34. 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 reference and actual buildings, but it will be necessary to separately demonstrate that the space will not overheat following the guidance in Technical Guidance Document L. If the mechanical ventilation system only operates in peak summer conditions to control overheating and during normal conditions, ventilation is provided naturally, then the space must be regarded as naturally ventilated, and the mechanical ventilation system can be ignored in both the reference and actual buildings. In this case, it will also be necessary to separately demonstrate that the space will not overheat following the guidance in Technical Guidance Document L.

35. If a zone is naturally ventilated, the modelling strategy must provide for enhanced natural ventilation in the reference 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 DSMs[5], the following modelling strategy must be used in the reference building. The strategy must increase the natural ventilation rate to 5 ac/h whenever the space temperature exceeds the heating set-point[6] by 1 K. This enhanced ventilation must cease immediately the space temperature falls below the heating set-point.

    By maintaining the increased natural ventilation until internal temperatures fall to the (high) heating set-point, the temperatures at start-up next day will be neither artificially high nor low.

36. If the actual building includes humidity control, this must be ignored in both the reference and actual buildings.

37. The fuel used in the reference building will be determined as follows:

    a. For space and water heating, the system in the reference building will use the same fuel used in the corresponding system in the actual building, except if the actual building uses a low or zero carbon (LZC) heating technology, in which case, the reference building will use natural gas as fuel for the corresponding system.

    b. For the purposes of the NEAP, low or zero carbon (LZC) heating technologies are to include: biomass, biogas, heat pumps, waste heat, and renewable energy sources (i.e., photovoltaic systems, solar thermal systems, wind generators, combined heat and power generators, etc.).

    c. The reference building will always use grid-supplied electricity as fuel for cooling, lighting, and auxiliary energy.

Heating (space or water) fuel in actual building	Fuel type in corresponding system in reference building
Natural gas	Natural gas
LPG	LPG
Oil	Oil
Coal	Coal

[5] 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.

[6] This guidance assumes that the 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.

LZC heating technology (biomass, biogas, heat pump, waste heat, etc…)	Natural gas
Grid supplied electricity	Grid supplied electricity
Anthracite	Anthracite
Smokeless fuel (inc. coke)	Smokeless fuel (inc coke)
Dual fuel appliances (mineral + wood)	Dual fuel appliances (mineral + wood)

Table 5: Fuel types to be assumed in the reference building specification

38. The efficiency of the HVAC systems in the reference building must be as given in Table 6.

39. The system performance definitions follow the practice set out in EN 15243[7]:

   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[8]. The auxiliary energy demand must be calculated as detailed in paragraph 40 as appropriate.

   b. The Seasonal System Efficiency for heating (SSEff) is the ratio of the sum of the heating demands of all spaces served by a heating system to the energy content of the fuels (or electricity) supplied to the boiler or other heat generator of the system. The SSEff includes, inter alia, the efficiency of the heat generator, thermal losses from pipework and ductwork, and duct leakage. It does not include the energy used by fans and pumps.

   c. The Seasonal System Energy Efficiency Ratio for cooling (SSEER) is the ratio of the sum of the sensible cooling demands of all spaces served by a cooling system to the energy content of the electricity (or fuel) supplied to the chiller or other cold generator of the system. The SSEER includes, inter alia, the efficiency of the cold generator, heat gains to pipework and ductwork, and duct leakage. It does not include energy used by fans and pumps. The electricity used by heat rejection equipment associated with chillers is accounted for in the SSEER (not as auxiliary energy). The 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 Energy Efficiency ratio (EER).

   d. The electricity used by fossil-fuelled equipment and its ancillaries, including fans in unit heaters and gas boosters, is included in the auxiliary energy.

Servicing strategy	Heating SSEff	Cooling SSEER	Auxiliary energy
Heating with natural ventilation	0.73	N/A	See paragraph 40.a)
Heated with mechanical ventilation	0.78	N/A	See paragraph 40.b)
Fully air-conditioned	0.83	1.67	See paragraph 40.c)
Changeover mixed-mode with natural ventilation	0.73	2.25†	See paragraph 40.a)
Changeover mixed-mode with mechanical ventilation	0.78	2.25†	See paragraph 40.b)
No heating with natural ventilation	N/A	N/A	0
† This SSEER includes an allowance for fan energy when the system operates, so no additional auxiliary energy needs to be determined beyond what is described above.			

Table 6: HVAC Seasonal system efficiencies in the reference building

[7] EN 15243, Ventilation for Buildings – Calculation of room temperatures and of load and energy for buildings with room conditioning systems, CEN, 2007.
[8] Energy use in offices, Energy Consumption Guide 19, Action Energy, 2003

40. The auxiliary energy per unit floor area in the reference building must be calculated as follows:

   a. For heated only and naturally ventilated spaces: the product of 0.61 W/m^2 and the annual hours of operation of the heating system from the NCM Activity database.

   b. For mechanically ventilated spaces: the product of the outside air rate for the space, the annual hours of operation (both from the Activity database) and the appropriate specific fan power from Table 7. If the zone is heated, then the auxiliary energy should also include the energy from paragraph 40.a).

   c. For air-conditioned spaces: the product of the annual hours of operation and the greater of either:

      i. the product of the fresh air rate (from the NCM Activity database) and the appropriate SFP from Table 7.

      ii. 8.5 W/m^2.

   d. For spaces with mechanical extract: the product of the extract rate provided by the user for the actual building, the annual hours of operation (from the NCM Activity database), and the appropriate SFP from Table 7. If the zone is heated only, mechanically ventilation, or air-conditioned, then the auxiliary energy should also include the energy from paragraph 40.a), 40.b), or 40.c), respectively.

System type	Specific fan power W/(litre/s)
Centralised balanced mechanical ventilation system	2.0**
Zonal supply system	1.2**
Zonal extract system serving multiple spaces, i.e., fan is remote from zone	0.8
Local extract serving a single area, i.e., fan is within zone (e.g., toilet extract)	0.5
** If the activity in the space requires the use of higher levels of filtration, e.g., High Efficiency Particulate Air (HEPA filters), the specific fan power is increased by 1.0 W/(litre/s).	

Table 7: Specific fan power for different ventilation systems in the reference building

41. 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.

42. The overall system efficiency (including generation and distribution) for the water heating system in the reference building must be taken as 0.45, and the fuel must be as specified in paragraph 37. 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 litres/(m^2.day). If users of DSMs wish to distribute this demand over the day, then the daily total should be distributed according to the occupancy profile.

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

3.6. Installed lighting power density in the reference building

44. For general lighting in the reference building:

a. in office, storage, and industrial spaces, divide the illuminance appropriate to the activity in the space, as given in the NCM Activity database, by 100, then multiply by 3.75 W/m^2 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, as given in the NCM Activity database, by 100, then multiply by 5.2 W/m^2 per 100 lux.

45. For display lighting in the reference building, take the display lighting density, in W/m^2, appropriate to the activity in the space from the NCM Activity database.

46. In all cases, the duration of the lighting demand must be as per the activity schedule in the NCM Activity database.

47. It must be assumed that the general lighting in the reference building has local manual switching only in all spaces. Display lighting, on the other hand, must be assumed to be always on, except if in the actual building, display lighting is controlled by a time-switch so that some or all of the display lighting is switched off or dimmed for a fraction of the time, in which case, display lighting will be assumed to be switched off in the reference building by the same fraction and during the same period as those defined for the actual building.

Calculation methods for the impact of controls on lighting energy demand must be at least as detailed as the procedure specified in section 12.4 of the SBEM Technical Manual.

3.7. Primary energy and carbon dioxide emissions

48. The reference building, with the parameters as defined above, must be used as the basis of determining the primary energy and CO_2 emissions used for assessing the actual building's compliance with Part L, irrespective of the calculation method used to determine the heating and cooling demands themselves. For the actual building, DSMs may represent HVAC systems explicitly, but they will be required to report overall seasonal performance parameters as an aid to checking.

49. Energy calculations for the Republic of Ireland must incorporate the primary energy factors and the CO_2 emission factors shown in Table 8 for the corresponding fuel types.

Fuel type	Primary energy factors kWh/kWh	Emission factors kgCO_2/kWh
Natural Gas	1.1	0.203
LPG	1.1	0.232
Biogas	1.1	0.025
Oil	1.1	0.272
Coal	1.1	0.361
Anthracite	1.1	0.361
Smokeless Fuel (inc. Coke)	1.2	0.392
Dual Fuel Appliances (Mineral + Wood)	1.1	0.289
Biomass	1.1	0.025
Grid Supplied Electricity	2.7	0.643
Grid Displaced Electricity	2.7	0.643
Waste Heat	1.05	0.018

Table 8: Primary energy and carbon dioxide emission factors

50. 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. Hence, the primary energy factors in Table 8 denote kWh of primary energy per kWh of the building's delivered energy.

51. The carbon dioxide emissions are calculated on the basis of the primary energy, i.e., due to the delivered energy at the building plus the energy incurred in extracting, processing, and transporting a fuel or other energy carrier to the building. The emission factors in Table 8 denote the CO_2 emissions released in $kgCO_2$ per kWh of the building's delivered energy.

52. Hence, after the delivered energy is calculated by for the actual building, it is converted using the appropriate factors for the fuels used in order to produce the estimated primary energy, in kWh/m^2 per annum, and the CO_2 emission rate, in $kgCO_2/m^2$ per annum. Similar values are calculated for the reference building, and the compliance criteria are assessed as specified in paragraph 14.

4. Building Energy Rating Certificates

53. The Building Energy Rating (BER) is an indication of the energy performance of the building and is expressed as a ratio of the calculated primary energy for the actual building to that calculated for a “notional” building.
54. A BER certificate and an advisory report are to be supplied by the owner of a building in the Republic of Ireland to a prospective buyer or tenant when the building is constructed, sold, or rented. The objective of the rating is:
    a. to give the prospective buyers or tenants information about the energy performance of the building and
    b. to give builders/developers and vendors/landlords an incentive to upgrade the energy performance of the building by giving visible credits to superior standards.
55. The BER certificate must be accompanied by an advisory report setting out recommendations for cost-effective improvements to the energy performance of the building. However, there will be no legal obligation on vendors or prospective purchasers to carry out the recommended improvements.
56. BER certificates are intended to send market signals about the relative performance of comparable buildings, and so it is necessary that the notional building should be the same for all buildings of a given type. In order to provide this consistency, the notional building must be the same irrespective of:
    a. whether the building is naturally ventilated or air-conditioned and
    b. the fuel choice

4.1. Definition of the notional building

57. The insulation levels and HVAC efficiencies in the notional building are identical to the Part L reference building defined earlier in this document except that certain parameters in the notional building are fixed irrespective of features in the actual building. These aspects are given below. Unless specified as being different, all other parameters must be taken as per the reference building definition given in the preceding paragraphs of this guide.
    a. The space heating and hot water services in the notional building are always met by natural gas-fired systems irrespective of whether a fuel other than natural gas is used in the actual building, or is even available in the locality of the actual building.
    b. The notional building has a fixed servicing strategy regardless of the strategy adopted in the actual building. Therefore:
        i. Each space is heated to the heating set-points defined in the NCM Activity database, irrespective of whether the corresponding space in the actual building has heating provision or not. The heating SSEff must be taken to be the same as for the “changeover mixed-mode with natural ventilation” case in the reference building (see Table 6).
        ii. Each space is cooled to a cooling set-point fixed at 27^{o}C, irrespective of whether the corresponding space in the actual building has cooling

provision or not[9]. The cooling SSEER must be taken to be the same as for the “changeover mixed-mode with natural ventilation” case in the reference building (see Table 6).

iii. Each space is naturally ventilated, irrespective of whether the corresponding space in the actual building has natural or mechanical ventilation. The auxiliary energy must be taken to be the same as for the “changeover mixed-mode with natural ventilation” case in the reference building (see Table 6).

58. It is not intended that the definition of the notional 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 notional building is always as defined above.

4.2. Calculating the BER

59. The performance criteria are based on the relative values of the calculated primary energy consumption and CO_2 emission rate of a building being assessed, and similar calculated values for the notional building. The criteria are determined as follows:

   a. The primary energy (in kWh/m^2.annum) and CO_2 emissions (in kgCO_2/m^2.annum) arising from the use of the fixed building services (space heating and cooling, water heating, ventilation, and lighting) are calculated for both the actual and notional buildings.

   b. The calculated primary energy consumption of the actual building is divided by that of the notional building, the result being the Building Energy Rating (BER) of the actual building. The rating is also converted into an energy band/grade on an “A-G” scale (see paragraph 60).

$$\frac{Primary\ Energy Use_{actual}}{Primary\ Energy Use_{notional}} \left[kWh / m^2.annum\right] = Building\ Energy\ Rating\ (BER)$$

   c. The calculated CO_2 emission rate of the actual building is divided by that of the notional building, the result being the CO_2 Emissions Indicator of the actual building.

$$\frac{CO_2\ Emissions_{actual}}{CO_2\ Emissions_{notional}} \left[kgCO_2 / m^2.annum\right] = CO_2\ Emissions\ Indicator$$

4.3. The rating scale

60. The A to G scale and energy labels corresponding to values of the BER are displayed in Figure 1, with A1 being the most efficient and G being the least efficient.

[9] 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 Activity database. User specified cooling set-points are not allowed.

$$
\begin{aligned}
BER < 0.17 &\Rightarrow A1 \\
0.17 \leq BER < 0.34 &\Rightarrow A2 \\
0.34 \leq BER < 0.50 &\Rightarrow A3 \\
0.50 \leq BER < 0.67 &\Rightarrow B1 \\
0.67 \leq BER < 0.84 &\Rightarrow B2 \\
0.84 \leq BER < 1.00 &\Rightarrow B3 \\
1.00 \leq BER < 1.17 &\Rightarrow C1 \\
1.17 \leq BER < 1.34 &\Rightarrow C2 \\
1.34 \leq BER < 1.50 &\Rightarrow C3 \\
1.50 \leq BER < 1.75 &\Rightarrow D1 \\
1.75 \leq BER < 2.00 &\Rightarrow D2 \\
2.00 \leq BER < 2.25 &\Rightarrow E1 \\
2.25 \leq BER < 2.50 &\Rightarrow E2 \\
2.50 \leq BER < 3.00 &\Rightarrow F \\
3.00 \leq BER \quad &\Rightarrow G
\end{aligned}
$$

Figure 1: BER scale and energy labels

5. Modelling thermal comfort in the actual building

61. In order to provide a consistent assessment of the BER, the calculation procedure must always control the space temperature to the set-point defined for the relevant activity area in the NCM Activity database, irrespective of the control temperature prevailing in the building as it operates in practice. The control set-point will only vary according to the level of servicing provided, i.e., no cooling, mixed-mode, or full air-conditioning.

62. In buildings without mechanical cooling, the level of thermal comfort achieved will vary during the summer months and will differ from building to building. Consequently, the degree of overheating must be reported via the advisory report, with the BER just being based on the systems actually installed in the building. This approach is more factually correct, and allows the incoming occupier to assess whether the overheating risk is significant or not in terms of the intended use of the space.

    Overheating risk analysis has only been included in Part L during changes in the last few years, and so there has been no formal assessment of the summer performance of the vast majority of existing buildings, many of which have much higher internal gains than when first designed, and where overheating may be a significant problem. Consequently, it would be possible for a building to have a better BER than another, but once occupied, the new owner/tenant might find it necessary to install cooling; hence the requirement to include an overheating assessment as part of the advisory report.

63. The degree of overheating must be assessed as shown in Table 9, with the overheating threshold temperature set at an operative temperature of 27°C.

    The results of this automated analysis are only approximate, and so it is recommended that potential occupiers and their advisors consider carrying out a specific risk assessment based on the intended use of the space and appropriate weather data, which might include estimates of the impact of future global warming.

Criterion	**(a) SBEM**	**(b) DSM**
	Ratio (R_k) of cooling demand with temperature of 27°C to that with cooling set-point from the NCM Activity database	% occupied hours (β) exceeding 27°C operative temperature
Low risk	$R_k < 0.15$	$\beta < 0.5\%$
Moderate risk	$0.15 \leq R_k < 0.30$	$0.5\% \leq \beta < 1$
Significant risk	$0.30 \leq R_k < 0.50$	$1\% \leq \beta < 1.5\%$
High risk	$R_k \geq 0.50$	$\beta \geq 1.5\%$

Table 9: Definition of overheating criteria

64. This assessment is only required for naturally ventilated spaces, since air-conditioned and mixed-mode zones will have the cooling capacity to prevent overheating. The assessment must be made on a zone by zone basis. For the DSM criterion, as set out in column (b) of Table 9, the occupied period should be taken as those hours where the occupancy is greater than 20% of the peak occupancy level.

6. Input data to approved tools

65. This section describes generally applicable approaches to data input and modelling strategies, and applies equally to Part L compliance and BER certificates. It also applies to the modelling of the reference, actual, notional, and typical buildings.

6.1. Defining internal gains and environmental conditions

66. In order to facilitate estimating energy performance on a consistent basis, a key part of the NEAP is a set of databases that define the activities in various types of spaces and in different classes of buildings[10]. One of these standard activities must be assigned to each space in the building being modelled[11].

67. The database provides standard occupancy, temperature set-points, outdoor air rates, heat gains, occupancy profiles, etc., 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 regulations compliance test and BER to compare buildings on the basis of their intrinsic potential performance, regardless of how they may actually be used in practice.

68. 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

    c. Set-back conditions for unoccupied periods

    d. Sensible and latent heat gain from other sources

    e. Outside air requirement

    f. Fixed lighting requirement, including 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.

69. If there is not an activity in the database that reasonably matches the intended use of a space, then this should be raised with the database managers, and an appropriate new activity 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[12]. 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

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[10] The NCM databases can be downloaded from http://www.seai.ie/ber.

[11] In a school, these activities might be teaching classrooms, science laboratories, a gymnasium, 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.

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

approved. In such situations, the energy assessor must select the closest match from the approved database. Because compliance and certification are both based on the performance of the actual building in comparison to a reference/notional building, the impact of this approximation should be minimal.

6.2. Constructions

70. The thermal performance of construction elements must take account of thermal bridges as follows:

    a. Repeating thermal bridges must be included in the calculated plane element U-value as detailed in BR443, excluding paragraph 3.10.2 which is currently not to be used, or the current editions of international standards to which Technical Guidance Document L refers. Simulation tools that use layer by layer definitions will need to adjust the thicknesses of insulation layers to achieve the U-value that accounts for the repeating thermal bridges.

    b. Thermal bridges at junctions and around openings as described in IP 1/06[13].

71. Available for download from the SEAI website is the NCM Construction database containing the calculated U-values, kappa values, etc, and for consistency, all implementations of the NEAP should preferably use this database. 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.

72. When using the software tool to generate a BER certificate for an existing building, the performance parameters for some constructions may not be known. In such situations, the parameters must be inferred using the procedures set out in the SBEM Technical Manual (Volume 2 of this document).

    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 approvals process.

6.3. Low and zero carbon systems

73. The following approach must be followed when calculating the impact of on-site electrical generation for both Part L calculations and BER certificates as applied to non-dwellings:

    a. Calculate the annual electrical energy used by the building irrespective of the source of supply. Multiply that demand by the CO_2 emission factor of grid-supplied electricity (Table 8).

    b. Calculate the electricity generated by the on-site system and multiply that by the CO_2 emission factor of grid-displaced electricity (Table 8), irrespective of the proportion of electricity that is used on-site and how much is exported.

    c. The electricity-related CO_2 emissions used to establish the building's emission rate is the net figure, i.e., the result of paragraph 73.a) minus the result of paragraph 73.b).

    d. Any fuel used in generating the electricity (e.g., in a CHP engine) is added (at its appropriate CO_2 emission factor) to arrive at the total building's CO_2 emissions.

[13] BRE IP 1/06: Assessing the Effects of Thermal Bridging at Junctions and around Openings.

6.4. Weather location

74. In order to calculate the reaction of the building fabric and systems to the variable loads imposed by the external environment, the NEAP needs an input of weather data. A standard weather set[14] has been adopted for Dublin, which must be used.

6.5. Zoning rules

75. The way a building is subdivided 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.

76. The end result of the zoning process should be a set of zones which are distinguished from all others in contact with it by differences in one or more of the following:

    a. The activity attached to it

    b. The HVAC system which serves it

    c. The lighting system within it

    d. The access to daylight (through windows or rooflights)

77. To this end, the zoning process within a given floor plate is as follows:

    a. Divide the floor into separate physical areas, bounded by physical boundaries, such as structural walls or other permanent elements.

    b. If any part of an area is served by a significantly different HVAC or lighting system, create a separate area bounded by the extent of those services.

    c. If any part of an area has a different activity taking place in it, create a separate area for each activity.

    d. Attribute just one "activity" (selected from the options available for each building type) to each resulting area. If the building is speculative, and the activity is not fully defined, select the appropriate 'speculative activity' for the relevant building type.

    e. Divide each resulting area into "zones" receiving significantly different amounts of daylight, defined by boundaries which are:

        i. At a distance of 6m from an external wall containing at least 20% glazing.

        ii. At a distance of 1.5 x room height beyond the edge of an array of rooflights if the area of the rooflights is at least 10% of the floor area.

        iii. If any resulting zone is less than 3m wide, absorb it within surrounding zones.

        iv. If any resulting zones overlap, use your discretion to allocate the overlap to one or more of the zones.

    f. Merge any contiguous areas which are served by the same HVAC and lighting systems, have the same activity within them (e.g., adjacent hotel rooms, cellular offices, etc.), and which have the similar access to daylight, unless there is a good reason not to.

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[14] Obtained from the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) at www.ashrae.org.

g. Each Zone should then have its envelopes described by the area and properties of each physical boundary. Where a zone boundary is virtual, e.g., between a daylit perimeter and a core zone, no envelope element should be defined.

78. Where contiguous areas have been merged into one, then the partitions that separate the physical spaces must be included in the definition of the zone's envelopes in order to properly represent the thermal storage impact.

6.6. Measurement and other conventions

79. 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 10 below:

Parameter	Definition
Zone Height	Floor to floor height (floor to soffit for top floor), i.e., including floor void, ceiling void, and floor slab. Used for calculating length of wall-to-wall junctions, radiant and temperature gradient corrections, and air flow through the external envelopes due to the stack effect. **NB:** For a zone with a flat roof, the zone height would be from top of floor to top of roof. For a zone with a pitched roof and a flat ceiling underneath it, the zone height would be from top of floor to underside of soffit. For a zone with a sloping roof (i.e., an exposed pitched roof with no flat ceiling underneath it), the zone height would be from top of floor to soffit height. If there is a suspended floor, the zone height would be measured from the floor surface (rather than the slab underneath it).
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, the area of the zone is that delimited by the 'line' created by that virtual boundary.
(Building) Total Floor Area	Sum of zone areas. Used to check that all zones have been entered.
Envelope Area	Area of vertical envelopes (walls) = h * w, where: h = floor to floor height (floor to soffit on top floor), i.e., including floor void, ceiling void, and floor slab. w = horizontal dimension of wall. Limits for that horizontal dimension are defined by the 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 floor, 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 surface area of the roof. This parameter is used to calculate fabric heat loss, so this is the area to which the U-value is applied.

Window Area	Area of the structural opening in the wall or roof, i.e., it includes the glass and the frame.
Deadleg 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 deadleg 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 a pitch of 10 degrees or less.
Pitched Roof	Roof with a pitch greater than 10 degrees and less than or equal to 70 degrees. If the pitch is greater than 70 degrees, the envelope should be considered a wall.
Display Window	As defined in the building regulations.
Personnel Door	As defined in the building regulations.
High Usage Entrance Door	As defined in the building regulations.
Vehicle Access Door	As defined in the building regulations.
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. (Otherwise, they are defined as opaque doors.)

Table 10: Measurement and other conventions

7. Definition of the typical building

80. The typical building is used only in calculating the payback for the recommendations that appear in the advisory report which accompanies the BER certificate.

81. The typical building is identical to the reference building apart from the parameters set out below. Unless specified as being different, all other parameters must be taken as per the reference building as defined in earlier sections of this guide.

82. The space heating and hot water services in the typical building are always met by natural gas-fired systems irrespective of whether a fuel other than natural gas is used in the actual building, or is even available in the locality of the actual building.

83. The U-values for the construction types in the typical building must be as per the reference building but with the variations shown in Table 11.

Exposed element - (Overall heat loss method)	U-value (W/m^2K)	Database reference IDs
Roofs (irrespective of pitch†)	0.5	482
Walls	0.45	483
Ground and other exposed floors	0.45	484
Windows, roof windows, rooflights, curtain walls, and glazed doors‡	3.3	See Table 12
External personnel doors	3.3	489
Vehicle access and similar large doors	1.5	485
Internal walls	2.0	490
Internal windows	3.85	481
Internal floors viewed from room above	1.25	486
Internal floors viewed from room below	1.23	487
† Any part of a roof with a pitch greater than or equal to 70° is considered a wall.		
‡ This U-value relates to the performance of the unit in the vertical plane. The U-value must be adjusted for slope as detailed in section 11.1 of BR443.		

Table 11: U-values of construction elements in the typical building

84. Solar and light transmittances of glazing in the typical building must be as per Table 12, which are the same as for the reference building shown in Table 3 but with the variation in the reference ID in the database to account for the changed U-value for windows and rooflights in Table 11.

Orientation of glazing	Solar transmittance (BS EN 410 g-value)	Daylight transmittance	Database reference IDs
N	0.72	0.76	374
NE	0.72	0.76	376
E	0.58	0.61	377
SE	0.58	0.61	378
S	0.72	0.76	379
SW	0.58	0.61	380
W	0.58	0.61	381
NW	0.72	0.72	382
Horizontal	0.43	0.46	375

Table 12: Solar and daylight transmittances in the typical building

85. The air permeability in the typical building must be taken as 15 $m^3/(h.m^2)$ at 50Pa.

86. The HVAC system seasonal efficiencies in the typical building must be as given in Table 13.

Servicing strategy	Heating SSEff	Cooling SSEER	Auxiliary energy
Heating with natural ventilation	0.55	N/A	See paragraph 87.a)
Heated with mechanical ventilation	0.55	N/A	See paragraph 87.b)
Fully air-conditioned	0.55	1.17	See paragraph 87.c)
Changeover mixed-mode with natural ventilation	0.55	1.9†	See paragraph 87.a)
Changeover mixed-mode with mechanical ventilation	0.55	1.9†	See paragraph 87.b)
No heating with natural ventilation	N/A	N/A	0
† This SSEER includes an allowance for fan energy when the system operates, so no additional auxiliary energy needs to be determined beyond what is described above.			

Table 13: HVAC Seasonal system efficiencies in the typical building

87. The auxiliary energy per unit floor area of the typical building must be calculated as follows:

    a. For heated only and naturally ventilated spaces: the product of 1.23 W/m^2 and the annual hours of operation of the heating system from the Activity database.

    b. For mechanically ventilated spaces: the product of the outside air rate for the space, the annual hours of operation (both from the Activity database) and the appropriate specific fan power from Table 14. If the zone is heated, then the auxiliary energy should also include the energy from paragraph 87.a).

    c. For air-conditioned spaces: the product of the annual hours of operation and the greater of either:

        i. the product of the fresh air rate (from the Activity database) and the appropriate SFP from Table 14.

        ii. 14 W/m^2.

    d. For spaces with mechanical extract: the product of the extract rate provided by the user for the actual building, the annual hours of operation (from the Activity database), and the appropriate SFP from Table 16. If the zone is heated only, mechanically ventilation, or air-conditioned, then the auxiliary energy should also include the energy from paragraph 87.a), 87.b), or 87.c), respectively.

System type	Specific fan power W/(litre/s)
Centralised balanced mechanical ventilation system	3.0**
Zonal supply system	1.8**
Zonal extract system serving multiple spaces, i.e., fan is remote from zone	1.1
Local extract serving a single area, i.e., fan is within zone (e.g., toilet extract)	0.75
** If the activity in the space requires the use of higher levels of filtration, e.g., High Efficiency Particulate Air (HEPA filters), the specific fan power is increased by 1.0 W/(litre/s).	

Table 14: Specific fan power for different ventilation systems in the typical building

88. For general lighting in the typical building:

a. in office, storage, and industrial spaces, divide the illuminance appropriate to the activity in the space, as given in the NCM Activity database, by 100, then multiply by 4.5 W/m^2 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, as given in the NCM Activity database, by 100, then multiply by 6.2 W/m^2 per 100 lux.

APPENDIX A: Seasonal Efficiency Calculation Tool

A.1. Introduction and general principles

The NEAP requires the user to enter values for the seasonal energy efficiency ratio (SEER) of cooling generators and the seasonal efficiency of boilers. Since efficiency varies with load (and other factors), this information is not always easy to obtain, especially for cooling generators.

The "Seasonal Efficiency Calculation Tool" provides a systematic way of calculating suitable values. Following the general philosophy embodied in the NEAP, it includes cautious default values which can be upgraded according to the level of information that is available.

The underlying principle is to determine the seasonal value from a weighted (harmonic) average of part-load values. If available, measured values may be used. If not, then different options are provided to make estimates. These, too, are intended to be cautious estimates so, in general, the more detailed the actual information, the better the inferred performance.

A.2. Part-load cooling generator performance

The calculation algorithms require a seasonal energy efficiency ratio (SEER) as an input for determining the cooling energy consumption. This can be complicated by the varying performance of cooling generators as a function of the cooling load.

In practice, cooling generators are normally tested under full-load conditions, but, in many cases, part-load testing is not undertaken by manufacturers. Full-load cooling performance for electrically-driven vapour compression units is determined in the EU in accordance with European Standard EN14511:2007. The energy efficiency ratio (EER) performance under part-loads can be determined in accordance with the draft standard prEN 14825:2008. This, essentially, follows the methodology for EN14511 but with the inclusion of methods to allow part-loading depending on the part-load control mechanisms of the unit under test.

Where reliable part-load performance figures are available, these may be used directly. If only full-load figures are available, estimates of part-load performance can be made using data from the German standard DIN 18599-7 and the general characteristics of the product. If the latter are not known, defaults are used. The weightings assigned to each part-load condition use formulae that give close agreement to the values for the appropriate climate in prEN 14825.

If no performance information is available, default values based on DIN 18599-7 and the general characteristics of the product are used. The DIN full-load EER figures tend to be fairly average in terms of the possible ranges for equipment currently installed thus as default values in the absence of other information are possibly somewhat generous. For the purpose of energy calculations using the approved tools, these defaults have been matched against the Eurovent-Certification bands for the same product category and, subsequently, "de-rated" by one band. The default for subsequent calculations, therefore, assumes the EER is the lower boundary of the band below that corresponding to the DIN default. Not all parameters required by the DIN standard to determine the appropriate product will be known in all cases; thus the possibilities are filtered due to some known input parameters. For the remaining options, the one with the lowest EER is assumed.

Specific points for Room Air Conditioners

Within the EU, Commission Directive 2002/31/EC requires room air conditioners of less than 12kW cooling capacity to be labelled according to the energy efficiency as determined

by EN14511 (i.e., at full-load). Efficiency is banded from A to G, where A is the most efficient, and the bands vary according to the classification by product type[15] (for example splits, single ducts, etc.). In the absence of a rating (for older products, for example), it is assumed, by default, that the product has a full-load EER equivalent to the bottom of the band E range according to 2002/31/EC banding.

Specific points for Chillers

For cooling systems utilising more than one generator, two scenarios are assumed:

- Sequence operation
- Parallel operation

In the sequence operation, it is assumed the first unit in the system runs to meet the cooling demand up to its full capacity. With additional demand, the second and subsequent units are activated sequentially. With this configuration, it can be seen that the first (and other units near the beginning) are likely to operate at full-load for much of the time where there is demand with the last unit running in the sequence at part-load. Since the load on the building is changing, the part-load ratio of individual units is different, with different EERs calculated accordingly.

In the parallel operation, it is assumed all units switch on simultaneously when there is a cooling demand, and each runs at the same part-load ratio to satisfy the building load at that time.

In both scenarios, oversizing is important since even when the building's cooling demand is at a maximum, oversizing will result in the part-load operation of one or more cooling generators depending on the control scenario, and the oversizing will also influence the degree of part-loading of individual units. If the oversizing is unknown, a figure of 20% of the maximum demand may possibly be considered a reasonable assumption based on historic practice.

DIN 18599-7 contains assumed full-load EERs for a variety of air- and water-cooled chillers. The values depend on the characteristics of the unit and include refrigerant and compressor type and, in the case of water-cooled units, the condenser water temperature range.

The Eurovent Certification Program (www.eurovent-certification.com) lists data for various cooling generator products including full-load EERs. Energy bands are also included, not just for <12kW cooling capacity room air conditioners, but also for larger systems, such as chillers. There is currently no mandatory EU labelling scheme for such products but Eurovent has an independent banding scheme in a similar fashion.

In the absence of part-load data, German standard DIN 18599-7 provides various part-load correction factors applied to full-load performance to estimate EER at any loading. These corrections depend on combinations of various factors including:

- Heat rejection medium (air- or water-cooled)
- Compressor type
- Method of part-load control
- System type, for example, single/multi-zone room air conditioners or water chillers

[15] There are proposals to change the basis of this labelling. If these come into force, a revision of the calculation will be necessary.

A.3. Part-load boiler performance

In a similar manner to cooling systems, the calculation algorithms require a seasonal efficiency for boilers as an input for determining the heating energy consumption. The efficiency variation of boilers as a function of part-loading is often less significant than for cooling generators but must still be accounted for.

Testing of low temperature hot water boilers in the EU is carried out according to several Standards (for example, EN 483, EN 303, and others) which include determining efficiencies. Boiler performance has been influenced by Council Directive 92/42/EEC (also referred to as the Boiler Efficiency Directive, BED) whereby minimum allowable full- and part-load (30% load) efficiencies have been specified according to boiler type, such as, condensing or non-condensing, the output heating capacity, and the type of fuel, either liquid or gaseous. In practice, an interim period after its implementation allowed de-stocking by manufacturers, and it is assumed that from 1998 onwards, new boilers were compliant with the efficiency requirements. Solid fuel and biogas boilers were not covered by these efficiency requirements.

In the United Kingdom, the Enhanced Capital Allowances (ECA) scheme (www.eca.gov.uk/etl) provides financial incentives for investment in energy efficient technology whereby the minimum performance requirements are specified on an equipment-specific basis. For boilers, this depends on output capacity, temperature classification, fuel, and whether condensing or non-condensing.

If full- and part-load data is available for the boiler(s) in question according to an appropriate standard, this data may be suitable. Alternatively, knowledge of whether the boiler is compliant with the BED can allow the minimum full- and part-load (30%) efficiencies to be assumed. Although the financial measures in the ECA scheme are not applicable outside the UK, confirmation of the presence of a particular boiler on the scheme allows the minimum efficiency limits at full- and part-load (30%) to be assumed in the absence of actual data.

For heating systems utilising more than one generator, two scenarios are assumed:

- Sequence operation
- Parallel operation

The operating principles and calculations involved are the same as per cooling systems.

A.4. Part-load calculation notes for heating and cooling

The calculation principles for boiler systems are also generally applicable to other heat generators (combustion warm air systems, heat pumps, etc.), but in these cases, defaults for full- and part-loading are not defined, and any figures used must be reliably sourced elsewhere.

The cooling and heating calculation tool allows the input of more than one fuel, for example, a combination of oil- and gas-fired boilers or electrical and absorption chillers. By selecting a different fuel type per unit, calculations yield the SEER/seasonal efficiency on a per fuel basis. This can then be used as an input for bivalent system energy/carbon calculations.

In practice, sequencing systems normally include controls to cycle the operation sequence, including the lead unit, automatically over a fixed time period, for example. This can be approximated manually by conducting a sequence calculation for a whole cooling/heating season and then altering the lead unit/sequence as would be expected in practice and re-calculating until a full rotation has occurred. A mean of the resulting efficiencies can then be used.

A.5. References

Air Conditioners, Liquid Chilling Packages, and Heat Pumps wWith Electrically-Driven Compressors for Space Heating and Cooling – Testing and Rating at Part-Load Conditions. CEN/TC 113. 2008. Draft prEN14825

Air Conditioners, Liquid Chilling Packages, and Heat Pumps with Electrically-Driven Compressors for Space Heating and Cooling. CEN/TC 113. 2007. EN14511

Energy Efficiency of Buildings – Calculation of the Net, Final, and Primary Energy Demand for Heating, Cooling, Ventilation, Domestic Hot Water and Lighting, Part 7: Final Energy Demand of Air Handling and Air Conditioning Systems for Non-Residential Buildings. Deutsches Institut fur Normung. 2005. DIN 18599-7

Efficiency Requirements for New Hot Water Boilers Fired with Liquid or Gaseous Fuels. Official Journal of the European Communities L167 of 22.06.1992, Council Directive 92/42/EEC

Heating Boilers (Various parts and dates), CEN/TC 57, EN303

Gas-Fired Central Heating Boilers – Type C Boilers of Nominal Heat Input Not Exceeding 70kw, CEN/TC 109, 1999 (and Amendment A4:2007), EN483

Volume

2

SBEM Technical Manual version 3.5.a

8. Introduction to the SBEM Technical Manual

8.1. Purpose

The purpose of this volume is to record the detail of the various calculation procedures adopted within SBEM, generally comprising for each:

- The input data required
- The source of each data item
- The assumptions made
- The calculation algorithm(s) used
- The source of those algorithms
- The output data generated
- A commentary on the strengths and weaknesses of the approach adopted

8.2. Audience

The document is intended to be technically detailed, aimed at:

- The SBEM development team, as a reference document
- SEAI[16], as a record of the SBEM project
- Developers of alternative simulation software, and of alternative interfaces
- Interested users of the tool, assumed to be building professionals such as:
    - Architects
    - Service and M&E engineers
    - Energy surveyors
    - Building energy modellers
    - Suppliers of energy-related building components

It is not intended to be required reading for users of the tool. An overview, in the form of a BRE Information Paper[17], is available, but all users are expected to read and refer to the iSBEM User Guide - Republic of Ireland Volume[18] if using iSBEM as the interface. That Guide contains all the information on the functioning of SBEM needed to operate the tool effectively.

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[16] Sustainable Energy Authority of Ireland http://www.seai.ie.
[17] IP 2/07: *SBEM for non-domestic buildings*
[18] Available for download from http://www.seai.ie/Your_Building/BER/Non_Domestic_Buildings/SBEM_Software_Download/.

9. Background

Having established the generalised content of the Non-domestic Energy Assessment Procedure (NEAP), SEAI sought software implementations of it. In particular, they required software which would handle the majority of buildings and could be made available free to users. They commissioned BRE to adapt for the Republic of Ireland the national calculation tool which BRE developed for the UK's Department for Communities and Local Government (CLG), under a contract managed for CLG by AECOM (formerly Faber Maunsell), to fulfil a similar role.

This tool has been developed into SBEM (Simplified Building Energy Model) by BRE as the default calculation for non-domestic buildings in the Republic of Ireland, to enable building regulations compliance checks and energy ratings to be carried out on a consistent basis.

It comprises several modules, some of which are common with other commercial software tools for consistency:

- SBEM, the core calculation engine
- iSBEM, an interface based on Microsoft Access®.
- BRIRL, the building regulations compliance checking module
- BERgen, the Building Energy Rating (BER) certificate (and advisory report) generator
- Standardised databases
- Standardised report format

This manual describes the basis of the calculation engine. Wherever possible, this has been based on European standards.

10. European standards (CEN) used by SBEM

The CEN umbrella document, *Standards supporting the Energy Performance of Buildings Directive (EPBD),* PG-N37, provides an outline of a calculation procedure for assessing the energy performance of buildings. It includes a list of some thirty European standards[19] both existing and those that are to be written, which together form a calculation methodology.

Although the Republic of Ireland is not bound to use these standards, except where applicable in public procurement, government policy is to adopt them generally. SBEM follows them as far as is practicable.

10.1. Summary of all CEN standards used by SBEM

PG-N37 Standards supporting the Energy Performance of Buildings Directive

EN 15193-1 Energy requirements for lighting – Part 1: Lighting energy estimation

EN 15217 Methods of expressing energy performance and for energy certification of buildings

EN 15243 Ventilation for buildings – Calculation of room temperatures and of load and energy for buildings with room conditioning systems

EN ISO 13786:2005 Review of standards dealing with calculation of heat transmission in buildings – Thermal performance of building components – Dynamic thermal characteristics – Calculation methods

EN ISO 13789 Review of standards dealing with calculation of heat transmission in buildings – Thermal performance of buildings –Transmission and ventilation heat transfer coefficients – Calculation methods

EN ISO 13790 Energy performance of buildings – Calculation of energy use for space heating and cooling

EN 15316-3 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – part 3 Domestic hot water systems

[19] Published standards can be obtained online from the British Standards Institution at http://www.bsonline.bsi-global.com/server/index.jsp.

11. The Calculation Process

11.1. Calculation overview

SBEM takes inputs from the software user and various databases, and by calculation, produces a result in terms of the annual primary energy consumption and CO_2 emissions resulting from the energy used by the building and its occupants. Some of the inputs are standardised to allow consistent comparisons for building regulation and energy rating purposes in new and existing buildings.

SBEM calculates the energy demands of each space in the building according to the activity within it. Different activities may have different temperatures, operating periods, lighting levels, etc. SBEM calculates the heating and cooling energy demands by carrying out an energy balance based on monthly average weather conditions. This is combined with information about system efficiencies in order to determine the energy consumption. The energy used for lighting and hot water is also calculated.

Once the data has been input using iSBEM, the SBEM calculation engine:

1. calculates lighting energy requirements on a standardised basis, which takes into account the glazing area, shading, light source, and lighting control systems.
2. establishes the standardised heat and moisture gains in each activity area, from the database.
3. calculates the heat energy flows between each activity area and the outside environment, where they are adjacent to each other, using CEN standard algorithms.
4. applies appropriate HVAC system efficiencies to determine the delivered energy requirements to maintain thermal conditions.
5. aggregates the delivered energy by source, and converts it into the equivalent primary energy consumption and CO_2 emissions.
6. determines, on the same basis, the primary energy consumption and CO_2 emissions of a reference building with the same geometry, usage, heat gains, temperature, illuminance requirements, ventilation conditions, and weather but with set specifications for building component construction, HVAC, and lighting systems.
7. determines, on the same basis, the primary energy consumption and CO_2 emissions of a notional building which is similar to the reference building but with fixed ventilation and cooling conditions and space and water heating fuel.

The primary energy and CO_2 emissions results of the actual and reference buildings are then handed over to the compliance checking module, BRIRL, to complete the assessment. BRIRL:

1. calculates the Energy Performance Coefficient (EPC) of the actual building as the ratio of the primary energy consumption of the actual building to that of the reference building, and compares it with the Maximum Permitted Energy Performance Coefficient (MPEPC).
2. calculates the Carbon Performance Coefficient (CPC) of the actual building as the ratio of the CO_2 emissions of the actual building to those of the reference building, and compares it with the Maximum Permitted Carbon Performance Coefficient (MPCPC).
3. undertakes a compliance check on certain fabric and building services parameters drawn from information input using iSBEM.

Reports are then prepared to the standard format to provide:

1. comparison of the EPC with the MPEPC and the CPC with the MPCPC.

2. confirmation of the elemental compliance check

The primary energy and CO_2 emissions results of the actual and notional buildings are also handed over to the Building Energy Rating certificate module, BERgen, to provide energy rating certification. BERgen:

1. calculates the Building Energy Rating (BER) of the actual building as the ratio of the primary energy consumption of the actual building to that of the notional building, and converts it into an energy grade on an A-G scale.
2. calculates the CO_2 Emissions Indicator of the actual building as the ratio of the CO_2 emissions of the actual building to those of the notional building.

Reports then are prepared to the standard format to provide:

1. a certificate showing the BER, energy grade, and CO_2 Emissions Indicator of the actual building.
2. an advisory report setting out recommendations for cost-effective improvements to the energy performance of the actual building.

Intermediate results produced by SBEM are available, in electronic format, to assist any diagnostic checks on the proposed building:

1. data reflection (to confirm entry associated with results).
2. monthly profiles of energy use by each end use and fuel type.
3. total electricity and fossil fuel use, and resulting carbon dioxide emissions.

11.2. Inputs and information sources

The inputs to the energy calculation include:

- physical configuration of the different areas of the building (geometry)
- internal conditions to be maintained in each activity zone (area in which identifiable, standardised activities take place)
- external conditions
- factors affecting fabric and ventilation heat losses, including insulation levels, airtightness, deliberate natural ventilation, and the geometry of the building
- expected heat gains which are determined by the occupancy pattern, installed equipment (including lighting and IT), and solar heat gains which will depend on glazing areas, thermal mass, geometry, and orientation
- information about the heating, cooling, lighting, and other building services systems

The input module iSBEM acts as the interface between the user and the SBEM calculation. As far as possible, the user is guided towards appropriate databases, and then the input is formatted so that data is presented correctly to the calculation engine and compliance checking module.

The steps involved in the input are as follows:

- User defines the activities taking place and inputs the areas they occupy in the proposed/actual building.
- Conditions in each of those areas are determined from a standard database.
- Durations of those conditions in each activity area are established from the database.
- User inputs the areas and constructions of the building components surrounding each activity area.
- User selects, from the standard database, a set of weather data relevant to the building location.

- User selects HVAC and lighting systems and their control systems, and indicates which activity areas they serve.
- Provided that supporting evidence is available, the user is enabled to over-write default assumptions for construction and building services parameters.
- Finally, the interface enables the user to see reports on the primary energy and CO_2 emissions comparisons and compliance check undertaken by the BRIRL module and/or the BER and energy grade determined by the BERgen module.

Hence, the user interacts with the interface module, iSBEM, and sets up a model of the building by describing its size, how it is used, how it is constructed, and how it is serviced. After the calculations are performed, the results and output reports become accessible through the interface.

When the calculation is used for building regulations compliance checking or building energy rating certificate purposes, the software should draw information from the sources described below.

11.2.1. User input

The user identifies the zones suitable for the analysis, according to the zoning rules (see Section 11.4.1) by examining the building and/or its drawings. The user describes the geometry of the building, i.e., areas, orientation, etc. of the building envelopes and zones, using location plans, architectural drawings, and, if necessary, measurements on site.

11.2.2. Accessible databases

By interacting with the software interface, the user can access databases for standardised construction details and for accepted performance data for heating, ventilation, and air conditioning systems. These databases are ‘accessible’ in that the user can override some default parameters by supplying their own data.

Hence, the user provides the software with the U-value and thermal mass for the building elements, the HVAC systems efficiencies, and lighting data and controls by either selecting from the internal databases, using the ‘inference’ procedures, or inputting parameters directly (see Sections 11.3.2 and 11.3.3).

11.2.3. Locked databases

SBEM also draws information from some ‘locked’ databases on activity parameters and weather data. These databases are ‘locked’ because the user cannot alter their parameters as they need to be the same for similar buildings to allow fair and consistent comparison.

Hence, the selection of occupancy conditions and profiles for spaces with different activities come from a database inside the software determined by the user-selected building type and zonal activity (see Section 11.3.1). The external conditions come from the internal weather database determined by the user-selected location (see Section 11.3.4).

11.3. Databases

11.3.1. Activities

11.3.1.1. Overview of the Activity Database – purpose and contents

The NEAP requires the activity definitions for a building to be defined by selecting from a set of standardised activities. For this purpose, an Activity database has been prepared, and is available from SEAI's website. The database contains a comprehensive list of building types (see Table 15 for the full list), and the space types that might exist in each one (see Table 16 for the full list). Each building type has a selection of the 64 activity types to choose from.

The NEAP divides each building up into a series of zones (following the zoning rules), each of which may have different internal conditions or durations of operation. This enables the calculation to be more analytical about the energy consumption of a mix of uses in a particular building, rather than relying on a generic type such as "office" or "school". For instance, an "office" may mean anything between a set of cellular offices, meeting rooms, and circulation spaces that are only occupied during the normal working day, and a dedicated 24 hour call centre. The approach of setting up multiple activity areas allows such buildings to be defined more correctly.

In order to achieve consistency in comparisons between similar buildings, which may be used in different actual operating patterns, a number of parameters for the activity areas are fixed for each activity and building type rather than left to the discretion of users. These are:

- Heating and cooling temperature and humidity set-points
- Lighting standards
- Ventilation standards
- Occupation densities and associated internal gains
- Gains from equipment
- Internal moisture gains in the case of swimming pools and kitchens
- Duration when these set-points, standards, occupation densities, and gains are to be maintained
- Set-back conditions for when they are not maintained
- Hot water demand

The data are drawn from respected sources, such as CIBSE recommendations, supplemented and modified where necessary to cover activity areas not listed in such sources.

Users should bear in mind that these data are used by the calculations for both proposed (actual), reference, and notional buildings, as with the choice of weather location. The need is to ensure that comparisons with the reference and other buildings are made on a standardised, consistent basis. For this reason, the energy and CO_2 emission calculations should not be regarded as predictions for the building in actual use.

Details of the parameters and schedules included in the database along with details on how they are used to calculate the values needed for SBEM, or any other energy simulation software, are described below.

1	AIRPORT TERMINALS
2	BUS STATION/TRAIN STATION/SEAPORT TERMINAL
3	COMMUNITY/DAY CENTRE
4	CROWN AND COUNTY COURTS

5	DWELLING
6	EMERGENCY SERVICES
7	FURTHER EDUCATION UNIVERSITIES
8	HOSPITAL
9	HOTEL
10	INDUSTRIAL PROCESS BUILDING
11	LAUNDRETTE
12	LIBRARIES/MUSEUMS/GALLERIES
13	MISCELLANEOUS 24HR ACTIVITIES
14	NURSING RESIDENTIAL HOMES AND HOSTELS
15	OFFICE
16	PRIMARY HEALTH CARE BUILDINGS
17	PRIMARY SCHOOL
18	PRISONS
19	RESTAURANT/PUBLIC HOUSE
20	RETAIL
21	RETAIL WAREHOUSES
22	SECONDARY SCHOOL
23	SOCIAL CLUBS
24	SPORTS CENTRE/LEISURE CENTRE
25	SPORTS GROUND ARENA
26	TELEPHONE EXCHANGES
27	THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA
28	WAREHOUSE AND STORAGE
29	WORKSHOPS/MAINTENANCE DEPOT

Table 15: List of building types

1	A&E consulting/ treatment/work areas	For all A&E consulting/treatment/work areas, occupied and conditioned 24 hours a day.
2	Baggage Reclaim area	The area within an airport where baggage is reclaimed from conveyor belts.
3	Bathroom	An area specifically used for bathing/washing, generally for individual use. Contains a bath and/or shower and usually a basin and toilet. For areas with washing facilities/showers designed for use by a number of people use "changing facilities".
4	Bedroom	An area primarily used for sleep.
5	Cell (police/prison)	A room which accommodates one or more prisoners.
6	Cellular office	Enclosed office space, commonly of low density.
7	Changing facilities	An area used for changing, containing showers. This activity should be assigned to the shower area and all associated changing areas. For areas which can be used to for changing but which do not contain showers, such as a cloak room/locker room, refer to the common room/staff room/lounge category.
8	Check in area	Area within an airport where travellers check in for their flight, containing check in desks and conveyer belt.
9	Circulation area	For all circulation areas such as corridors and stairways.
10	Circulation area- non public	For all non-public corridors and stairways.
11	Classroom	All teaching areas other than for practical classes, for which refer "Workshop - small scale".
12	Common circulation areas	For all common circulation areas such as corridors and stairways.
13	Common room/staff room/lounge	An area for meeting in a non work capacity. May contain some hot drink facilities.
14	Consulting/treatment areas	For all clinic consulting, interview, examination, and treatment areas.
15	Data Centre	For data centres such as a web hosting facilities, with 24hr high internal gains from equipment and transient occupancy. For an area with 24hrs low-medium gains from equipment, use the 'IT Equipment' activity in the 'Miscellaneous 24hr activities' building type. For activities with internal gains from equipment which are not 24 hr, choose 'IT equipment' or an office based activity from the appropriate building type.
16	Diagnostic Imaging	For areas which contain diagnostic imaging equipment (such as MRI and CT scanners,

		Bone Mineral Densitometry, Angiography, Mammography, PET, General Imaging, Linear Accelerator, Ultrasound). This category should be used for any associated plant areas where people work.
17	Display area	An area where display lighting is used to illuminate items.
18	Dry sports hall	An area where indoor sports can be played.
19	Eating/drinking area	An area specifically designed for eating and drinking. For areas where food and drink may be consumed but where this is not the specific function of the area, use “common/staff room” and for areas with transient occupancy, use “tea making”.
20	Fitness Studio	An area used for exercising/dance, usually with high person density but with no machines.
21	Fitness suite/gym	An area used for exercise containing machines.
22	Food preparation area	An area where food is prepared.
23	Hall/lecture theatre/assembly area	An area which can accommodate a large number of seated people.
24	High density IT work space	High density desk based work space with correspondingly dense IT.
25	Hydrotherapy pool hall	The area in which the hydrotherapy pool is contained.
26	Ice rink	An area which contains an ice rink.
27	Industrial process area	An area for practical work on a large scale, involving large machinery.
28	Intensive care/high dependency	For all intensive care and high dependency wards such as baby care.
29	IT equipment	An area dedicated to IT equipment such as a printers, faxes and copiers with transient occupancy (not 24 hrs). For areas which have 24 hr gains from equipment select from the 'Miscellaneous 24 Hr Activities' building type either IT Equipment (low-medium gains) or Data Centre (high gains). For areas with IT equipment and desk based staff, use one of the office activities.
30	Laboratory	A facility that provides controlled conditions in which scientific research, experiments, and measurement may be performed.
31	Laundry	An area used only for washing and/or drying clothes using washing machines and/or tumble dryers. This is not for where there is an individual washing machine within another space (e.g. a food preparation area).
32	Meeting room	An area specifically used for people to have meetings, not for everyday desk working. For everyday desk working areas refer to the appropriate office category.
33	Open plan office	Shared office space commonly of higher density than a cellular office.
34	Operating theatre	For the operating theatre suite, including anaesthetic, scrub & preparation rooms.
35	Patient accommodation (Day)	For all areas containing beds which accommodate (during the day only - not overnight) either single or multiple patients except for intensive care and high dependency wards. For overnight accommodation, see WardPatients.
36	Patient accommodation (wards)	For all areas containing beds which accommodate (overnight) either single or multiple patients except for intensive care and high dependency wards.
37	Performance area (stage)	For stages with dedicated lighting and equipment in addition to that within the remainder of the space. For stages within other activity areas which do not have specific lighting or additional electrical equipment, do not define these as separate spaces.
38	Physiotherapy Studio	For all physiotherapy areas, e.g., Fitness Suite/Gym, activity area, Cardiac stress test area.
39	Plant room	Areas containing the main HVAC equipment for the building e.g.: boilers/air conditioning plant.
40	Post Mortem Facility	Post-Mortem Facility (including Observation room and body preparation area)
41	Public circulation areas	All areas where passengers are walking/sitting which are not covered by the other space types. This includes departure lounge, corridors, stairways and gate lounges. For non public spaces use "Circulation areas (corridors and stairways)- non public areas"
42	Reception	The area in a building which is used for entry from the outside or other building storeys.
43	Sales area - chilled	A sales area designed to accommodate a considerable quantity of fridges/freezers such as a supermarket or food hall.
44	Sales area - electrical	Sales areas designed to accommodate considerable electrical equipment loads such as lighting sales areas and IT/TV/Hi-fi sales areas.
45	Sales area - general	All Sales areas which do not have a large concentration of fridges/freezers or electrical appliances.
46	Security check area	For the security areas of an airport containing equipment such as X-ray machines.
47	Speculative industrial space	Speculative industrial space
48	Speculative office space	For speculative office space
49	Speculative retail space	For speculative retail spaces
50	Storage area	Areas for un-chilled storage with low transient occupancy.
51	Storage area - chilled	A storage area containing items which need to be chilled. The area itself can be conditioned.
52	Storage area - cold room (<0degC)	A storage area kept at below 0degC. Cooling load is assumed to be a process load and therefore not included in the calculation.
53	Swimming pool	The area in which a swimming pool is contained. This activity should be used for the whole pool hall.

54	Tea making	Areas used for making hot drinks, often containing a refrigerator with transient occupancy. For larger areas containing seating and a small hot drinks making area refer to "Common room/staff room".
55	Toilet	Any toilet areas. If toilets are subsidiary to changing/shower activities refer to "changing facilities"
56	Waiting room	A waiting area with seating.
57	Ward common room/staff room/lounge	An area for meeting in a non work capacity which may be occupied 7 days a week. This category can be used for patient/relative day rooms and lounges as well as staff rooms and common rooms.
58	Ward offices	For all ward office areas and any other offices which may be occupied 7 days a week.
59	Warehouse sales area - chilled	All warehouse sized sales areas designed to accommodate a considerable quantity of fridges/freezers such as a hypermarket.
60	Warehouse sales area – electrical	All warehouse sized sales areas designed to accommodate considerable electrical equipment loads such as IT sales.
61	Warehouse sales area - general	All warehouse sized sales area which do not contain a large concentration of freezers/fridges or electrical appliances.
62	Warehouse storage	Large (warehouse sized) storage areas (unchilled).
63	Warehouse storage - chilled	Large (warehouse sized) storage area containing items which need to be chilled. The area itself can be conditioned.
64	Workshop - small scale	An area for sedentary-light practical work. Often containing some machinery.

Table 16: List of Activity areas with definitions (in some cases the definition will change slightly depending on building type)

11.3.1.2. Occupation densities and associated internal gains

An occupancy density, metabolic rate, and schedule of occupancy are used to calculate the internal heat gains from people. The percentage of the metabolic gains which are sensible rather than latent (released as moisture) is also taken into account.

11.3.1.3. Heating and cooling set-points and set-back temperatures

The heating and cooling set-points define the conditions which the selected HVAC system will be assumed to maintain for the period defined by the heating and cooling schedules. For the unoccupied period, the system will be assumed to maintain the space at the set-back temperature defined in the database.

11.3.1.4. Lighting standards

The database contains the illuminance levels (in lux) which need to be maintained in each activity area for the period defined by the lighting schedules. This level of illumination is then provided by the lighting system selected by the user. In addition to general lighting, some activities are assumed to have display lighting. The lux levels, along with the user selected lighting system are used to calculate the heat gains from lighting.

11.3.1.5. Ventilation requirements

The database contains the required fresh air rate for each activity for the occupied period. This value is used along with the occupancy (as described below) to calculate the quantity of ambient air which then needs to be heated or cooled to the required heating or cooling set-point. Whether or not the activity will include high pressure filtration is also defined in the database (such as commercial kitchens and hospital operating theatres).

11.3.1.6. <u>Heat gains from equipment</u>

Following a similar procedure as for calculating heat gains from people and lighting, the database calculates the expected heat gains from equipment for each activity based on the Watts per square meter and schedules of activity.

11.3.1.7. <u>Humidity requirements</u>

The database contains the maximum and minimum humidity requirements for each activity. This information is for dynamic simulation models.

11.3.1.8. <u>Hot Water requirements</u>

A hot water demand is defined for all occupied spaces. The hot water demand is associated with the occupied spaces rather than the spaces where the hot water is accessed, i.e., there is a demand for hot water associated with an office rather than a toilet or tea room.

11.3.2. Constructions

The SBEM user can specify the U-value and thermal mass information for a particular wall, window, roof, or floor for which the construction is accurately known. Where the construction is less precisely known, the SBEM user can make use of SBEM's construction and glazing databases. These databases contain a library of constructions covering different regulation periods and different generic types of construction.

The user may access a particular construction directly from the library by selecting first the generic type of construction and then selecting the particular construction which appears to match most closely the actual construction. Once the user has selected the construction, the database provides a U-value and thermal mass and, in the case of glazing, solar factors, and these values are then fed directly into the SBEM calculation.

For cases where the SBEM user has only minimal information, SBEM has an inference procedure. When using the inference procedure, the user supplies basic data such as the sector (building use), the building regulations that were in use at the time of construction, and a description of the generic type of construction. SBEM will then select the type of construction which most closely matches the description selected in the inference and will use this construction as the basis for the U-value and thermal mass value that are to be used in the calculation.

11.3.3. HVAC system efficiencies

11.3.3.1. <u>Definitions</u>

The definition of “system efficiency” for HVAC systems is less straightforward than appears at first sight, because of the difficulty of attributing energy for fans, pumps, and controls to the different end-uses (heating, cooling, and ventilation). The EPBD standards resolve this by separating the energy associated with these, mainly transport, components from the losses associated with the generation of heating or cooling from fuels or electricity. The energy associated with fans, pumps, and controls is treated as a separate item denoted as “auxiliary energy”. The consequent definitions for system heating and cooling efficiencies then become more straightforward - but are now different from the more familiar meanings that include the auxiliary energy.

“Auxiliary Energy”: is the energy used by the fans, pumps, and controls of a system, irrespective of whether this supports heating, cooling, or ventilation.

For heating, the “System Seasonal Efficiency for heating”, SSEff, is the ratio of the total heating demand in spaces served by an HVAC system divided by the energy input into the heat generator(s) - typically boilers. It takes account of, for example, the efficiency of the heat generator, thermal losses from pipework and ductwork, and duct leakage. It does not include energy used by fans and pumps

For cooling, the “System Seasonal Energy Efficiency Ratio”, SSEER, is the ratio of the total cooling demand in spaces served by a system divided by the energy input into the cold generator(s) - typically chillers. It takes account of, for example, the efficiency of the cold generator, thermal gains to pipework and ductwork, and duct leakage. It does not include energy used by fans and pumps. Since many cooling demand calculations only estimate sensible cooling, the definition may be extended to include allowances for deliberate or inadvertent latent loads.

As the demand calculations are carried out monthly, the HVAC system calculations have to be on a similar basis, i.e., explicit hourly (or more frequent) calculation would be incompatible. As a result, we need to calculate values for the three system efficiency parameters for each month.

11.3.3.2. Scope

The calculation of energy consumed by HVAC systems obviously starts with the outputs of the heating and cooling demand calculations. These produce monthly values of heating demand and sensible cooling demand for each space. These demand calculations are for idealised conditions, i.e., perfect temperature controls, uniform air temperatures, etc., so the scope of the term “HVAC system” has to be sufficiently broad to encompass some factors that relate to the spaces themselves.

EN 15243[20] is the EPBD standard that deals with the calculation of HVAC system efficiencies. It contains a number of informative annexes that illustrate different approaches, but it does not prescribe specific calculation procedures. It permits the HVAC system performance to be calculated either monthly or hourly.

The standard identifies nearly 40 mechanisms that can affect the relationship between the cooling or heating demand of a building and the energy used by an HVAC system in meeting that demand. (Heating-only systems are covered by the various parts of EN 13790. EN 15243 reflects the scope of EN 13790 where the two standards overlap. Some parts of EN 13790 require levels of detailed information that are impractical for SBEM. In these cases, simplified options addressing the same mechanisms have been used).

In EN 15243, the mechanisms are mapped against 20 or so types of HVAC systems to show which mechanisms may apply to which system types. Any compliant calculation procedure is required to declare which system types it claims to cover, and how it addresses each of the applicable mechanisms. The standard does not prescribe how each mechanism should be handled (although there are “informative” suggestions). SBEM includes all the mechanisms that were in the draft standard at the time SBEM was being developed.

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

11.3.3.3. Determination of system performance parameters from the mechanisms

The basic energy flow diagram of the HVAC calculation in SBEM is shown below in Figure 2. The basic philosophy is to provide a consistent set of parameters that address all the mechanisms in EN 15243. The energy flow diagram is simplified in that some of the parameters are relatively aggregated - for example, heat pickup in chilled water distribution pipework is expressed as a percentage of the cooling energy flow handled.

Putting reliable values to each mechanism for any given system would be extremely difficult, unreliable, and difficult to check, especially for existing systems. SBEM offers the user a range of system types – the system choice sets standard values for most of the mechanisms. The user is required to input (or accept a default value for) specific fan power, heat or cold generator efficiency, duct leakage, and fuel. Corrections are then applied to the standard system performance parameters.

At present, system performance parameters and the correction routines are calculated outside SBEM and inserted into look-up tables in SBEM. Internalising the calculation and providing the user with access to more of the mechanism values is a high-priority future upgrade.

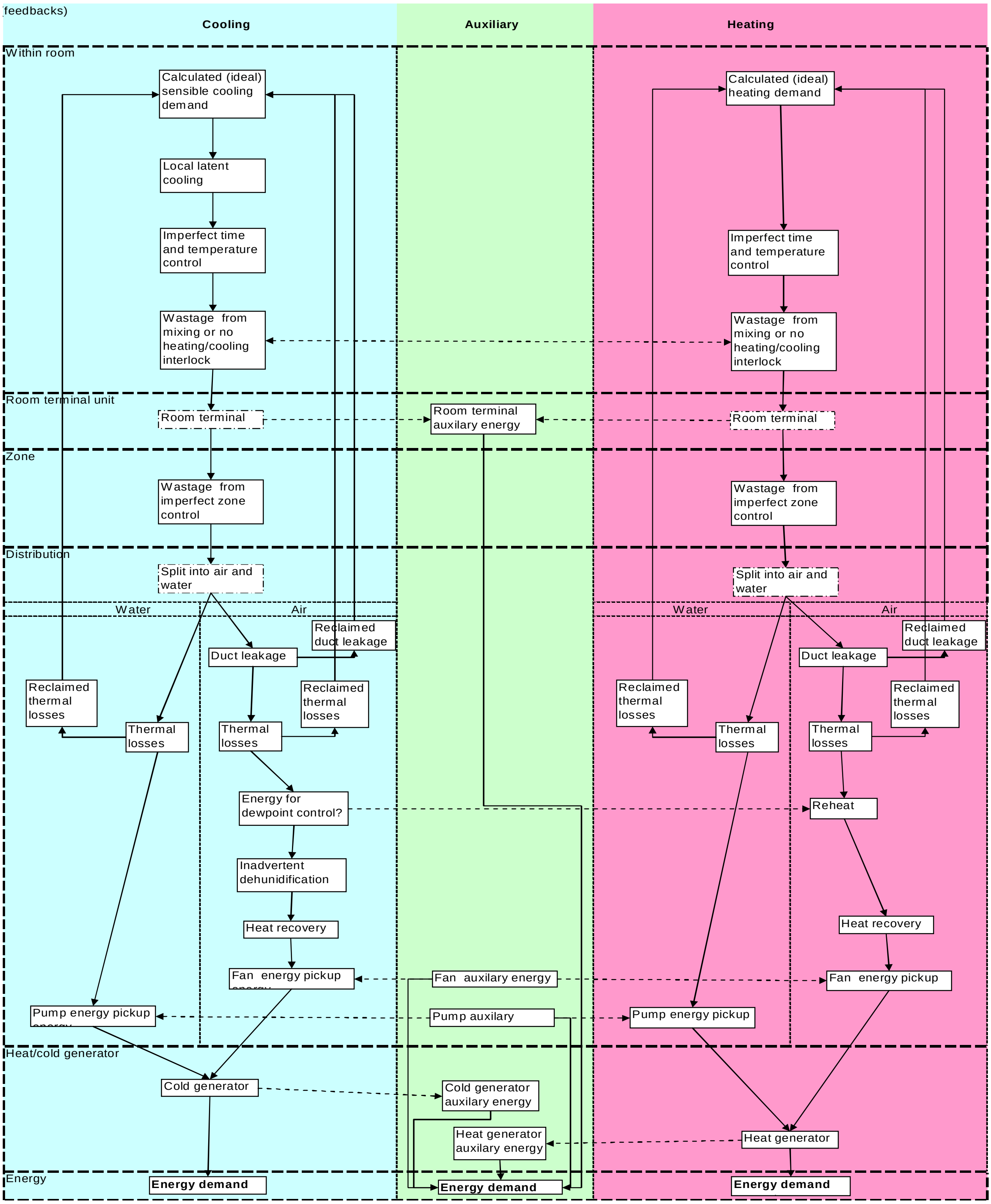

Figure 2: Basic energy flow diagram of the HVAC calculation in SBEM

11.3.3.4. The Mechanisms

The tables below, Table 17 and Table 18, list the mechanisms and summarise key points about them. Table 19 contains a complete parameter list.

HVAC parameters used in SBEM					
Note: this is a subset of the longer list in Table 5a of prEN 15243. It omits, for example, change-over wastage for 2 pipe FCU *Note:some values are arbitrary but the overall impact of all assumptions is consistent with simulation results.*					
Parameter	**Purpose**	**Source of information**	**Likely range**	**Comment**	**User Access**
Controls factor	Allows for presence or absence of time controls, metering and monitoring	ADL2A:	0.9 to 1		Separate input to iSBEM
Terminal auxiliary power parameter	Electricity demand by terminal units	TM32	0.001 to 0.005	Depends on HVAC system type and design	Currently fixed for given system type, possible to provide access in future
Local latent load	Additional demand to sensible load to allow for (local) coils sometimes operating below dewpoint.	Sensible heat ratio values in manufacturers catalogues	0 to 0.25	Depends on HVAC system type and design	Currently fixed for given system type, possible to provide access in future
Terminal Auxiliary pickup factor	Factor for the proportion of terminal fan energy that contributes to cooling load.	Cautious assumption that all fan energy contributes	0 to 1	Depends on terminal design	Currently fixed for given system type, possible to provide access in future
Allowance for imperfect local control (cooling)	Factor added to cooling demand to account for imperfect local time or temperature control	Somewhat arbitrary figures based on CEN draft prEN 15232	0 to 0.02	Depends on control sensor and system performance	Currently fixed for given system type, difficult to find meaningful values that relate to identifiable characteristics
Extra cooling load from mixing reheat etc	Factor added to both cooling and heating demands to account for some systems intentionally (and others through imperfect interlocks) allowing simultaneous heating and cooling	Mixture of factors used by NEN2916 and results of TAS and DOE2 simulations	0 to 0.4	Depends on HVAC system type and design	Currently fixed for given system type, possible to provide access in future
Extra load from imperfect zoning (cooling)	Factor added to demands for systems serving more than one space without local temperature control.	Arbitrary figure (0.05) but not applied to individual room systems.	0 to 0.2	Depends on controls zoning	Effect of different operating periods is picked up automatically from activity databases
Proportion of cooling load handled by air sub-system	Indirectly affects energy performance via assumed fan and pump power, pipe and duct heat gains and duct leakage	Obvious for all-air or all-water systems, otherwise somewhat arbitrary assumption	0 to 1	Depends on system design	Currently fixed for given system type, possible to provide access in future
Duct leakage	Factor added to air quantities. (Implicitly assuming that commissioining will result in correct airflows to spaces!).	Classes for duct and AHU leakage in prEN 15242	0 to 0.3	Depends on extent and quality of ductwork	User selection in iSBEM
Reclaimed leakage losses	Factor to allow for some of the leaked air being useful:	Cautious assumption that nothing is usefully recovered	0 to 1	Depends on location of ductwork	Currently fixed, possible to provide access in future
Duct heat pickup	Factor to allow for effect of heat transfer through duct walls	Based on Dutch standard NEN2916 and other sources	0 to 0.1	Depends on extent and insulation of ductwork	Currently fixed, possible to provide access in future
Reclaimed cold losses (cold ducts)	Factor to allow for some of the lost coolth being useful	Cautious assumption that nothing is usefully recovered	0 to 1	Depends on location of ductwork	Currently fixed, possible to provide access in future
Central latent load	Addition to sensible cooling for systems with central cooling coils.	Based on example calculations in textbooks (assumes no intentional moisture control)	0 to 0.5?	Depends on HVAC system type and design	Currently fixed for given system type, possible to provide access in future
Reheat energy	Factor added to heating demand for systems with dewpoint control	No dewpoint control assumed	0 to 0.5?	Depends on HVAC system type and design	Currently fixed, possible to provide access in future

Table 17: Mechanisms and key points

Mechanism	SBEM process
Within-room mechanisms	
Room heat balance and temperature	Monthly calculation in accordance with EN 13790
Room moisture balance and moisture content	Not addressed
Control and Zoning Issues	
Definition of zones and ability to combine room demands into zonal demands	Explicit definition of zones and ability to combine spaces into zones served by each system
Combination of room conditions into zonal return air state	Perfect mixing assumed
Contribution to room demands from separate ventilation / base cooling system	Choice of HVAC system type sets proportion of load met by sub-systems when appropriate
Contribution to room demands from heat gains or losses from pipes and ducts	Taken as zero
Impact of proportional band on energy supplied	Not explicitly included but fixed factor for imperfect control
Impact of dead band on energy supplied	Not explicitly included but fixed factor for imperfect control
Effect of open-loop control or averaging of sensors	Fixed factor when there is more than one zone.
Effect of absence of interlock between heating and cooling	For new buildings, presence is assumed. For existing buildings a fixed penalty is applied
Distribution: terminal issues	
Energy penalties from hot/cold mixing or reheat systems	Proportional penalty according to system type
Terminal auxiliary energy.	Proportional to heat demand for unit heaters, fixed default in other cases
Effect of sensible heat ratio of terminal *(and risk of condensation)*	Fixed sensible heat ratio.
Lack of local time control	For new buildings, presence is assumed. For existing buildings a fixed penalty is applied
Heat gains and losses from pipes and ducts *Includes AHUs and other air-handling components*	Fixed percentage loss assumed with no useful contribution to loads
Duct system air leakage *Includes AHUs and other air-handling components*	User selects class of leakage
Refrigerant pipework heat losses	Ignored
Fan and pump energy pickup	Fixed proportion of fan or pump energy
Heat recovery provision	User selects from list of options
Distribution systems: operation	
Latent demand calculation at central (zonal) plant *(includes dewpoint control plus reheat)*	Fixed sensible heat ratio.
Adiabatic spray cooling	Not included
Additional demands produced by hot deck:cold deck mixing systems	Proportional penalty
Impact of mixing of return water temperature in 3-pipe systems	Ignored
Wastage due to changeover in 2-pipe systems	Ignored
Impact of variable ventilation air recirculation *Typically CO2 controlled – total air flow unchanged*	Not included explicitly but possible to approximate in input parameters
Impact of air-side free cooling	Provided as an option
Distribution systems: auxiliary energy	
Auxiliary energy use by fans and pumps (other than in terminals)	Calculated according to system type, hours of use and (for fans) SFP
Cold and Heat Generation	
Cold generator (chiller) part-load performance (including multiple installations)	Calculated externally and provided to software
Water-side free-cooling	Can be included in external calculation of seasonal performance
Thermosyphon operation	May in principle be included in external calculation of seasonal performance
Impact on chiller performance of central heat rejection equipment *Includes cooling towers, dry coolers etc. Included in overall performance of packaged systems*	May in principle be included in external calculation of seasonal performance
Auxiliary energy use by central heat rejection equipment *Included in overall performance of packaged systems*	For air-cooled equipment, included in calculation of seasonal performance. For water –cooled, fixed proportional penalty is added
Heat generator (boiler) part-load performance. (including multiple installations)	Calculated externally and provided to software
Auxiliary energy use by heat generators *Includes gas boosters, fuel pumps, etc. Included in overall performance of packaged systems*	Not included
Energy use for humidification	Not included
Bivalent systems *Includes boiler + CHP, condensing boiler + non-condensing boiler, heat pump + top-up, evaporative cooling + chiller......*	Not included explicitly but possible to approximate in input parameters

Table 18: Summary of how SBEM deals with the HVAC mechanisms identified in EN 15243

	Cooling Demand	Cooling Demand	Intermediate calculation	Auxiliary	Intermediate calculation	Cooling Demand	Cooling Demand and heating demand	Cooling Demand	Cooling Demand	Cooling Demand	
Parameter	**Peak cooling demand**	**Equivalent full load cooling hours**	**Room cooling demand**	**Terminal auxiliary power parameter**	**Terminal auxiliary energy**	**Local latent load**	**Terminal Auxiliary pickup factor**	**Allowance for imperfect local control**	**Extra cooling load from mixing reheat etc**	**Extra load from imperfect zoning**	
Description					Fans for FCUs for example	Coils may operate below dewpoint, generating extra demand	Fans etc contribute to load: picked up as extra cooling load and reduction in heating load pro-rata to consumptions	Imperfect time or temperature control will cause extra consumption	Hot/cold mixing systems, 3-pipe systems, imperfect interlock with heating, terminal reheat all add cooling load	Different spaces may have different needs - imperfect time or temperature control will cause extra consumption	
Application	Base for calculation	Base for calculation				Factor applied to room cooling demand - but be careful with the algebra	factor applied toenergy use	Factor applied to room cooling demand	Add equal amount to heating demand	Factor	
Units	Kw/m2	hours pa	kWhpa/m2	kW/kW	kWhpa/kWhpa cooling	dimensionless		dimensionless	kWhpa/m2	dimensionless	
Comment	Building dependent. Expressed per unit floor area	Building dependent	Building dependent. Expressed per unit floor area	System dependent	System dependent	System dependent		Control and load dependent	system dependent	Building and sytem dependent	
	Cooling-air and w	Cooling-air	Cooling-air	Cooling-air	Cooling-air	Cooling-air	Heating-water	Cooling-air	Auxiliary	Cooling-air	
Parameter	**Proportion of load handled by air sub-system**	**Duct leakage**	**Reclaimed leakage losses**	**Duct heat pickup**	**Reclaimed cold losses**	**Central latent load**	**Reheat energy**	**Heat recovery or economiser**	**Specific fan power**	**Fan energy pickup factor**	
Description	Can vary from all-air to no air	Can be substantial	Some of the lost coolth may be useful	Heat transfer through duct walls	Some of the lost coolth may be useful	May be inadvertent operation below dewpoint or humidity control	For dewpoint control	Airside free cooling or heat recovery wheel (etc) can reduce net loads	Used to determine fan energy. *Both supply and extract*	Most of fan energy is transferred to air as heat gain	
Application	factor	Leakage factor - think about the algebra when applying!	factor applied to the duct loss figure	factor	factor applied to the duct heat pickup figure	factor, but be careful with the algebra!	factor, but result is added to ***heating*** load	factor applied to room cooling demand		Proportion of fan energy - but remember that fan also runs in non-cooling modes	
Units	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	kWhpa/m2	dimensionless	W/l/s	kWhpa/m2	
Comment	system dependent	Depends on quality of ducts and AHUs	Depends on location of ductwork	Depends on extent and insulation of ductwork	Depends on location of ductwork	System dependent	System dependent	System dependent	System dependent	System dependent	
	Auxiliary	Intermediate calc	Cooling-water	Cooling-water	Cooling-water	Intermediate calc	Auxiliary	Cooling generation	Cooling generation		
Parameter	**Fan run hours**	**Fan energy**	**Pipe heat pickup**	**Reclaimed cold losses**	**Cooling pump pickup factor**	**Cooling pump power**	**Cooling pump energy**	**Chiller performance**	**Chiller Ancillaries**		
Description	All services. Same figure used for terminals	All services	Heat transfer through pipe walls	Some of the lost coolth may be useful	Most pump energy is transferred to water as heat gain		Depends on pressure drop	Seasonal value - also applied to room units	May need to add cooling towers etc		
Application	Depends on controls	Based on 10 l/s m2 for all-air systems, proportioned to % cooling by air. SFP effect increased to allow for extract etc	factor	factor applied to the pipe heat pickup figure	Proportion of pump energy - - but remember that pump also runs in non-cooling modes	Taken as 0.01 times wet part of peak cooling load.	Pump power times hours. Operating hours proportioned to loads.	(inverse) factor	factor added to chiller energy consumption, may be included in chiller performance		
Units	hours	kWhpa m2	dimensionless	dimensionless	kWhpa/m2		kWhpa/m2	dimensionless	dimensionless		
Comment			Depends on extent and insulation of pipework	Depends on location of pipework	System dependent		System dependent	depends on chiller,climate etc	depends on chiller,climate etc		
	Heating Demand	Heating Demand	Intermediate calculation	Intermediate ca	Heating Demand	Heating Demand	Heating-air and wa	Heating-air	Heating-air	Heating-air	Heating-air
Parameter	**Heating Load**	**Heating EFLH**	**Room heating demand**	**Cooling proportion**	**Allowance for imperfect local control**	**Extra load from imperfect zoning**	**Proportion of load handled by air sub-system**	**Duct leakage**	**Reclaimed leakage losses**	**Duct heat loss**	**Reclaimed heat losses**
Description	Peak heating load		Ideal annual demand	cooling energy demand divided by heating + cooling energy demand	Imperfect time or temperature control will cause extra consumption	Different spaces may have different needs - imperfect time or temperature control will cause extra consumption	Can vary from all-air to no air	Can be substantial	Some of the lost heat may be useful	Heat transfer through duct walls	Some of the lost heat may be useful
Application			Base for calculation	Rather arbitrary value used to split fan and terminal pickup between cooling and heating (and where fan etc energy has to be split between services)	Factor applied to room heating demand	Factor	factor, should this be constrained to be the same as for cooling?	set to be the same s for cooling	factor applied to the duct loss figure	factor	factor applied to the duct heat loss figure
Units	kW/m2	hours pa	kWhpa/m2		dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless
Comment	Building dependent	Building dependent	Building dependent		Control and load dependent	Building and sytem dependent	system dependent	Depends on quality of ducts and AHUs	Depends on location of ductwork	Depends on extent and insulation of ductwork	Depends on location of ductwork
	Heating-air	Heating-air	Heating-air	Heating-water	Heating-water	Heating-water	Auxiliary	Auxiliary	Heat generation	Heat generation	
Parameter	**Heat recovery or economiser**	**Fan power**	**Fan energy pickup**	**Pipe heat losses**	**Reclaimed heat losses**	**Heating pump pickup**	**Heating pump power**	**Heating pump energy**	**Boiler performance**	**Boiler Ancillaries**	
Description	Heat recovery wheel (etc) can reduce net loads	Pick up from cooling	Pick up from cooling	Heat transfer through pipe walls	Some of the lost heat may be useful	Most pump energy is transferred to water as(useful) heat gain		Depends on pressure drop	Seasonal value - also applied to room units. May be reverse cycle chiller	May need to add gas boosters etc. more relevant for reverse cycle	
Application	factor, but really needs thinking about carefully			factor	factor applied to the pipe heat loss figure	Proportion of pump energy - - but remember that pump also runs in non-heating modes	Taken as 0.02 times wet part of peak heating load.	hours times power	(inverse) factor	factor added to boiler energy consumption,	
Units	dimensionless			dimensionless	dimensionless	kWhpa/m2	kW/m2	kWhpa m2	dimensionless	dimensionless	
Comment	System dependent			Depends on extent and insulation of pipework	Depends on location of pipework	System dependent		System dependent	depends on chiller,climate etc	depends on chiller,climate etc	

Table 19: Parameter list

11.3.3.5. Calibration process

As can be seen from Table 17, the likely range of values for each mechanism is known – albeit with varying degrees of reliability. Starting from a set of plausible but sometimes arbitrary figures, the values were progressively revised to provide calibrated combinations of values for each system type.

The process is illustrated in Figure 3.

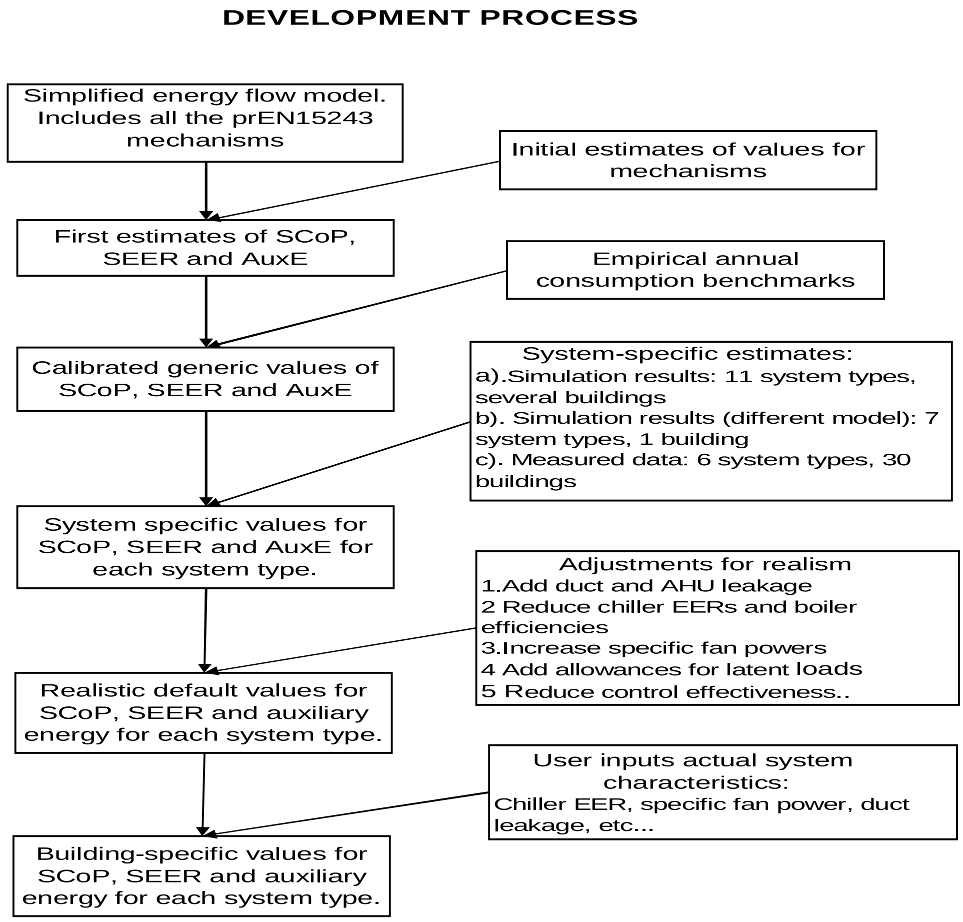

Figure 3: HVAC Model Development Process

We first produced initial estimates of typical values of the flow sheet parameters and calculated initial figures of the three performance parameters (auxiliary energy, SSEff, and SSEER). With some relatively small adjustments to the initial assumptions, the consumption figures that these implied were brought into general alignment with empirical benchmarks, notably ECG 019. This provided us with calibrated generic estimates of the parameter values.

In parallel with this, we brought together several sets of existing comparisons between the energy consumptions of different types of systems in offices. These included two sets of simulation results using different models to compare different systems in identical buildings. One of the studies examined 11 different system types in a number of buildings, while the other examined 7 system types in a single building, but modelled the system components in more detail. We combined these results with measured data from 30 buildings covering 6

system types[21] to develop a set of system-specific values for SSEff, SSEER, and auxiliary energy. For each system type, we then adjusted the spreadsheet parameters until the spreadsheet generated the same figures.

Since the simulations assumed idealised control and other conditions, we then degraded some parameters to provide less optimistic default assumptions. In particular, we added duct and AHU leakage, reduced chiller EERs and boiler efficiencies, increased specific fan powers, added allowances for latent loads, and reduced control effectiveness.

The resulting "default" consumption levels straddle the "typical" consumption benchmarks (some systems being better than the benchmark, others worse). The idealised figures straddle the equivalent "good practice" benchmark.

11.3.3.6. Adjustments to demand figures

There are two system-related issues associated with temperature distributions within spaces that are part of the translation from heating or cooling demand to energy consumption. These are the effect of vertical temperature gradients and of radiant heating or cooling.

Temperature gradient adjustment

General Principle

Vertical temperature gradients increase the average air temperature and thus the heat loss in tall spaces. Some systems generate bigger gradients than others. De-stratification fans (and similar systems) reduce gradients but use energy for fans.

Derivation

This follows the principle summarised in the draft CEN standard (un-numbered, possibly EN 14335 section 5.1.3).

- Assume that there is a linear temperature gradient, with the required comfort temperature t_c maintained at 1.5 m above the floor. At this height, air temperature is $t_{1.5}$
- Average air temperature is $t_{av} = t_{1.5} + grad*(h/2-1.5)$ where h is room height and $grad$ is air temperature gradient K/m.
- Assume that surface temperatures are unaffected.
- Design operative temperature is $(t_r + t_{1.5})/2$ so nominal heat loss is $U*((t_r + t_{1.5})/2 - t_o)$
- Ignoring how losses vary between floors, walls, and roof, actual heat loss is $U*((t_r + t_{av})/2 - t_o)$

Valuing grad

Actual heat loss should be based on a temperature that is higher than design value by $grad*(h/2-1.5)$. For room heights around 3 m, this correction is very small.

From GPG 303, typical values of *grad* are:

Radiant heating	0.3ºC
Radiators	1.5ºC
Convector heaters	2.3ºC

[21] Knight IP, Dunn GN, Measured Energy Consumption and Carbon Emissions of Air-conditioning and Heat-pumps in UK Office Buildings, BSER&T, CIBSE 26(1) 2005.

For tall spaces, they can be significant - for 10 m height, they are:

Radiant heating	1.1ºC
Radiators	5.3ºC
Convector heaters	8.1ºC

De-stratification systems (either de-stratification fans or high level downflow air heaters) gain a benefit of reducing or removing this gradient, but their fan energy use is added to the energy calculation.

11.3.3.7. Direct radiation from Heating and Cooling Systems

General Principle

Direct radiation falling on occupants allows a lower air temperature for a given level of thermal comfort. This, in turn, reduces ventilation losses.

Derivation

EN 15316-2-1 provides tabulated values of corrections based on detailed simulations of specific cases. These are difficult to capture within the structure of SBEM, and the following simplified, but more flexible process, has been derived. In practice, it gives similar corrections to those of the EN for the situations reported there.

Thermal comfort criteria are defined as a weighted mean (commonly the simple average) of the air and mean radiant temperature in a space. For practical purposes, it is usual to replace the mean radiant temperature by the mean internal surface temperature of the space and to ignore direct radiation from the heating system.

As is well-known from the use of sol-air temperatures, the effect of direct radiation is equivalent to a temperature increase of the surroundings equal to the product of the radiant intensity, *I*, the absorption coefficient, *a*, and the surface heat loss resistance, *r*.

Reduction in air temperature

Radiation from the heating system will also fall on the surfaces of the space. For a given indoor air temperature, this will increase the surface temperatures, and therefore the fabric heat losses. Different surfaces will be affected to different extents. However, if the air temperature is lowered to provide a constant comfort temperature, this will tend to reduce the surface temperature. As a simplification, assume that, for a given comfort level, the mean internal surface temperature is independent of the amount of direct radiation from the heating system.

With this assumption, we can calculate the air temperature reduction needed to maintain the same comfort temperature in the presence of direct radiation. If the comfort temperature t_c is expressed as the arithmetic mean of air and mean surface temperature, t_a and t_s, respectively, we have

$$t_c = I*a*r + (t_a+t_s)/2$$

And the reduction in air temperature due to direct radiation is $2*I*a*r = dt$

Radiant intensity

For heat emitters, such as heated floors, the proportion of heat output that is radiant can be determined from the radiant and convective heat transfer coefficients. For radiant heating systems, the radiant component is

$Q_t * h_r / h_t$

where Q_t is the total heat output, h_r is the radiant efficiency, and h_t is the total efficiency of the system.

Not all the radiant energy falls on the occupied area. Denote the proportion that does as *d*. The occupied area will usually be the floor area of the space, *A*.

So the radiant intensity on the occupied area is

$I = d*Qt* h_r / (h_t*A).$

Correction factor

The heating requirement for the space is

$Q_t = (t_i-t_o)*(U+V) - dt*V$

where t_i is the internal temperature (strictly speaking environmental temperature, but say comfort temperature),

t_o is the outdoor air temperature

U is the total conductance associated with the fabric (that is the sum of *U*A* terms)

V is the ventilation conductance

(For purely convective heating, *dt* is zero, and we have the conventional formula)

However, we know that *dt* is proportional to Q_t. For brevity, set $dt = k*Q_t$.

Substituting and rearranging, we obtain

$Q_t = (t_i - t_o)*(U+V)/(1+k)$

That is, the conventional heat demand is multiplied by a factor $1/(1+k)$

Valuing k

V, the ventilation conductance is *0.33*N*room volume*, where *N* is the ventilation rate in ac/h.

So $k = 2*a*r*d*0.33*N*\text{room volume}*h_r / (h_t*A)$

And *room volume/A* is equal to room height, *h*

A typical value of *a* is 0.9, and of *r*, 0.123.

RADIANT HEATING SYSTEMS:

The radiant efficiency of a radiant heater is measured taking into account only the downwards radiation so, in a very large space, we might expect *d* to approach 1. More commonly, some radiation will fall on (the lower part of) walls.

As a default, it is proposed that *d* should be equal to 0.6 (for typical radiant heaters, this yields results close to those proposed by the industry using alternative reasoning).

$k = 0.00438*N*h*h_r / h_t$

k increases with increasing ventilation rate, room height, and radiant efficiency

h_r / h_t is a property of the radiant heater. A value of 0.5 would be reasonable as a default; rising to 0.7 for ECA listed radiant heaters.

Note that, having calculated the heat demand, it is still necessary to divide by h_t to obtain fuel consumption.

OTHER TYPES OF SYSTEM:

The same logic applies to all heating systems that have a radiant component. For systems operating reasonably close to room temperature, the h_r / h_t term simply represents the proportion of the output that is radiant.

The following values are suggested:

Emitter	h_r / h_t	***d***
Radiator	0.56	0.25 (includes 50% straight to wall behind radiator)
Heated floor	0.55	0.60
Chilled ceiling	0.55	0.40

The corrections are smaller but typically in the range 5% to 10%.

11.3.3.8. Energy Use Calculation for Hot Water in SBEM

The basic calculation scheme is straightforward:

- Hot water demand is taken from the Activity database. It is expressed per unit of floor area, but this reflects occupancy density and nominal consumption per person for the activity in question.
- Heat losses from storage and distribution are added (if they are present).
- Heat losses associated with residual hot water in distribution pipes of more than 3 metres in length are added (as in SAP).
- Energy consumption is calculated using the heat generation efficiency.
- CO_2 emissions are calculated depending on the fuel source.
- Additionally, if there is a secondary circulation system, auxiliary energy and the consequent CO_2 emissions are calculated.

The calculation does not take account of detailed draw-off patterns or of adequacy of service. Energy use by any secondary pump and heat losses from secondary pipework reflect the hours of operation defined in the Activity database.

The user can define values for the parameters below. In most cases, default (rather pessimistic) assumptions are provided.

- storage volume
- heat loss per litre of stored hot water
- insulation type and thickness on storage vessel
- length of secondary pipework
- heat loss per metre of pipework
- secondary pump power
- heat generation efficiency

11.3.3.9. Heat and Cold generator seasonal efficiency

These values have to be provided by the user. The calculation of the seasonal efficiency of boilers and (especially) chillers is not entirely straightforward, especially when there are multiple chillers and a degree of oversizing. Methods of handling this have been reported elsewhere[22,23].

11.3.4. Weather

In order to calculate the reaction of the building and systems to the variable loads imposed by the external environment, the NEAP needs an input of weather data. In addition, information regarding weather data is necessary to calculate the energy yield by some renewable energy systems, such as solar and wind technologies.

Although some NEAP-accredited software only requires monthly figures, other software will require year round hourly data on the following parameters for each location:

- Dry and wet bulb temperature
- Beam and diffuse solar radiation (from which radiation for any slope and orientation of surface can be calculated)
- Wind speed

In order to provide consistency of application, a standard weather set has been adopted as the only weather data set to be used for the Republic of Ireland as part of the NEAP. The standard weather set adopted is for Dublin and has been obtained from ASHRAE[24].

11.4. Building geometry

There is a number of stages to defining the geometry of the building in the interface:

- Zone the building on the drawings according to the zoning rules shown in Section 6.5.
- After "zoning" the building, create the zones in the interface (i.e., select their building and activity types), and enter their basic dimensions, i.e., area, height, air permeability, etc.
- Define the envelopes of each zone, in terms of their type, i.e., walls, floor, ceiling/roof, areas, orientations, the conditions of the adjacent spaces, the constructions, and any thermal bridges additional to the ones defined in Section 11.4.3.
- Within each envelope element, there may be windows/rooflights or doors. The areas, types, shading systems, and constructions of windows and doors within each envelope element need to be entered.
- Similarly, within the envelope elements or within the window/door, there may be additional thermal bridges, (other than those defined in Section 11.4.3) which need to be defined.

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[22] Hitchin, R. and Law, S. The Seasonal Efficiency of Multi-Boiler and Multi-Chiller Installations, Improving Energy Efficiency in Commercial Building (IEECB'06) Frankfurt, 26-27 April 2006.
[23] CEN EN 15243 Appendix I.
[24] The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) at www.ashrae.org.

11.4.1. Zoning rules

The way a building is subdivided into zones will influence the predictions of energy performance. Therefore, so as to ensure consistency of application, the NEAP defines zoning rules that should be applied when assessing a building for building regulations compliance or energy rating certification. These rules are detailed in Section 6.5.

11.4.2. Envelope definitions

When the user creates a zone, envelope element, or window, what is being created is referred to in iSBEM as a 'building object'. These building objects need to be linked together correctly in order to define the geometry of a zone. When the user defines an envelope element in the *Envelopes* main tab, he will be prompted to link (or assign) it to a zone. Equally, when he defines a window in the *Windows & Rooflights* main tab, he is prompted to link it to an envelope element. If the user creates the envelope element or window in the *Quick Envelopes* sub-tab of a particular zone, these links are established automatically.

Figure 4 below is an example of a simple zone. To define the geometry of this zone, you would need to create the zone, 6 envelope elements, one window, and one door. The south wall door and window would need to be linked to the south wall, which in turn (along with the other 5 envelope elements) would need to be linked to the zone, as shown by the arrows in the diagram below.

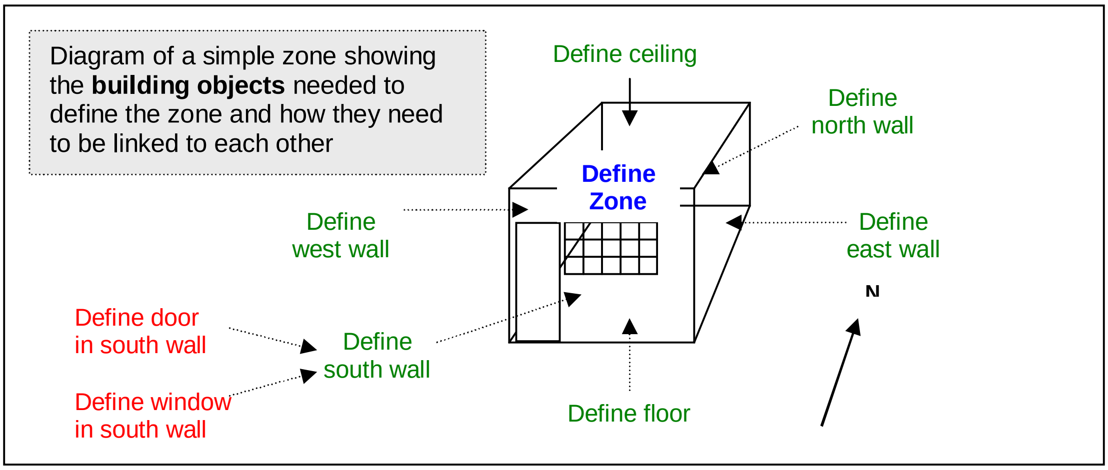


Figure 4: Diagram of building objects needed to define a simple zone

11.4.3. Thermal bridges

There are two types of thermal bridge: repeating and non-repeating. Repeating thermal bridges should be taken into account when calculating the U-value of a construction. Non-repeating thermal bridges can arise from a number of situations, but SBEM is only concerned with those arising from junctions between envelope elements, windows, and doors which are in contact with the exterior. These types of junctions fall into two categories:

- Junctions involving metal cladding
- Junctions NOT involving metal cladding.

At these junctions between different building elements, there can be additional loss of heat from the building which is not attributed to the U-values and areas of the adjoining elements. The additional heat loss which is attributed to the junction is expressed as a linear thermal transmittance, Ψ (Psi) value, (expressed in W/mK). SBEM contains a table of types of junctions and default linear thermal transmittance values for each of these types of junctions, Table 20. These default values are determined according to the method in BRE IP 1/06: *Assessing the Effects of Thermal Bridging at Junctions and around Openings*.

	Non-Metal cladding constructions		**Metal cladding constructions**
Type of junction	**Ψ (W/(m·K))**	**Ψ (W/(m·K))** (*)	**Ψ (W/(m·K))** (**)
Roof-Wall	0.12	0.12	0.6
Wall-Ground floor	0.28	0.16	1.15
Wall-Wall (corner)	0.09	0.09	0.25
Wall-Floor (not ground floor)	0.18	0.07	0.07
Lintel above window or door	0.53	0.3	1.27
Sill below window	0.21	0.04	1.27
Jamb at window or door	0.2	0.05	1.27
(*) Recommended in Accredited Robust Details (**) Recommended by Metal Cladding and Roofing Manufacturers Association (MCRMA)			

Table 20: SBEM's default values for the linear thermal transmittance of linear thermal bridges

For each type of junction, the user can either enter an Ψ (Psi) value (W/m.K) or leave the default values. For junctions not involving metal cladding, the user can also tick a box indicating whether or not that type of junction complies with the relevant standards. The standards for junctions not involving metal cladding are Accredited Robust Details. The default Ψ (Psi) values for junctions involving metal cladding are compliant with the Metal Cladding and Roofing Manufacturers Association (MCRMA) standards.

Additional thermal bridging at junctions and around openings, which are not covered in Table 20, can be defined by the user in iSBEM in relation to the relevant building object, i.e., envelope, window, door, etc.

Note: Point thermal transmittances are ignored as point thermal bridges are normally part of plane building elements and already taken into account in their thermal transmittance, U-value.

12. The calculation algorithms

The calculation methodology can, in theory, be based on any process which evaluates the energy consumption, and hence the primary energy use and CO_2 emissions of a building, as long as it complies with the following NEAP requirements:

- Considers the energy uses required by article 3 of the EPBD
- Draws on standard conditions in the activity area and other databases
- Compares with a reference building (and notional building), defined in a standard way

The calculation method in SBEM mostly follows the CEN standard umbrella document PG-N37, which lists standards relevant to the implementation of the EPBD. The CEN umbrella document PG-N37 provides an outline of the calculation procedure for assessing the energy performance of buildings. It includes a list of the European standards, both existing and those that are to be written, which together form a calculation methodology. In particular, EN ISO 13790 deals with *Energy performance of buildings – Calculation of energy use for space heating and cooling*. Within this standard, there are several optional routes to undertaking the calculation; for instance, it includes three explicit methods – a seasonal calculation, one based on monthly heat balance, and a simplified hourly calculation, and also permits detailed simulation.

It has been decided that a seasonal calculation is unacceptable for the NEAP, and that only one implementation of the monthly average calculation method will be accepted in the Republic of Ireland, namely SBEM. However, some necessary parts of the calculation are not dealt with explicitly or completely by these CEN standards or draft prEN standards. Where this is the case, alternative acceptable calculation methodologies, to deal with the areas not covered by the standards, were developed. For example, the following energy calculations needed to be determined:

- Fixed lighting with different control systems
- Hot water for washing
- Contributions from renewable energy systems such as solar thermal water heating and photovoltaic electricity

12.1. Space heating and cooling energy demand

In EN 13790, the building energy demands for heating and cooling are based on the heat balance of the building zones (Note: EN 13790 only deals with sensible cooling and heating demand in a single room). This energy demand for the building is then the input for the energy balance of the heating and cooling systems, and hence, the primary energy use and CO_2 emissions for the building as a whole. The main structure of the calculation procedure is summarised in Table 21. The options chosen for SBEM from those available in the EN ISO 13790, and the resulting equations to be used are described and/or referenced in Table 22.

1	Define the boundaries of the conditioned and unconditioned spaces, and partition them into zones according to the activities undertaken in them and the conditions required for each of those activities
2	Calculate for each period and each zone, the energy needed to heat or cool them to maintain the required set-point conditions, and the length of the heating and cooling seasons

3	Combine the results for different periods and for different zones served by the same systems, and calculate the delivered energy use for heating and cooling taking into account the heat dissipated by the heating and cooling systems through distribution within the building or inefficiencies of heating and cooling production.
4	Combine the results for all zones and systems, to give building delivered energy totals.
5	Convert the totals into equivalent primary energy use and CO_2 emissions (this is not part of the CEN Standard – the conversion factors are described in Section 3.7)

Table 21: Summary of CEN standard calculation

	Issues/options	**Chosen route**	**References in CEN standard EN ISO13790**
1	Different types of calculation method: dynamic or quasi-steady state	Quasi-steady state, calculating the heat balance over a month	5.3
2	If steady state, how to take account of dynamic effects on heating	Determine utilisation factors for internal and solar heat sources using equations 31 & 32, to allow non-utilised heat which leads to an undesired increase in temperature above set-points to be ignored. This depends on the thermal capacity of the structure	5.4.2
3	Effects of thermal inertia in case of intermittent heating	Adjust set-point temperature as described in EN ISO 13790 (i.e., thermal capacity-dependent) using information in databases	13.2
4	How to take account of dynamic effects on cooling	Using equations 35 & 36, determine utilisation factors for internal and solar heat sources, to take account of that part which takes the temperature to a certain level, so only non-utilised heat beyond that level contributes to cooling needs. This depends on the thermal capacity of the structure	12.2.1
5	Effects of thermal inertia in case of intermittent cooling	Adjust set-point temperature using information in databases.	13.2
6	Energy balance at system level	Includes energy needs at zone level; from renewables; generation, storage, distribution, emission and control losses; input to space heating and cooling systems; energy outputs e.g., from CHP; energy recovered within the system	5.5; see also figs 3a&c in the section for all energy flows
7	Relationship with unconditioned spaces	The boundary of the building is the elements between the conditioned and unconditioned spaces, including exterior. Heat transfer between conditioned spaces is ignored.	6.2

8	Dimension system for calculating areas	Internal dimensions of each zone's structural elements, so that the area presented to heat flux from inside the building coincides with the overall internal dimensions	6.2, 6.3.2
9	Thermal zones	Building is partitioned into several zones, taking no account of thermal coupling between zones	6.3.1, 6.3.3.2
10	Calculation procedure for multi-zone	Regard as a series of single zone calculations, but with boundary conditions and input data coupled when zones share same heat/cooling system. Zones are aggregated when served by the same heating/cooling system.	6.3.5
11	Energy demand for heating	Equation 3; correction for holidays applied where relevant through schedules in activity area database.	7.2.1.1
12	Energy demand for cooling	Equation 4; correction for holidays applied where relevant through schedules in activity area database.	7.2.1.2
13	Length of heating season	Not calculated in SBEM – heat is available whenever monthly calculation demands it.	7.2.1.3
14	Length of cooling season	Not calculated in SBEM – cooling is available whenever monthly calculation demands it.	7.2.2
15	Calculation in two steps, to determine dissipation of heat from systems based on 1st iteration	Not done in SBEM	7.2.5
16	Total heat transfer by transmission	Equation 11	8.2
17	Transmission heat transfer coefficients	Calculate according to EN ISO 13789:2005 taking into account other standards listed in 8.3.1	8.3.1
18	Thermal bridges	Calculate transmission heat loss according to EN ISO 13789:2005	8.3.1
19	Differences in transmission calculation between heating and cooling modes	Not implemented in SBEM - physical characteristics of building do not change	
20	Nocturnal insulation	Not implemented in SBEM	8.3.2, 8.4.2
21	Special elements	Optional; if applied, comply with 8.4.3	8.4.3
22	Total heat transfer by ventilation	Equation 13	9.2
23	Ventilation heat transfer coefficients	Determine according to section 9.3.1, using volume flow rate based on NEN 2916:1998 methodology section 6.5.2.1. Infiltration based on section 7.1.3.2 of EN 15242:2005	9.3.1
24	Differences in ventilation calculation between heating and	Infiltration and heat recovery are currently ignored during cooling	9.3.2

	cooling modes		
25	Ventilation heat recovery	Only during heating. Based on section 6.5.2 of NEN 2916:1998 methodology, where according to efficiency of heat recovery system, the air flow to be heated is effectively reduced.	
26	Night-time ventilation for free cooling	Not implemented in SBEM	9.4.3
27	Special elements	Optional; if applied, comply with 9.4.4	9.4.4
28	Internal heat sources, including cold sources (i.e., sinks, etc)	Calculate contribution using equations 16, 17 & 18	10.2, 10.3.1
29	Heat dissipated by system within the building	Impact on building heating/cooling needs ignored in SBEM, but heat dissipated is included in system efficiency adjustment factors	10.3.1
30	Heat gain from people and appliances	Determined from activity area database	10.3.2.1
31	Heat gain from lighting	Determined using method described in this manual	10.3.2.2
32	Heat to/from washing water and sewerage	Ignored in SBEM	10.3.2.3
33	Heat dissipated from or absorbed by heating, cooling and ventilation systems	Determined from efficiency factors	10.3.2.4
34	Heat from processes or goods	Determined from activity area database	10.3.2.5
35	Total solar heat sources	Equations 22 & 23 based on monthly average solar irradiance from weather data, including the effect of gains in adjacent unconditioned spaces	11.2
36	Effective solar collecting area of glazed elements	Equations 24, 27 & 29. Movable shading is included. Shading factors determined from user input	11.3.2, 11.4.1, 11.4.2, 11.4.3
37	Frame fraction	Included in SBEM	11.4.4
38	Effective collecting area of opaque elements	Equations 25, 26 & equations in 11.4.5 including 30 to deal with radiation from the element to the sky. Sky temperature taken from weather data	11.3.3, 11.4.5
39	Gain utilisation factor for heating	Equations 31, 32, 33 & 34 using reference numerical parameter for monthly calculation from table 8 based on building type and calculated building time constant (see below)	12.2.1.1
40	Loss utilisation factor for cooling	Equations 35, 36, 37, 38 & 39 using reference numerical parameter for monthly calculation from table 9 based on building type and calculated building time constant (see below)	12.2.1.2
41	Building time constant	Equations 40 (heating) and 41 (cooling) using internal heat capacity of building	12.2.1.3
42	Internal heat capacity of building	Sum of internal capacities of all building elements, using C_m values calculated	12.3.1

		according to EN ISO 13786:2005.	
43	Internal temperatures used in energy calculations	Where heating or cooling is continuous during the whole heating period, use the set-point temperature indicated by the activity area database. If not continuous, see below.	13.1
43	Correction for holiday periods	SBEM obtains this information from the activity area database	13.4
44	Internal temperature correction for intermittent heating	As 13.2.1 – resolve mode of intermittency which is dependent on building time constant (calculated above) and difference in set-point temperature between normal and reduced heating periods	13.2.1
45	Correction for intermittent cooling	Equations 44 & 45, which need input of building time constant (calculated above) and set-point temperatures for normal cooling and intermittent periods.	13.3
46	Annual energy need for heating and cooling per building zone	Sum of heating and cooling needs in each month; as equation 47	14.1
47	Annual energy need for heating and cooling, per combination of systems	Sum of heating and cooling needs served by the same combination of systems, then sum of needs of all systems; as equation 48	14.2
48	Total system energy use, including system losses	Use option b in section 14.3.1, in order to present auxiliary energy separately from system losses, for each energy carrier.	14.3.1
49	System losses	SBEM does not require separation of total losses and system losses that are recovered in the system.	14.3.2
50	Results presentation of heating and cooling energy needs	Not in SBEM	14.3.3
51	Additional annual energy by ventilation system	Not displayed separately, but calculated as section 14.3.4, in accordance with EN 15241. For HVAC systems involving ventilation, auxiliary energy comes from method in appendix G. Where ventilation comes from individual fans, use EN 13779	14.3.4
52	Reporting of building and systems evaluation	Results broken down for the whole building, each zone and each month, with heating and cooling heat transfer and energy needs as in section 15.3.1. Input data reflection (as section 15.2) is available on screen but is not printed automatically, to reduce paper consumption prior to final version.	15.2, 15.3.1, 15.3.2
53	Climate related data	Hourly climatic data are needed, even though the calculation is monthly based, in order to prepare the monthly values. Data should include the parameters	Annex A

		required in CEN standard annex A	
54	Multi-zone calculation with thermal coupling between zones	Not implemented in SBEM	Annex B
55	Alternative formulation for monthly cooling method	Not implemented in SBEM	Annex D
56	Heat loss of special envelope elements (e.g., ventilated walls)	Not implemented in SBEM	Annex E
57	Solar gains of special elements (e.g., unconditioned sunspaces, opaque elements with transparent insulation, ventilated walls)	Not implemented in SBEM.	Annex F
58	Data for solar gains	Refer to annex G	Annex G
59	Calculation of heat use in different heating modes (e.g., if different modes have different costs)	Not implemented in SBEM	Annex H
60	Accuracy of the method	Not required for NEAP	Annex I
61	Conventional input data (to be used in the absence of national data)	Not required for NEAP – use activity area database	Annex J

Table 22: Options chosen in the CEN standard EN ISO 13790

12.1.1. Calculation method

SBEM adopts the quasi-steady state calculation method, calculating the heat balance over a month. The monthly calculation gives reasonable results on an annual basis, but the results for individual months close to the beginning and the end of the heating and cooling season can have errors relative to the actual profile of cooling and heating demands.

In the quasi-steady state methods, the dynamic effects are taken into account by introducing correlation factors:

For heating: a utilisation factor for the internal and solar heat sources takes account of the fact that only part of the internal and solar heat sources is utilised to decrease the energy demand for heating; the rest leading to an undesired increase of the internal temperature above the set-point. In this approach, the heat balance ignores the non-utilised heat sources, which is counterbalanced by the fact that it ignores at the same time the resulting extra transmission and ventilation heat transfer from the space considered due to the increased internal temperature above the set-point.

The effect of thermal inertia in case of intermittent heating or switch-off can be taken into account by introducing an adjustment to the set-point temperature or a correction to the calculated heat demand.

For cooling: (mirror image of the approach for heating) a utilisation factor for the transmission and ventilation heat transfer takes account of the fact that only part of the

transmission and ventilation heat transfer is utilised to decrease the cooling needs, the “non-utilised” transmission and ventilation heat transfers occur during periods or moments (e.g., nights) when they have no effect on the cooling needs occurring during other periods or moments (e.g., days). In this approach, the heat balance ignores the non-utilised transmission and ventilation heat transfer. This is counterbalanced by the fact that it ignores that the cooling set-point is not always reached. With this formulation, it is explicitly shown how the heat transfer attributes to the reduction of the building energy needs for cooling.

The effect of thermal inertia in the case of intermittent cooling or switch-off can be taken into account by introducing an adjustment on the set-point temperature or an adjustment on the calculated cooling needs.

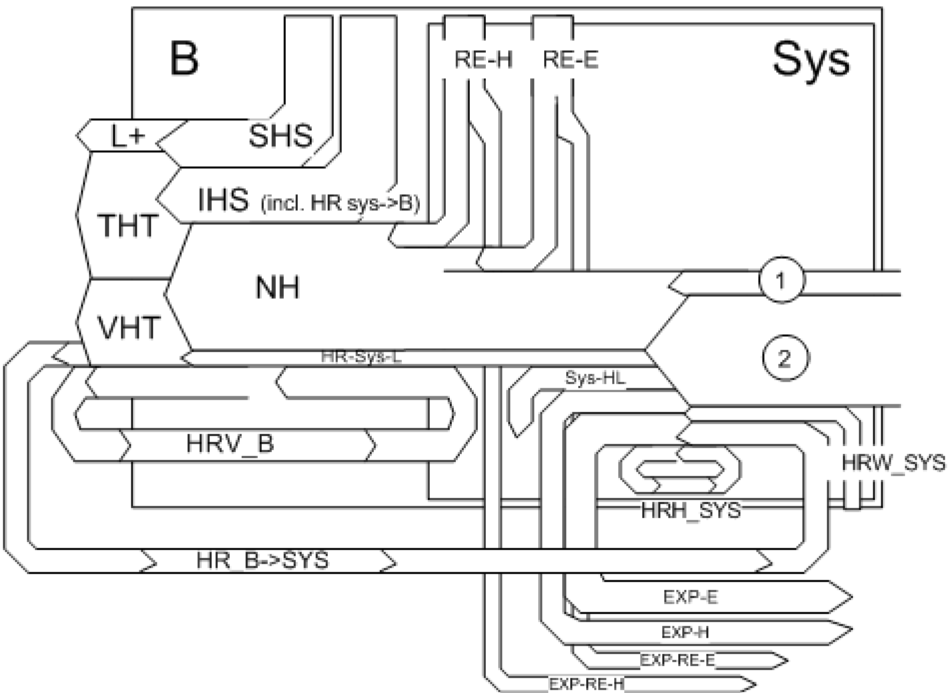
12.1.2. Overall energy balances for building and systems

The building energy demand for heating and cooling is satisfied by the energy supply from the heating and cooling systems. At the system level, the energy balance for heating and cooling, if applicable, includes:

- energy demand for heating and cooling of the building zones
- energy from renewable energy systems
- generation, storage, distribution, emission, and control losses of the space heating and cooling systems
- energy input to the space heating and cooling systems
- special energy output from the space heating or cooling systems (export; e.g., electricity from a combined heat and power installation)

The system energy balance may also include energy recovered in the system from various sources.

The main terms of the (time-average) energy balance for heating and cooling are schematically illustrated in Figure 5 and Figure 6, respectively.

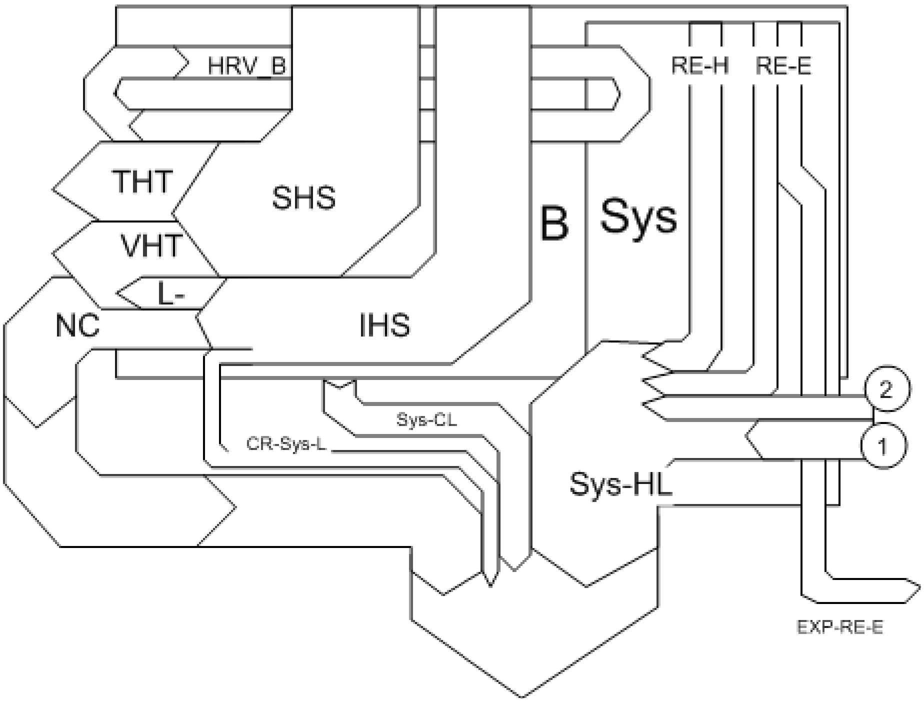


Key

B	Building	Sys	System
THT	Transmission heat transfer	Sys-HL	System heat losses, not recovered (from generation, transport, electronics, storage, distribution, emission)
VHT	Ventilation heat transfer	HRH-Sys	System heat losses, recovered in system
L	THT+VHT	HRW-Sys	Heat from waste water, recovered in system
SHS	Solar heat sources	RE-H	Renewable energy, heat e.g. solar, ground,..)
IHS	Internal heat sources (persons and appliances). Including heat recovered from hot water, heat transferred to cold water, heat from lighting and fan or pump dissipation Heat from heating system: shown as separate flow: see HR-Sys-L	RE-E	Renewable energy, electric (PV)
L+	Mismatch between transmission and ventilation heat transfer and solar and internal heat sources, leading to average internal temperature higher than required	HR-B->Sys	Heat recovered in building (into the system) e.g. ventilation exhaust air as source for heat pump; heat from building mass into vent.system,..
NH	Energy need for space heating	EXP-E	Exported electricity, non-renewable
HRV-B	Heat recovered in ventilation system (into the building)	EXP-H	Exported heat, non-renewable
HR-Sys-L	Heat recovered from system loss in building (distribution, storage, emission, etc.)	EXP-RE-E	Exported electricity, from renewable source
		EXP-RE-H	Exported heat, from renewable source
		1	Delivered energy, electricity
		2	Delivered energy, gas or coal or oil or …

NOTE: Cross-flows between heating and cooling are not shown

Figure 5: Energy balance of a building for space heating



Key

B	**Building**	**Sys**	**System**
THT	Transmission heat transfer	Sys-HL	System energy use for cooling, including heat losses, not recovered (from generation, transport, electronics)
VHT	Ventilation heat transfer	RE-H	Renewable energy for cooling, heat e.g. solar, ground,..)
L	THT+VHT	RE-E	Renewable energy for cooling, electric (PV)
SHS	Solar heat sources		
IHS	Internal heat sources (persons and appliances). Including heat recovered from hot water, heat transferred to cold water, heat from lighting and fan or pump dissipation Heat extracted by cooling system: shown as separate flow: see HR-Sys-L	CR-B->Sys	Additional heat removed from building (into the system e.g. from building mass into vent.system, ..
L-	Mismatch between transmission and ventilation heat transfer and solar and internal heat sources, leading to average internal temperature lower than required	EXP-E	Exported electricity, non-renewable
NC	Energy need for space cooling	EXP-RE-E	Exported electricity, from renewable source
HRV-B	Heat recovered in ventilation system (into the building, if not by-passed during cooling period)	1	Delivered energy, electricity
CR-Sys-L	Cold recovered from system loss in building (distribution, storage, emission, etc.)	2	Delivered energy, (gas, coal, oil, etc)

NOTE: Cross-flows between heating and cooling are not shown

Figure 6: Energy balance of a building for space cooling

12.1.3. Boundary of the building

Firstly, the boundaries of the building for the calculation of energy demands for heating and cooling are defined. Secondly, the building is, if necessary, divided into calculation zones. The boundary of the building consists of all the building elements separating the conditioned space or spaces under consideration from the external environment (air, ground, or water) or from adjacent buildings or unconditioned spaces. Heat transfer between conditioned spaces is ignored in SBEM.

The floor area within the boundary of the building is the useful floor area A_{fl} of the building. The dimension system used to calculate A_{fl} uses the internal dimensions of each zone's structural elements (i.e., the internal horizontal dimensions between the internal surfaces of the external zone walls and half-way through the thickness of the internal zone walls) so

that the area presented to the heat flux from inside the building coincides with the overall internal dimensions.

12.1.4. Thermal zones

The building is partitioned into several zones (multi-zone calculation), taking no account of thermal coupling between the zones.

For a multi-zone calculation without thermal coupling between zones (calculation with uncoupled zones), any heat transfer by thermal conduction or by air movement is not taken into account. The calculation with uncoupled zones is regarded as an independent series of single zone calculations. However, boundary conditions and input data may be coupled, for instance because different zones may share the same heating system or the same internal heat source.

For zones sharing the same heating and cooling system, the energy demand for heating and cooling is the sum of the energy demand calculated for the individual zones.

For zones not sharing the same heating and cooling system, the energy use for the building is the sum of the energy use calculated for the individual zones.

12.1.5. Climate data

Hourly climatic data is needed for the preparation of monthly climatic values and climate dependent coefficients. This data comprises at least:

- Hourly external air temperature, in °C;
- Hourly global solar radiation at a horizontal plane, in W/m^2 (and indicators needed for the conversion of global solar radiation at a horizontal plane to incident radiation at vertical and tilted planes at various orientations).
- Local or meteorological wind speed, in m/s;
- Wind direction

12.1.6. Calculation procedure for energy demand for space heating and cooling

The calculation procedure to obtain the energy demand for space heating and cooling of the building or building zone is summarised below. For each building zone and for each calculation period:

- calculate the characteristics for the heat transfer by transmission
- calculate the characteristics for the heat transfer by ventilation
- calculate the heat gains from internal heat sources and solar heat sources
- calculate the dynamic parameters (the gain utilisation factor for heating and the loss utilisation factor for cooling)
- calculate the building energy demand for heating, Q_{NH}, and the building energy demand for cooling, Q_{NC}

12.1.7. Energy demand for heating

For each building zone, the energy demand for space heating for each calculation period (month) is calculated according to:

$Q_{NH} = Q_{L,H} - h_{G,H} \, . \, Q_{G,H}$

subject to $Q_{NH} \geq 0$

where (for each building zone, and for each month):

Q_{NH} is the building energy demand for heating, in MJ;

$Q_{L,H}$ is the total heat transfer (losses) for the heating mode, in MJ;

$Q_{G,H}$ are the total heat sources (gains) for the heating mode, in MJ;

$h_{G,H}$ is the dimensionless gain utilisation factor. It is a function of mainly the gain-loss ratio and the thermal inertia of the building.

If applicable, corrections are applied to account for holidays, according to the occupancy schedules in the Activity database.

12.1.8. Energy demand for cooling

For each building zone, the energy demand for space cooling for each calculation period (month) is calculated according to:

$Q_{NC} = Q_{G,C} - h_{L,C} \, . \, Q_{L,C}$

subject to $Q_{NC} \geq 0$

where (for each building zone, and for each month)

Q_{NC} is the building energy demand for cooling, in MJ;

$Q_{L,C}$ is the total heat transfer (losses) for the cooling mode, in MJ;

$Q_{G,C}$ are the total heat sources (gains) for the cooling mode, in MJ;

$h_{L,C}$ is the dimensionless utilisation factor for heat losses. It is a function of mainly the loss-gain ratio and inertia of the building.

If applicable, corrections are applied to account for holidays, according to the occupancy schedules in the Activity database.

12.1.9. Total heat transfer (loss) and heat sources (gain)

The total heat transfer, Q_L, is given by:

$Q_L = Q_T + Q_V$

where (for each building zone and for each month):

Q_L is the total heat transfer, in MJ;

Q_T is the total heat transfer by transmission, in MJ;

Q_V is the total heat transfer by ventilation, in MJ;

The total heat sources, Q_G, of the building zone for a given calculation period, are:

$Q_G = Q_i + Q_s$

where (for each building zone and for each calculation period):

Q_G are the total heat sources, in MJ;

Q_i is the sum of internal heat sources over the given period, in MJ;

Q_S is the sum of solar heat sources over the given period, in MJ.

12.1.10. Total heat transfer by transmission

The total heat transfer by transmission is calculated for each month and for each zone, z, by:

$$Q_T = \sum_k \{H_{T,k} \cdot (q_i - q_{e,k})\} \cdot t \cdot f$$

where (for each building zone, z, and for each month)

Q_T is the total heat transfer by transmission, in MJ;

$H_{T,k}$ is the heat transfer coefficient by transmission of element k to adjacent space(s), environment, or zone(s) with temperature $\theta_{e,k}$, in W/K;

θ_i is the internal temperature of the building zone, in degrees Celsius; taken from the Activity database (heating set-point);

$\theta_{e,k}$ is the external (outdoor) temperature (the monthly average temperature obtained from the hourly weather data for the location) of element k, in degrees Celsius; taken from the Weather database;

t is the duration of the calculation period, i.e., number of days in the month;

f is a factor for conversion from Wh to MJ.

The summation is done over all the building components separating the internal and the external environments.

NOTE: The heat transfer or part of the heat transfer may have a negative sign during a certain period.

12.1.10.1. <u>Transmission heat transfer coefficients</u>

The values for the heat transmission coefficient, $H_{T,k}$, of element k are calculated according to EN ISO 13789:2005, taking into account the standards for specific elements, such as windows (EN ISO 10077-1:2004), walls and roofs (EN ISO 6946:2005), and ground floor (EN ISO 13370:2005).

The value for temperature $\theta_{e,k}$ is the value for the temperature of the external environment of element k, for the following situations:

- Heat transmission to external environment
- Heat transmission to adjacent unconditioned space
- Heat transmission to the ground

The transmission heat transfer coefficient through the building elements separating the heated or cooled space and the external air is calculated by:

$$H_T = \sum_i A_i U_i + \sum_k l_k \Psi_k$$

where

H_T is the heat transfer coefficient by transmission of building envelope, in W/K;

A_i is the area of element *i* of the building envelope, in m^2, (the dimensions of windows and doors are taken as the dimensions of the aperture in the wall);

U_i is the thermal transmittance (U-value) of element *i* of the building envelope, in W/(m²·K);

l_k is the length of linear thermal bridge *k*, in m;

Ψ_k is the linear thermal transmittance of linear thermal bridge *k*, in W/(m·K).

12.1.10.2. Thermal bridges:

The default values used in SBEM for the linear thermal transmittance, Ψ, of linear thermal bridges are determined according to the method in BRE IP 1/06: *Assessing the Effects of Thermal Bridging at Junctions and around Openings*. These are the values used in the calculations unless the user overrides them, as described in Section 11.4.3.

12.1.11. Total heat transfer by ventilation

The total heat transfer by ventilation Q_V is calculated for each month and for each zone, z, as described in Section 12.2.

12.1.12. Heat gains

Heat gains result from a contribution from internal heat sources Q_i in the building, consisting of occupants, lighting, appliances, and a contribution from solar heat through transparent constructions Q_{sun} and through opaque constructions $Q_{sun,nt}$.

The heat gains are calculated by

$Q_{gain} = Q_i + Q_{sun,t} + Q_{sun,nt}$

where:

Q_{gain} is the heat gain per month, in MJ;

Q_i is the internal heat production, in MJ;

$Q_{sun,t}$ is the solar heat gain through transparent construction parts of the external envelope, in MJ;

$Q_{sun,nt}$ is the solar heat gain through opaque construction parts of the external envelope, in MJ;

12.1.12.1. Internal heat sources

Internal heat sources, including cold sources (sinks, sources with a negative contribution), consist of any heat generated in the conditioned space by internal sources other than the energy intentionally utilised for space heating, space cooling, or hot water preparation.

The heat gain from internal heat sources is calculated from:

$Q_i = Q_{i,occ} + Q_{i,app} + Q_{i,li}$

where

Q_i is the sum of internal heat production from internal heat sources, in MJ;

$Q_{i,occ}$ is the internal heat production from occupants, in MJ; determined from the Activity database, according to the building and activity types selected for the zone.

$Q_{i,app}$ is the internal heat production from appliances, in MJ; determined from the Activity database, according to the building and activity types selected for the zone.

$Q_{i,li}$ is the internal heat production from lighting, in MJ.

Dissipated heat from lighting devices is determined from the lighting energy consumption calculated for the zone.

The value for the internal heat production from lighting, $Q_{i,li}$, is calculated from:

$Q_{i,li} = W_{light} * A * 3.6 * f_{li,gain}$

where

$Q_{i,li}$ is the internal heat production from lighting, in MJ;

W_{light} is the energy consumption by lighting, in kWh/m^2, as determined in Section 12.4;

A is the area of the zone, in m^2;

3.6 is the conversion factor from kWh to MJ;

$f_{li,gain}$ is a gain factor that is dependent on whether there are air-extracting luminaires in the zone. It has a value of 0.9 if there are air-extracting luminaires and 1 if there are no air-extracting luminaires in the zone.

12.1.12.2. Solar heat gain through transparent constructions

The solar heat gain per month through transparent construction parts of the external envelope is determined as:

$$Q_{sun,t} = \sum_j \left(q_{sun,j} \times f_{sh,j} \times f_{sun,j} \times g_j \times f_f \right)$$

where:

$Q_{sun;t}$ is the solar heat gain through transparent constructions, in MJ;

$q_{sun,j}$ is the quantity of solar radiation per month on the plane in MJ/m^2, for weather location and orientation of window j;

$f_{sh;j}$ is the shading correction factor for window j;

$f_{sun;j}$ is the reduction factor for moveable solar protection for window j, taken from Table 23;

g_j is the total solar energy transmittance, for window j;

$A_{r,j}$ is the areas of window j , in m^2, including the frame;

$f_{,f}$ is the computation value for the frame factor, taken as (1-frame factor for window from user input).

	f_{sun}	
Shading system	**Jan-Apr, Oct-Dec**	**May-Sep**
External solar protection. User moveable	0.5	0.5
External solar protection with automatic control	0.5	0.35
All other cases	1	1

Table 23: Reduction factor f_{sun} for moveable solar protection devices

The external shading reduction factor, $f_{sh;j}$, which is in the range 0 to 1, represents the reduction in the incident solar radiation due to permanent shading of the surface concerned resulting from overhangs and fins.

The shading correction factor can be calculated from:

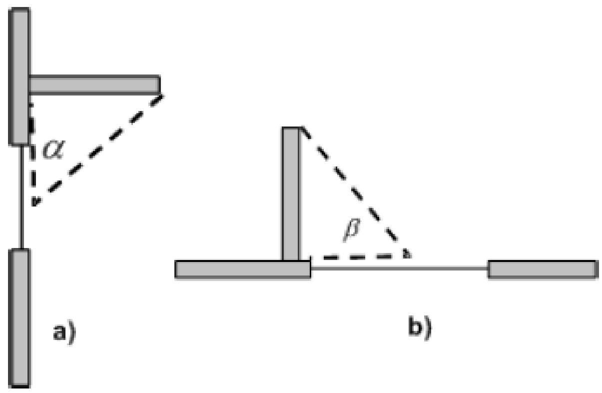
$f_{sh;j} = F_o F_f$

where

F_o is the partial shading correction factor for overhangs;

F_f is the partial shading correction factor for fins.

The shading from overhangs and fins depends on overhang or fin angle, latitude, orientation, and local climate. Seasonal shading correction factors for typical climates are given in Table 24 and Table 25.



a) Vertical section b) Horizontal section

Key
α overhang angle
β fin angle

Figure 7: Overhang and fin: a) Vertical section b) Horizontal section

NB: For the purposes of this calculation, the angles a and b, indicated by the dashed lines in Figure 7, are taken between the plane of the window and the overhang or fin shadow line at mid-window.

Overhang angle	45° N lat.			55° N lat.			65° N lat.		
	S	E/W	N	S	E/W	N	S	E/W	N
0°	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
30°	0,90	0,89	0,91	0,93	0,91	0,91	0,95	0,92	0,90
45°	0,74	0,76	0,80	0,80	0,79	0,80	0,85	0,81	0,80
60°	0,50	0,58	0,66	0,60	0,61	0,65	0,66	0,65	0,66

Table 24: Partial shading correction factor for overhang, F_o

Fin angle	45° N lat.			55° N lat.			65° N lat.		
	S	E/W	N	S	E/W	N	S	E/W	N
0°	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
30°	0,94	0,92	1,00	0,94	0,91	0,99	0,94	0,90	0,98
45°	0,84	0,84	1,00	0,86	0,83	0,99	0,85	0,82	0,98
60°	0,72	0,75	1,00	0,74	0,75	0,99	0,73	0,73	0,98

Table 25: Partial shading correction factor for fins, F_f

The total solar energy transmittance, g, is the time-averaged ratio of energy passing through the unshaded element to that incident upon it. For windows or other glazed envelope elements with non-scattering glazing, ISO 9050 or EN 410 provide a method to obtain the solar energy transmittance for radiation perpendicular to the glazing. This value, $g_{\perp}$, is somewhat higher than the time-averaged transmittance, and a correction factor, F_w, is used:

$$g = F_W \, g_{\perp}$$

The factor F_w is approximately 0.9. It depends on the type of glass, latitude, climate, and orientation.

12.1.12.3. Solar heat gain through opaque constructions

The solar heat gain per month through opaque construction parts of the external envelope is determined as:

$$Q_{sun,nt} = \sum_j \left(f_{ab} \times q_{sun,j} \times U_{c,j} \times A_{c,j} \right)$$

where:

$Q_{sun;nt}$ is the solar heat gain through opaque constructions, in MJ;

f_{ab} is a factor 0.045 which consists of an assumed value of 0.9 for the dimensionless absorption coefficient for solar radiation of the opaque construction multiplied by the external surface heat resistance which is taken as 0.05 m^2K/W.

$q_{sun,j}$ is the quantity of solar radiation per month on the plane in MJ/m^2, for weather location and orientation of construction part j;

$U_{c;j}$ is the thermal transmittance of construction part j; in W/m^2K;

$A_{c,j}$ is the area of construction part j , in m^2.

12.1.13. Gain utilisation factor for heating

The gain utilisation factor indicates the capability of the building of utilizing the solar heat and the internal heat in such a way that this will lead to a reduction of the heating demand which without these sources would have to be supplied by the heating installation. The gain utilisation factor for heating, h_H is a function of the gain/loss ratio, $\gamma_{H,}$ and a numerical parameter, $a_{H,}$ that depends on the building inertia, according to the following equation:

if $\gamma_H \neq 1$: $$\eta_{G,H} = \frac{1-\gamma_H^{a_H}}{1-\gamma_H^{a_H+1}}$$

if $\gamma_H = 1$: $$\eta_{G,H} = \frac{a_H}{a_H+1}$$

with

$$\gamma_H = \frac{Q_{G,H}}{Q_{L,H}}$$

where (for each month and for each building zone)

h_{GH} is the dimensionless gain utilisation factor for heating;

γ_H is the dimensionless gain/loss ratio for the heating mode:

$Q_{L,H}$ are the total heat losses for the heating mode, in MJ;

$Q_{G,H}$ are the total heat gains for the heating mode, in MJ;

a_H is a dimensionless numerical parameter depending on the time constant, τ_H, defined by:

$$a_H = a_{0,H} + \frac{\tau_H}{\tau_{0,H}}$$

where

$a_{0,H}$ is a dimensionless reference numerical parameter, determined according to Table 26;

τ_H is the time constant for heating of the building zone, in hours, determined according to Section 12.1.15;

$\tau_{0,H}$ is a reference time constant, from Table 26, in hours.

Type of building		$a_{0,H}$	$\tau_{0,H}$ (h)
I	Continuously heated buildings (more than 12 hours per day) such as residential buildings, hotels, hospitals, homes and penitentiary buildings	1,0	15
II	Building heated during day-time only (less than 12 h per day) such as education, office and assembly buildings and shops	0,8	70

Table 26: Values of the numerical parameter $a_{0,H}$ and reference time constant $t_{0,H}$ for heating

NOTE: The gain utilisation factor is defined independently of the heating system characteristics, assuming perfect temperature control and infinite flexibility. A slowly responding heating system and a less-than-perfect control system can significantly affect the use of gains.

12.1.14. Loss utilisation factor for cooling

The loss utilisation factor for cooling, h_C, is a function of the loss/gain ratio, λ_C, and a numerical parameter, a_C, that depends on the building thermal inertia, according to the following equation:

if $\lambda_C > 0$ and $\lambda_C \neq 1$: $$\eta_{L,C} = \frac{1 - \lambda_C^{a_C}}{1 - \lambda_C^{a_C+1}}$$

if $\lambda_C = 1$: $$\eta_{L,C} = \frac{a_C}{a_C + 1}$$

if $\lambda_C < 0$: $$\eta_{L,C} = 1$$

with

$$l_C = \frac{Q_{L,C}}{Q_{G,C}}$$

where (for each month and each building zone)

$h_{L,C}$ is the dimensionless utilisation factor for heat losses;

l_C is the dimensionless loss-gain ratio for the cooling mode;

$Q_{L,C}$ are the total heat losses for the cooling mode, in MJ;

$Q_{G,C}$ are the total heat gains for the cooling mode, in MJ;

a_C is a dimensionless numerical parameter depending on the time constant, t_C, defined by:

$$a_C = a_{0,C} + \frac{\tau_C}{\tau_{0,C}}$$

where

$a_{0,C}$ is a dimensionless reference numerical parameter, determined according to Table 27;

τ_C is the time constant for cooling of the building zone, in hours; determined according to Section 12.1.15.

$\tau_{0,C}$ is a reference time constant, from Table 27, in hours.

Type of building		$a_{0,C}$	$\tau_{0,C}$ (h)
I	Continuously cooled buildings (more than 12 hours per day) such as residential buildings, hotels, hospitals, homes and penitentiary buildings	1,0	15
II	Building cooled during day-time only (less than 12 h per day) such as education, office and assembly buildings and shops	1,0	15

Table 27: Values of the numerical parameter $a_{0,H}$ and reference time constant $t_{0,H}$ for cooling

NOTE: The loss utilisation factor is defined independently of the cooling system characteristics, assuming perfect temperature control and infinite flexibility. A slowly responding cooling system and a less-than-perfect control system may significantly affect the utilisation of the losses.

12.1.15. Building time constant for heating and cooling mode

This time constant for the heating mode, τ_H, characterises the internal thermal inertia of the heated space during the heating period. It is calculated from:

$$\tau_H = \frac{C_m / 3,6}{H_{L,H}}$$

where

τ_H is the time constant of the building zone for the heating mode, in hours;

C_m is the effective thermal capacity of the building zone, in kJ/K, determined according to Section 12.1.15.1;

$H_{L,H}$ is the heat loss coefficient of the building zone for the heating mode, in W/K.

3.6 is introduced to convert the effective thermal capacity from kJ to Wh.

Similarly, the time constant for the cooling mode, τ_C, characterises the internal thermal inertia of the cooled space during the cooling period. It is calculated from:

$$\tau_C = \frac{C_m / 3,6}{H_C}$$

where

τ_C is the time constant of the building or building zone for the cooling mode, in hours;

C_m is the effective thermal capacity of the building zone, in kJ/K, determined according to Section 12.1.15.1;

H_C is the heat loss coefficient of the building zone for the cooling mode, in W/K;

3.6 is introduced to convert the effective thermal capacity from kJ to Wh.

12.1.15.1. Effective thermal capacity of the building zone

The effective thermal capacity of the building zone, C_m, is calculated by summing the heat capacities of all the building elements in direct thermal contact with the internal air of the zone under consideration:

$$C_m = \sum \chi_j A_j = \sum_j \sum_i \rho_{ij} c_{ij} d_{ij} A_j$$

where

C_m is the effective thermal capacity, in kJ/K;

k_j is the internal heat capacity per area of the building element j, in kJ/(m²·K);

A_j is the area of the element j, in m²;

r_{ij} is the density of the material of the layer i in element j, in kg/m³;

c_{ij} is the specific heat capacity of the material of layer i in element j, in kJ/(kg·K);

d_{ij} is the thickness of the layer i in element j, in m.

The sum is done for all layers of each element, starting from the internal surface and stopping at the first insulating layer, the maximum thickness given in Table 28, or the middle of the building element; whichever comes first.

Application	Maximum thickness m
Determination of the gain or loss utilisation factor	0,10
Effect of intermittence	0,03

Table 28: Maximum thickness to be considered for internal heat capacity

12.1.16. Set-points and corrections for intermittency, heating mode

For continuous heating or cooling during the whole heating or cooling period, θ_i, the set-point temperature (degrees Celsius) from the Activity database is used as internal temperature of the building zone.

NOTE: The real mean indoor temperature may be higher in the heating mode, due to instantaneous overheating. However, this is taken into account by the gain utilisation factor. Similarly for the cooling mode, the real mean indoor temperature may be lower, due to instantaneous high heat losses.

When intermittent heating is applied, an adjusted set-point temperature is calculated, taking into account normal heating periods alternating with reduced heating periods (e.g., nights, week-ends, and holidays).

The adjusted internal temperature, θ_i, is the constant internal temperature, which would result in the same heat loss as that obtained with intermittent heating during the period. All the normal heating periods shall have the same set-point temperature.

There can be several types of reduced heating periods with different patterns. Within each calculation period, each type of reduced heating period is characterised by:

- its duration;
- the number of occurrences of that type of period in one calculation period;
- the relevant mode of intermittence;
- where relevant, the set-back temperature.

The method is not applicable for complex cases, such as cases with periods with reduced heating power and/or a boost mode, with a maximum heating power during the boost period.

There are three relevant modes of intermittency:

O) set-point temperature variations between normal heating and reduced heating periods are less than 3 K: in this case, time average of set-point temperatures may be used;

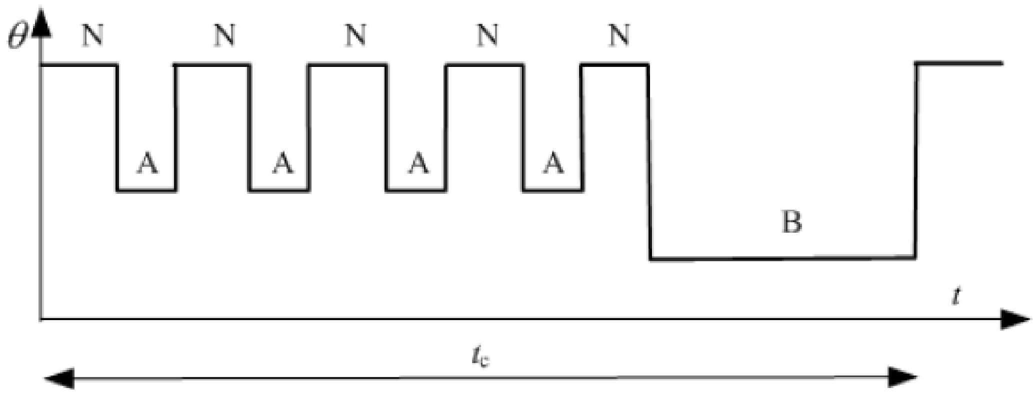
A) the time constant of the building is greater than three times the duration of the longest reduced period: in this case, the normal set-point temperature may be used for all periods;

B) the time constant of the building is less than 0.2 times the duration of the shortest reduced heating period: in this case, the time average of set-point temperatures may be used.

If the time constant of the building does not fulfil mode B, nor mode A, the adjusted temperature are calculated by linear interpolation, on the basis of the actual time constant and the two limit values for mode A and mode B.

The heating system is supposed to deliver sufficient heating power to enable intermittent heating.

An example is shown in Figure 8, where the calculation period includes four reduced heating periods of mode A (e.g. nights) and one reduced heating period of mode B (week-end).



Key

θ set-point temperature

t time

t_c calculation period

N normal heating period

A reduced heating period mode A

B reduced heating period mode B

Figure 8: Example of intermittence pattern

12.1.17. Set-points and corrections for intermittency, cooling mode

NB: Intermittence calculation for cooling has been temporarily disabled in SBEM due to some concerns regarding the related algorithm in the CEN standard.

Due to the diurnal pattern of the weather and the effect of the building thermal inertia, an evening/night thermostat set-back or switch-off has in general a relatively much smaller effect on the energy demand for cooling than a thermostat set-back or switch-off has on the heating energy demand. This leads to differences in the calculation procedures.

NOTE: This implies that a thermostat set-back or switch-off during evening/night will result in only a small or no decrease in energy demand for cooling, unless during very warm months or in the case of high internal gains, in combination with small heat losses. For longer periods of intermittency or switch-off (weekends, holidays), the approach can be similar to the approach for the heating mode.

The energy demand for cooling in case of intermittent cooling is calculated according to:

$$Q_{NC} = a_{interm,C} \cdot Q_{NC,N}$$

where

Q_{NC} is the energy demand for cooling, taking account of intermittency, in MJ;

$Q_{NC,N}$ is the energy demand for cooling, assuming for all days of the month, the control and thermostat settings for the normal cooling period, in MJ;

$a_{interim,C}$ is the dimensionless correction factor for intermittent cooling;

NOTE: In case of zero cooling during the intermittency period, Q_{NC} is simply zero.

The dimensionless correction factor for intermittent cooling, $a_{Interim,C}$, is calculated as follows:

$$a_{nterim,C} = 1 - b_{interim,C} \; (\tau_{0,C} / \tau_C) \; (1 / \lambda_C) \; (1 - f_{N,C})$$

with minimum value: $a_{interim,C} = f_{N,C}$

where

$a_{interim,C}$ is the dimensionless correction factor for intermittent cooling;

$f_{N,C}$ is the fraction of the number of days in the month with normal cooling mode (e.g., 10/31);

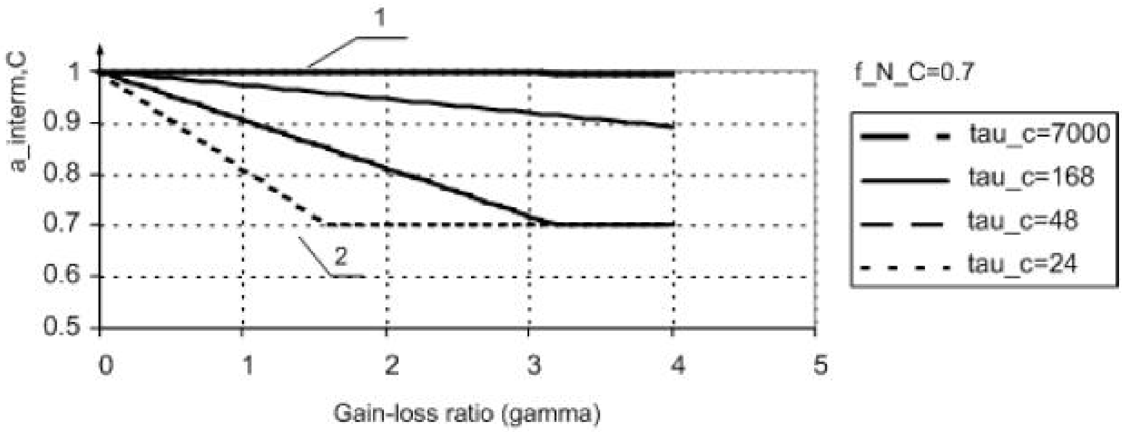
$b_{interim,C}$ is an empirical correlation factor; value $b_{interim,C} = 3$;

t_C is the time constant of the building or building zone for the cooling mode, in hours;

$t_{0,C}$ is the reference time constant for the cooling mode, in hours;

l_C is the dimensionless loss-gain ratio for the cooling mode.

NOTE: In a simple but robust way, the correction factor takes into account the fact that the impact of the intermittency on the energy demand for cooling is a function of the length of the intermittency period, the amount of heat gains compared to the amount of heat losses (gain/loss ratio), and the building inertia.



Key

1 High inertia

2 Low inertia

Figure 9: Example of intermittence factor for cooling

12.1.18. Annual energy demand for heating and cooling, per building zone

The annual energy demand for heating and cooling for a given building zone is calculated by summing the calculated energy demand per period, taking into account possible weighting for different heating or cooling modes.

$$Q_{\mathrm{NH,yr}} = \sum_i Q_{\mathrm{NH},i} \text{ and } Q_{\mathrm{NC,yr}} = \sum_j Q_{\mathrm{NC},j}$$

where

$Q_{\mathrm{NH,yr}}$ is the annual energy demand for heating of the considered zone, in MJ;

$Q_{\mathrm{NH},i}$ is the energy demand for heating of the considered zone per month, in MJ;

$Q_{\mathrm{NC,yr}}$ is the annual energy demand for cooling of the considered zone, in MJ;

$Q_{\mathrm{NC},j}$ is the energy demand for cooling of the considered zone per month, in MJ.

12.1.19. Annual energy demand for heating and cooling, per combination of systems

In case of a multi-zone calculation (with or without thermal interaction between zones), the annual energy demand for heating and cooling for a given combination of heating, cooling, and ventilation systems servicing different zones is the sum of the energy demands over the zones, zs, that are serviced by the same combination of systems:

$$Q_{\mathrm{NH,yr},zs} = \sum_z Q_{\mathrm{NH,yr},z} \text{ and } Q_{\mathrm{NC,yr},zs} = \sum_z Q_{\mathrm{NC,yr},z}$$

where

$Q_{\mathrm{NH,yr},zs}$ is the annual energy demand for heating for all building zones, zs, serviced by the same combination of systems, in MJ;

$Q_{\mathrm{NH,yr},z}$ is the annual energy demand for heating of zone, z, serviced by the same combination of systems, in MJ;

$Q_{NC,yr,zs}$ is the annual energy demand for cooling for all building zones, zs, serviced by the same combination of systems in MJ;

$Q_{NC,yr,z}$ is the annual energy demand for cooling of zone, z, serviced by the same combination of systems, in MJ.

12.1.20. Total system energy use for space heating and cooling and ventilation systems

In case of a single combination of heating, cooling, and ventilation systems in the building, or per combination of systems, the annual energy use for heating, $Q_{sys,H}$, and the annual energy use for cooling, $Q_{sys,C}$, including system losses, are determined as a function of the energy demands for heating and cooling in the following way: as energy loss and auxiliary energy of the system, $Q_{sys\_loss,H,i}$ and $Q_{sys\_aux,H,i}$ and $Q_{sys\_loss,C,i}$ and $Q_{sys\_aux,C,i}$ per energy carrier i, expressed in MJ. The losses and auxiliary energy comprise generation, transport, control, distribution, storage, and emission.

12.1.21. Reporting results

For each building zone and each month, the following results are reported:

For heating mode:

- Total heat transfer by transmission;
- Total heat transfer by ventilation;
- Total internal heat sources;
- Total solar heat sources;
- Energy demand for heating.

For cooling mode:

- Total heat transfer by transmission;
- Total heat transfer by ventilation;
- Total internal heat sources;
- Total solar heat sources;
- Energy demand for cooling.

For the whole building, the annual energy used for heating and cooling is reported.

12.2. Ventilation demand

12.2.1. Heat transfer by ventilation, heating mode

For every month, the heat transfer by ventilation, $Q_{V\text{-}heat}$, is calculated as

$$Q_{v-heat} = H_{V-heat} \bullet (q_i - q_e) \bullet n \bullet 0.0864$$

where

Q_{V-heat} is the heat transfer by ventilation, in MJ

H_{V-heat} is the ventilation heat loss coefficient, in W/K

q_i is the internal (indoor) temperature (the heating set-point taken from the NCM Activity database for the activity zone where the envelope belongs)

q_e is the external (outdoor) temperature (the monthly average temperature obtained from the hourly weather data for the location), in K

n is the number of days within a month

0.0864 is a conversion factor

12.2.1.1. Ventilation heat loss coefficient

$$H_{V-heat} = r_a \bullet c_a \bullet u_{v-heat} \bullet A$$

where

H_{V-heat} is the ventilation heat loss coefficient, in W/K

$r_a \bullet c_a$ is the air heat capacity per volume ~ 1.2 kJ/m^{3}K (product of the air density, in kg/m^3, and the air specific heat capacity, in kJ/kgK).

u_{v-heat} is the air flow rate through the conditioned space, in l/sm^2 floor area

A is the zone floor area, in m^2

12.2.1.2. Ventilation air flow rate

$$u_{v-heat} = u_{v-\inf} / 3.6 + (1 - h_{HR}) \bullet u_{v,m,heat} + u_{v,n,heat}$$

where

u_{v-heat} is the air flow rate through the conditioned space, in l/sm^2 floor area

$u_{v-\inf}$ is the air flow rate through the conditioned space due to infiltration, converted by dividing by 3.6 from m^3/hm^2 to l/sm^2 floor area

h_{HR} is the efficiency of the heat recovery system. The default values are shown in Table 29, which can be over-ridden by the user.

$u_{v,m,heat}$ is the air flow rate through the conditioned space resulting from mechanical ventilation during operation time, in l/sm^2 floor area. This value has been obtained using the ventilation requirements as established in the NCM Activity database for each type of activity.

$u_{v,n,heat}$ is the air flow rate through the conditioned space resulting from natural ventilation, in l/sm^2 floor area. This value has been obtained using the ventilation requirements as established in the NCM Activity database for each type of activity.

Heat recovery system	Efficiency
Plate heat exchanger (Recuperator)	0.65
Heat-pipes	0.6
Thermal wheel	0.65
Run around coil	0.5

Table 29: Default efficiencies of the heat recovery systems

12.2.2. Heat transfer by ventilation, cooling mode

For every month, the heat transfer by ventilation $Q_{V\text{-}cool}$ is calculated as

$$Q_{v-cool} = H_{V-cool} \bullet (q_i - q'_e) \bullet n \bullet 0.0864$$

where

$Q_{V\text{-}cool}$ is the heat transfer by ventilation, in MJ

$H_{V\text{-}cool}$ is the ventilation heat loss coefficient, in W/K

q_i is the internal (indoor) temperature (the cooling set-point taken from the NCM Activity database for the activity zone where the envelope belongs)

q'_e is the modified external air temperature as appearing in Table 30;

n are the number of days within a month, in days

0.0864 is a conversion factor

Month	q'_e (°C)
January	16.0
February	16.0
March	16.0
April	16.0
May	16.0
June	17.0
July	18.5
August	18.3
September	16.0
October	16.0
November	16.0
December	16.0

Table 30: Values used for the temperature of the supply air for the calculation of monthly ventilation losses for cooling demand

12.2.2.1. <u>Ventilation heat loss coefficient</u>

$$H_{V-cool} = r_a \bullet c_a \bullet u_{v-cool} \bullet A$$

where

$H_{V\text{-}heat}$ is the ventilation heat loss coefficient, in W/K

$r_{a\bullet}c_a$ is the air heat capacity per volume ~ 1.2 kJ/m^{3}K (product of the air density, in kg/m^3, and the air specific heat capacity, in kJ/kgK).

u_{v-cool} is the air flow rate through the conditioned space, in l/sm^2 floor area

A is the zone floor area, in m^2

12.2.2.2. Ventilation air flow rate

$$u_{v-cool} = u_{v-\inf} / 3.6 + u_{v,m}$$

where

u_{v-cool} is the air flow rate through the conditioned space, in l/sm^2 floor area

$u_{v-\inf}$ is the air flow rate through the conditioned space due to infiltration, converted by dividing by 3.6 from m^3/hm^2 to l/sm^2 floor area

$u_{v,m}$ is the air flow rate through the conditioned space resulting from mechanical ventilation during operation time, in l/sm^2 floor area. This value is given by the ventilation requirements as established in the NCM Activity database for each type of activity.

12.2.3. Infiltration air flow rate (heating and cooling)

This methodology has been extracted from the CEN standards EN 15242. When it can be assumed that there is no interaction between the ventilation system (e.g., mechanical system) and the leakages impact, a simplified approach can be used to calculate the infiltrated and exfiltrated values as follows.

Calculate the air flow through the envelope due to the stack impact, $u_{v\text{-}inf\text{-}stack}$, and the wind impact, $u_{v\text{-}inf\text{-}wind}$, without considering mechanical or combustion air flows.

Calculate infiltration due to the stack effect ($u_{v\text{-}inf\text{-}stack}$)

For each external envelope, the air flow due to the stack impact is calculated using the following equation:

$$u_{v-\inf-stack} = 0.0146 \bullet Q_{4Pa} \bullet (h_{stack} \bullet abs(q_e - q_i))^{0.667} \text{ [m}^3\text{/hm}^2 \text{ outer envelope]}$$

where:

Q_{4Pa} is the air leakage characteristics for a pressure difference of 4 Pa, in m^3/hm^2 of outer envelope, i.e., the average volume of air (in m^3/h) that passes through unit area of the building envelope (in m^2) when subject to an internal to external pressure difference of 4 Pascals. The value input by the user is the air flow for a pressure difference of 50 Pa and is converted to air flow for a pressure difference of 4 Pa using the information in Table 31, before being used in the above equation. The outer envelope area of the building is defined as the total area of the floor, walls, and roof separating the interior volume from the outside environment.

The conventional value of h_{stack} is 70% of the zone height H_z.

abs is the absolute value.

θ_e is the external (outdoor) temperature (the monthly average obtained from the hourly weather data for the location).

θ_i is the internal (indoor) temperature(the heating set-point taken from the NCM Activity database for the activity zone where the envelope belongs)

			m3/h per m2 of outer enveloppe (exp n = 0.667)	
	leakages level	Q4Pa	Q10Pa	Q50Pa
single family	low	0.5	1	2.5
	average	1	2	5
	high	2	3.5	10
multi family ; non residential except industrial	low	0.5	1	2.5
	average	1	2	5
	high	2	3.5	10
industrial	low	1	2	5
	average	2	3.5	10
	high	4	7	20

		n (vol.h) (exp n=0.667)			outer
	leakages level	n4Pa	n10Pa	n50Pa	area/vol
single family	low	0.4	0.8	1.9	0.75
	average	0.8	1.5	3.8	0.75
	high	1.5	2.6	7.5	0.75
multi family ; non residential except industrial	low	0.2	0.4	1.0	0.4
	average	0.4	0.8	2.0	0.4
	high	0.8	1.4	4.0	0.4
industrial	low	0.3	0.6	1.5	0.3
	average	0.6	1.1	3.0	0.3
	high	1.2	2.1	6.0	0.3

			m3/h per m2 of floor area (exp n = 0.667)		outer area /
	leakages level	Q4Pa	Q10Pa	Q50Pa	floor area
single family	low	0.9	1.8	4.5	1.8
	average	1.8	3.6	9.0	1.8
	high	3.6	6.3	18.0	1.8
multi family ; non residential except industrial	low	0.6	1.1	2.8	1.1
	average	1.1	2.2	5.5	1.1
	high	2.2	3.9	11.0	1.1
industrial	low	1.5	3.0	7.5	1.5
	average	3.0	5.3	15.0	1.5
	high	6.0	10.5	30.0	1.5

Table 31: Examples of leakages characteristics

Calculate infiltration due to the wind impact ($u_{v\text{-}inf\text{-}wind}$)

For each external envelope, the air flow due to the wind impact is calculated as

$$u_{v-\inf-wind} = 0.0769 \bullet Q_{4Pa} \bullet (\Delta C_p \bullet V_{site}{}^2)^{0.667} \quad \text{[m}^3\text{/hm}^2 \text{ outer envelope]}$$

where:

Q_{4Pa} is the same as defined above.

ΔC_p is the wind pressure coefficient defined as:

- for vertical walls: the wind pressure coefficient difference between the windward and leeward sides for a given wind direction. The conventional value of ΔC_p is 0.75.
- for roofs: the wind pressure coefficient at the roof surface.
  - flat roof: ΔC_p is averaged to 0.55
  - pitched roof: ΔC_p is averaged to 0.35

V_{site} is the wind speed at the building in m/s defined as:

- for vertical walls: average wind speed for a wind sector of ±60º to the external wall axis (orientation)
- for roofs: wind speed considering all wind sectors

Then, for each zone, the air flow contributions of all its external envelopes due to the wind impact are totalled.

Calculate the resulting air flow, u_{v-sw}, for each zone using the following equation:

$$u_{v-sw} = \max(u_{v-\inf-stack}, u_{v-\inf-wind}) + \frac{0.14 \bullet u_{v-stack} \bullet u_{v-\inf-wind}}{Q_{4Pa}} \quad \text{[m}^3\text{/hm}^2 \text{ outer envelope]}$$

where:

$u_{v-inf-stack}$ is the air flow contributions of all external envelopes due to the stack impact totalled for the zone, in m^3/hm^2.

$u_{v-inf-wind}$ is the air flow contributions of all external envelopes due to the wind impact totalled for the zone, in m^3/hm^2.

Q_{4Pa} is the same as defined above.

As an approximation, the infiltered part, u_{v-inf}, can be defined using the following equation:

$$u_{v-\inf} = \max(0, u_{v-diff}) + u_{v-sw} \quad \text{[m}^3\text{/hm}^2 \text{ outer envelope]}$$

where:

u_{v-diff} is the difference between supply and exhaust air flows (calculated without wind or stack effect).

However, this simplified approach does not take into account the fact that if there is a difference between supply and exhaust, the zone is under-pressurised or over-pressurised. Therefore:

$u_{v\text{-}inf} = u_{v\text{-}sw}$ [m^3/hm^2 outer envelope]

At the same time, the resulting air flow is converted to be per unit floor area.

$$u_{v-\inf} = u_{v-sw} \bullet \frac{A_{env}}{A_{zone}}$$ [m^3/hm^2 floor area]

where:

A_{env} is the total area of the outer envelopes defined as the total area of the floor, walls, and roof separating the interior volume of the specific zone from the outside environment, in m^2.

A_{zone} is the floor area of the zone, in m^2.

12.2.4. Outputs produced

$Q_{v\text{-}heat}$: heat transfer by ventilation for the heating requirements calculations.

$Q_{v\text{-}cool}$: heat transfer by ventilation for the cooling requirements calculations.

12.3. Hot water demand

Demand for each zone is calculated as:

Hot water Demand (MJ/month) = *Database demand * 4.18 /1000 * zone AREA * ΔT*

where

Database demand is the hot water demand from the Activity database, in l/m^2 per month.

ΔT is the temperature difference (deg K that water is heated up), taken as 50°K.

4.18 /1000 is the specific heat capacity of water in MJ/kgK

zone AREA in m^2

Calculate distribution loss for each zone for each month (MJ/month):

If the dead leg length in the zone is greater than 3m, then distribution losses are calculated as:

Distribution loss = 0.17 Hot water demand*

where

0.17 is the default monthly hot water system distribution loss (MJ/month) per monthly hot water energy demand (MJ/ month)

For each Hot Water System (HWS):

- Carry out calculations for each solar energy system serving the HWS to calculate SES contribution to HWS, used to reduce hot water demand;

- Evaluate hot water demand, area served, and distribution losses for HWS using:
    - o Sum monthly demand for all zones served by HWS;
    - o Sum monthly distribution losses for all zones served by HWS;
    - o Sum area of all zones served by HWS;
- Evaluate earliest start time and latest end time for any zone served HWS;
- Account for contribution from solar energy system, Section 12.9, if applicable;
- Account for contribution from CHP, if applicable.

12.3.1. Hot Water storage

If the hot water system includes storage, and the storage volume has not been input by the user, then the storage volume is calculated as:

Storage volume (litres) = *Daily demand* (MJ/day) * *18*

where

Daily demand = Maximum monthly demand / Number of days in the month

18 is a computational value – storage volume is *18* litres per MJ of daily demand

If the storage losses have not been input by the user, then storage losses are calculated as:

Storage losses (MJ/month) = *Daily storage loss (kWh/litre of storage)*(Storage volume5)*$^{1/3}$ **(365/12)*(Storage volume)*$^{2/3}$ ** 3.6*

where

Daily storage loss is the storage losses per day in kWh per litre of storage and is calculated as follows:

- for an uninsulated storage vessel: *0.1425* kWh/day per litre of storage
- for a vessel with loose jacket of insulation thickness *t* mm: *0.005 + 1.76/(t+12.8)*
- for a vessel with factory fitted insulation of thickness *t* mm: *0.005 + 0.55/(t + 4)*

Storage volume5 is the storage volume, in litres, if the annual hot water demand were 5 MJ/m^2, i.e., it is calculated as = *(5/365)*36*Area served*

365/12 is multiplication by the number of days and division by the number of months in order to obtain the monthly storage losses.

Storage volume is the hot water storage volume, in litres, as calculated above or as input by the user.

3.6 is a factor to convert the storage losses from kWh to MJ.

12.3.2. Secondary circulation

If the HWS includes a secondary circulation, then if not input by the user, the secondary circulation loop length is calculated as:

Loop length = sqrt(Area served) 4.0*

where

Area served is the total area served by the HWS, in m^2.

4.0 is a computational value.

The secondary circulation losses are calculated as:

Secondary circulation losses (MJ/month) = *Losses per metre* (W/m) * *Loop length* (m) * *Hours of operation * Numbers of days in month * 3.6/1000*

where

Losses per metre is the secondary circulation losses per metre, taken as 15 W/m of secondary circulation loop length if it is not input by the user;

Loop length is the secondary circulation loop length in m;

Hours of operation number of hours of daily operation of the HWS;

3.6/1000 to convert W to kWh and then kWh to MJ;

The secondary circulation pump power, if not input by the user, is calculated as:

Secondary circulation pump power (kW) = (*0.25 * Loop length + 42*) / *500*

where

Loop length is the secondary circulation loop length, in m;

0.25, 42, and *500* are computational values;

The secondary circulation pump energy is then calculated by multiplying the pump power by the hours of operation of the HWS.

12.4. Lighting energy use

Lighting energy is calculated according to CEN EN 15193-1. Inputs to this calculation include lighting power, duration of operation including the impact of occupancy, and terms to deal with the contribution of daylight under different control regimes.

Equation for lighting:

$$W_{light} = \frac{\sum_{j=1}^{12}\left[N_j \times \left(\sum_{i=1}^{24}\left[P_j\left(F_{Dji} \times F_{Oji}\right)\right] + 24 \times \left(P_p + P_{dj} \times F_{Od}\right)\right)\right]}{1000} \ {}^{kWh}\!/_{m^2 year}$$

With:

N_j = [31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]. Number of days in each month

P_j = Lighting power in W/m^2 for each hour of month *j*

P_p = Parasitic power in W/m^2 hour

P_{dj} = Display lighting power in W/m^2 for each hour of month *j*

F_{Dji} = Daylight correction factor (utilisation factor) for hour *i* of month *j*

F_{Oji} = Occupancy correction factor for hour *i* of month *j*

F_{Od} = Occupancy correction factor for display lighting throughout the year

12.4.1. Calculate lighting power in the actual and reference buildings, P_j

For the actual building

- **Where lighting parameters are not available:**

  1. Find the notional illuminance in each space from the Activity database.
  2. Obtain the installed power by dividing by 100, then multiplying by the standard factor from Table 35 for that particular lighting system type and by the floor area of the space.

- **Where a full lighting design has been carried out:**

  1. Use the actual lighting circuit wattage, multiply it by the illuminance level for this zone from the Activity database, divide it by the illuminance level for which the lighting design was carried out, and divide it by the zone area.

- **Where lighting has been chosen but a full illuminance calculation has not been carried out:**

  For office storage and industrial spaces:

  1. This option is not permitted.

  For all other spaces:

  1. Take the same installed power as the reference building (see below).
  2. Multiply by 50, and divide by the average lamp and ballast efficacy (in lamp lumens per circuit Watt).

For the reference building

1. Find the notional illuminance in each space from the Activity database.
2. Obtain the installed power by dividing by 100, then multiply by 3.75 W/m^2/100lux (for office, storage and industrial spaces) or 5.2 W/m^2/100lux (for all other spaces) and by the floor area of the space.

12.4.2. Calculate display lighting power in the actual and reference buildings, P_{dj}

For the actual building

1. Take the same installed power as the reference building (see below).

2. If the user wants to take credit for using efficient lamps, multiply by 15, and divide by the average lamp and ballast efficacy (in lamp lumens per circuit Watt).

For the reference building

1. Take the notional display lighting power density for that space type from the Activity database, then multiply by the floor area of the space.

Local manual switching should be used for the reference building, except for display lighting which is assumed to be always on [unless a time switch switches it off].

12.4.3. Calculate parasitic power, P_p

Unless actual data are supplied, the parasitic power loading P_p is assumed to be:

- Manual switching: 0 W/m^2
- Photocell control: default for digitally addressable systems = 0.57 W/m^2, default for stand alone sensors = 0.3 W/m^2, or user can specify value for system used.
- Occupancy sensing: default = 0.3 W/m^2, or user can specify value for system used.

12.4.4. Calculate daylight correction factor, F_{Dji}

The daylight impact factor (utilization factor), F_D, is the lighting use in a space, expressed as a fraction of that with no daylight contribution.

12.4.4.1. Daylight penetration

This is expressed in terms of the average daylight factor (DF). It can also be used with rooflights. The average daylight factor in SBEM is assumed to be:

- For side windows: $DF = DF_1 = 45\ W_{win}/A$
- For spaces with horizontal or shed type rooflights: $DF = DF_2 = 90\ W_{roof}/A$
- For both side windows and rooflights: $DF = DF_1 + DF_2$

Where W_{win} is the total window area including frame, W_{roof} is the total rooflight area including frame, and A is the area of all room surfaces (ceiling, floor, walls and windows).

These figures are for clear low-e double glazing. If tinted glazing is used, multiply by the manufacturer’s normal incidence light transmittance and divide by 0.76.

Calculate the daylight factor for front and back of room:

DF_F is average daylight factor in front half of room (%)
$DF_F = 1.75 \times DF$

DF_B is average daylight factor in back half of room (%)
$DF_B = 0.25 \times DF$

12.4.4.2. Photoelectric control

Calculate the utilisation factor:

For zones that are daylit by windows in only one orientation, the utilisation factor should take account of the difference in control between the front and back of the zone as follows:

If the photo sensor is in the front only, then: $F_D = (F_{D,F} + 1) / 2$

If the photo sensor is in the front and back, then: $F_D = (F_{D,F} + F_{D,B}) / 2$

For zones with rooflights or with windows in opposite orientations, where the difference in azimuth is 175º or more, and the ratio of the daylight contribution between the opposite sides is less than 3:1, then the utilisation factor is calculated as:

$$F_D = (F_{D,F} + F_{D,B}) / 2$$

where

$F_{D,F}$ is the utilisation factor for the front half of the room
$F_{D,B}$ is the utilisation factor for the back half of the room

and they are calculated according to the type of lighting control as follows:

Photoelectric switching:

E_{ext} is the external illuminance (in kLux) - currently limited to Kew illuminance data - from Table 33.
E_{design} is the design illuminance (in Lux)

Front half of room:

If $E_{ext} \times DF_F \times 10 > E_{design}$ then $F_{D,F} = 0$

Elseif: $E_{ext} \times DF_F \times 10 > 0.5 \times E_{design}$ then $F_{D,F} = 0.5$

Else: $F_{D,F} = 1$

Back half of room:

IF: $E_{ext} \times DF_B \times 10 > E_{design}$ then $F_{D,B} = 0$

Elseif: $E_{ext} \times DF_B \times 10 > 0.5 \times E_{design}$ then $F_{D,B} = 0.5$

Else: $F_{D,B} = 1$

Photoelectric dimming

Front half of room:

If: $E_{ext} \times DF_F \times 10 > E_{design}$ then $F_{D,F} = 0$

Else: $F_{D,F} = (E_{design} – E_{ext} \times DF_F \times 10) / E_{design}$

Back half of room:

If: $E_{ext} \times DF_B \times 10 > E_{design}$ then $F_{D,B} = 0$

Else: $F_{D,B} = (E_{design} - E_{ext} \times DF_B \times 10) / E_{design}$

[In normal operation, their residual light output and power consumption will occur throughout working hours unless (future modifications to SBEM) the circuit is switched off by the occupants, an occupancy sensor, or a time switch.]

12.4.4.3. Manual switching

This only applies where there is local manual switching, i.e.,

- maximum distance from a switch to the luminaire it controls is 6m or twice the luminaire mounting height if this is greater
- or if the area of the room is less than $30m^2$
- It does not apply in corridors or other circulation areas, dry sports/fitness, ice rinks, changing rooms, swimming pools, sales areas, baggage reclaim areas, security check areas, eating/drinking areas, halls, lecture theatres, cold stores, display areas, A and E, industrial process areas, warehouse storage, and performance areas (stages) for which F_D=1

A manual switching choice is only assumed to occur when either:

- the building is occupied for the first time in the day
- (not currently included in SBEM) a period when the lighting is required follows a period when the lighting is not required
- (not currently included in SBEM) following a period when the space has been completely unoccupied for at least an hour; or
- (not currently included in SBEM) an overriding time switch has switched off the lighting.]

Following such an event, F_D is calculated as follows:

If: $E_{ext} \times DF \times 10 > E_{design}$ then $F_D = 0.5$

Else: $F_D = 1$

12.4.4.4. Manual plus photoelectric control

F_D is calculated for each control separately. Then the minimum of the two F_D values is taken.

12.4.5. Occupancy correction, F_{Oji}

If the building is occupied but there is no requirement for lighting (e.g., a hotel room or hospital ward at night), F_O = 0

At other times, F_O equals 1 if the lighting is switched on 'centrally' (this is assumed in SBEM if there is no manual switching or photoelectric control, the following 3 points are not checked directly by SBEM):

- more than 1 room at once
- or if the area illuminated by a group of luminaires that are switched together, is larger than 30 m^2.
- Exceptions are meeting rooms where this area limitation does not apply.

In corridors and other circulation areas and sales and display areas, F_O equals 1 even if occupancy sensing or manual control is provided, unless a time switch switches off the lighting.

12.4.5.1. Local occupancy sensing

$F_{Oi} = F_{OC}$ (i means for each hour in the calculation)

In these expressions F_{OC} is given in Table 34. System types are defined in the CEN standard PrEN 15193: *Energy performance of buildings — Energy requirements for lighting*.

12.4.6. Time switching – used for display lighting only – calculate F_{Od}

Automatic time switch:

- switches a fraction f of the lighting off during a number of hours h_{off}
  => $F_0 = (1-f) \times h_{off}/24 + (24-h_{off})/24$.
- dims the lighting to a fraction f of its total illuminance during a number of hours h_{off}
  => $F_0 = (1- f \times (1-R_w)/(1-R_f)) \times h_{off}/24 + (24-h_{off})/24$

Typical values of R_f and R_w are 0.125 and 0.33 respectively for the longer established form of dimmer.

Times of day and night/ days per month:

t_{start} = Lighting schedule start time
t_{end} = Lighting schedule end time

The Number N of days within each month is given by
[31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]

Sunrise and sunset times:
$t_{sunrise}$ and t_{sunset} are given in the table below.

Month	Sunrise	Sunset
January	7:59	16:21
February	7:14	17:16
March	6:15	18:05
April	6:05	19:57
May	5:09	20:46
June	4:43	21:19
July	5:01	21:11
August	5:46	20:23

September	6:35	19:15
October	7:25	18:07
November	7:19	16:11
December	8:00	15:52

Table 32: tsunrise and tsunset

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
630	0.0	0.2	2.2	2.1	6.8	9.0	7.4	3.7	0.7	0.0	0.0	0.0
730	0.3	2.0	7.3	7.3	13.0	15.1	13.9	9.9	4.5	0.7	0.7	0.1
830	2.2	6.5	12.5	12.6	19.3	20.9	20.0	16.6	11.0	4.2	3.8	1.6
930	5.8	10.6	17.1	18.2	24.7	26.0	26.1	22.6	16.9	9.4	7.8	4.7
1030	8.7	14.0	20.7	22.7	28.7	30.6	31.1	26.9	22.2	13.8	10.9	7.6
1130	10.2	15.3	22.5	26.1	31.0	32.6	34.9	30.6	25.0	17.1	12.6	9.0
1230	10.1	15.9	22.4	27.7	33.6	34.8	36.3	32.9	25.9	18.7	12.6	9.1
1330	8.9	13.7	20.4	27.6	33.8	35.4	35.9	33.1	25.4	19.0	11.0	7.7
1430	6.0	10.9	16.8	26.6	32.6	34.0	34.2	31.8	24.5	17.1	8.2	4.9
1530	2.5	6.7	12.5	24.0	29.1	30.2	31.1	28.3	21.1	14.0	3.9	1.6
1630	0.3	2.0	7.4	18.7	24.4	25.6	26.6	23.1	16.2	9.8	0.6	0.1
1730	0.0	0.2	2.3	13.4	18.9	20.5	20.7	17.0	10.5	4.2	0.0	0.0
1830	0.0	0.0	0.3	7.6	13.2	14.8	14.6	10.5	4.3	0.7	0.0	0.0
1930	0.0	0.0	0.0	2.1	6.8	9.1	8.1	3.8	0.7	0.0	0.0	0.0

Table 33: External illuminances in Kew in kilolux. Outside these times the external illuminance is assumed to be zero

Occupancy Sensing	F_{OC}
Systems without automatic presence or absence detection	
Manual On/Off Switch	1.00
Manual On/Off Switch + additional automatic sweeping extinction signal	0.95
Systems with automatic presence and/or absence detection	
Auto On / Dimmed	0.95
Auto On / Auto Off	0.90
Manual On / Dimmed	0.90
Manual On / Auto Off	0.82

Table 34: F_{OC} values

Lamp Type	Power Density in W/m^2 per 100 Lux	
	Commercial Application	Industrial Application
Tungsten lamp	28	-
Fluorescent - compact	4.6	-
T12 Fluorescent - halophosphate - low frequency ballast	5	3.9
T8 Fluorescent - halophosphate - low frequency ballast	4.4	3.4
T8 Fluorescent - halophosphate - high frequency ballast	3.8	3
T8 Fluorescent - triphosphor - high frequency ballast	3.4	2.6
Metal Halide	5.5	4.1
High Pressure Mercury	7.6	5.7
High Pressure Sodium	4.5	3.3

T5 Fluorescent - triphosphor-coated - high frequency ballast	3.3	2.6
Fluorescent with no details	5	5
Lamp type unknown	28	28

Table 35: Application, lamp type, and power density

12.4.7. Correction for Metering

Apply metering correction of 5% reduction to the lighting energy calculated, if applicable.

12.5. Heating energy use

Heating energy use is determined on a monthly basis for each HVAC system defined in the building. Having calculated the energy demand for heating in each zone of the building (Q_{NH}) as described in section 12.1.7, the heating energy demand for the HVAC system h_i will be the addition of the demand of all the zones attached to that HVAC system (H_d). The heating energy use for the HVAC system h_i (H_e) is then calculated by:

$H_e = H_d / SSEff$

where *SSEff* is the system seasonal efficiency of the heating system as discussed in section 11.3.3.

The building heating energy use will be the addition of the heating energy use of all the HVAC systems included in the building.

12.5.1. Correction for Metering

Apply metering correction of 5% reduction to the heating energy calculated, if applicable.

12.6. Cooling energy use

Cooling energy use is determined on a monthly basis for each HVAC system defined in the building. Having calculated the energy demand for cooling in each zone of the building (Q_{NC}) as described in section 12.1.8, the cooling energy demand for the HVAC system h_i will be the addition of the demand of all the zones attached to that HVAC system (C_d). The cooling energy use for the HVAC system h_i (C_e) is then calculated by:

$C_e = C_d / SSEER$

where *SSEER* is the system seasonal energy efficiency ratio of the cooling system as discussed in section 11.3.3.

The building cooling energy use will be the addition of the cooling energy use of all the HVAC systems included in the building.

12.6.1. Correction for Metering

Apply metering correction of 5% reduction to the cooling energy calculated, if applicable.

12.7. Auxiliary energy use

Auxiliary energy use is calculated on a monthly basis for each zone, depending on its servicing strategy, defined in the building.

12.7.1. Data requirements

Ventilation rate:

- For mechanical ventilation, SBEM uses outside fresh air rates from the Activity Database (for the chosen activity in zone).
- For mechanical exhaust, users need to enter air flow rate.

Specific fan power (SFP):

- Users need to enter the SFP where there is mechanical ventilation, either at zone level or HVAC level.
- Users must also enter the SFP at zone level where there is zonal mechanical exhaust.

12.7.2. Definition of algorithms

The auxiliary energy for each zone is calculated monthly as shown below in (kWh/m^2) and then multiplied by the area of the zone in (m^2), and if applicable, also corrected for the electrical power factor of the building:

12.7.2.1. If the zone has heating only and natural ventilation

Auxiliary energy (kWh/m^2) = *AUX-ENERGY of the HVAC system serving the zone * monthly hours of operation from Activity database / 3255 hours*

where

AUX-ENERGY is an auxiliary energy value calculated in the iSBEM interface, based on a default value for each HVAC system type for 3255 annual hours of operation and adjusted for the input parameters regarding the specific fan power, ductwork and AHU leakages, and system controls.

If there is mechanical exhaust, the following product is added to the above:

*exhaust flow rate * exhaust SFP * monthly hours of operation from Activity database*

12.7.2.2. If the zone has heating and mechanical ventilation

Auxiliary energy (kWh/m^2) = *AUX-ENERGY of the HVAC system serving the zone * monthly hours of operation from Activity database / 3255 hours +*

*outside air flow rate * supply/extract SFP * monthly hours of operation from Activity database*

where

AUX-ENERGY is an auxiliary energy value calculated in the iSBEM interface, based on a default value for each HVAC system type for 3255 annual hours of operation and adjusted for the input parameters regarding the specific fan power, ductwork and AHU leakages, and system controls.

<u>If there is mechanical exhaust, the following product is added to the above:</u>

*exhaust flow rate * exhaust SFP * monthly hours of operation from Activity database*

12.7.2.3. <u>If the zone has heating and cooling</u>

Auxiliary energy (kWh/m^2) = *AUX-ENERGY of the HVAC system serving the zone * monthly hours of operation from Activity database / 3255 hours*

where

AUX-ENERGY is an auxiliary energy value calculated in the iSBEM interface, based on a default value for each HVAC system type for 3255 annual hours of operation and adjusted for the input parameters regarding the specific fan power, ductwork and AHU leakages, and system controls.

<u>If there is mechanical ventilation at HVAC or zone level, then</u>

if the value calculated above is <u>less</u> than the product of:

*outside air flow rate * supply/extract SFP * monthly hours of operation from Activity database*

then

Auxiliary energy (kWh/m^2) = *outside air flow rate * supply/extract SFP * monthly hours of operation from Activity database*

<u>If there is mechanical exhaust, the following product is added to the above:</u>

*exhaust flow rate * exhaust SFP * monthly hours of operation from Activity database*

12.7.2.4. <u>If the zone has no heating or cooling</u>

<u>If there is mechanical ventilation at zone level, then</u>

Auxiliary energy (kWh/m^2) = *outside air flow rate * supply/extract SFP * monthly hours of operation from Activity database*

<u>If there is mechanical exhaust, the following product is added to the above:</u>

*exhaust flow rate * exhaust SFP * monthly hours of operation from Activity database*

12.7.2.5. If the zone has de-stratification fans

In this case, the following is added to the above monthly calculations:

1/3.6 kWh/m^2 (i.e., 1 MJ/m^2)

12.8. Hot water energy use

As described in section 12.3, for each HWS, calculate:

- storage losses
- secondary circulation losses
- secondary circulation pump energy (added to auxiliary energy)

The monthly HWS distribution efficiency is calculated as:

Distribution efficiency = *Hot water demand (MJ/month) / [Hot water demand (MJ/month) + Distribution losses (MJ/month) + Storage losses (MJ/month) + Secondary circulation losses (MJ/month)]*

Calculate hot water energy consumption for the HWS as:

Hot Water energy consumption (MJ/month) = *(Hot water demand / Distribution efficiency) / HWS generator efficiency*

If the hot water system is connected to a solar water heating system and/or a CHP generator, the water heating energy consumption is calculated as:

Hot Water energy consumption (MJ/month) = *((Hot water demand / Distribution efficiency) – Contribution from CHP – Contribution from Solar system) / HWS generator efficiency*

12.9. Solar thermal energy systems

The energy yield given by the solar thermal energy system is calculated according to the collector orientation and inclination. In order to calculate the radiation at the collector plane, the hourly radiation data was processed to yield values of global solar radiation for the orientations and inclinations shown in Table 36 and Table 37, respectively.

For the purposes of SBEM calculations, solar hot water is used to displace the fuel that would otherwise be used by the hot water generator.

12.9.1. Data requirements

General

- HWS which the solar energy system is serving: Specifies the name given by the user for the hot water system (HWS) to which the solar energy system (SES) is connected. This

parameter is needed for the software to know the primary fuel that is being displaced by the solar energy system.

- Area: specifies the solar collector maximum projected area through which un-concentrated solar radiation enters the collector, in m^2
- Orientation: specifies the orientation of the solar collectors
- Inclination: specifies the inclination of the solar collectors in degrees from the horizontal where 0° stands for a horizontal surface and 90° for a vertical surface.

Orientations
N
NE
E
SE
S
SW
W
NW

Table 36: Orientations for which the solar radiation has been calculated

Inclinations
0
15
30
45
60
75
90

Table 37: Inclinations for which the solar radiation has been calculated

Collector parameters

If the collector parameters are known, they should be entered by the user. Otherwise, the default values in Table 38 will be used. The collector parameters are as follows:

- η_0: (sigma-zero) is the zero-loss collector efficiency factor from the collector test standards EN 12975-2 and related to the aperture area.
- a_1: is the linear heat loss coefficient from the collector test standards EN 12975-2 and related to the aperture area, in W/m^2K.
- a_2: is the temperature dependence of the heat loss coefficient from the collector test standards EN 12975-2 and related to the aperture area, in W/m^2K

- IAM: is the incidence angle modifier of the collector from the collector test standard EN 12975-2 when the test angle of incidence between the collector and the direct solar radiation for the test condition is 50°.

Collector type	η_o	**a1**	**a2**	**IAM**
Unglazed collector	0.9	20	0	1
Flat plate collector	0.75	6	0	0.94
Evacuated tube collector	0.65	3	0	0.97

Table 38: Default collector parameters

Solar storage

The solar storage parameters are as follows:

- Solar pre-heating type: specifies the arrangements for solar pre-heating as one of the following options:
  - dedicated solar pre heating storage: when there is one or more dedicated solar storage vessel that are heated with the solar collectors only and that do not contain any other heating sources.
  - combined cylinder: the solar storage is combined in a hot water cylinder with one or more back-up heating sources, i.e., the solar energy system shares the same storage vessel with the hot water system.
- Solar storage volume, V_{sol}: This refers to the dedicated solar storage volume, and it should be calculated according to the arrangements for solar pre-heating as indicated in the schematics in Figure 10:
  - in the case of one or more separate pre-heat tank(s), such as arrangements a or c in Figure 10, the solar storage volume is the volume of the pre-heat tank(s)
  - in the case of a combined cylinder, such as arrangement b in Figure 10, the solar storage volume is the volume between the bottom of the lowest back up element (electric element or heat exchanger) to the lowest element of the solar primary.
  - in the case of a thermal store (hot water only) where (only) the solar coil is within the thermal store, i.e., no back-up heating, the solar storage volume is the volume of the dedicated thermal storage
  - in the case of a direct system, such as arrangement d in Figure 10, the solar volume should be calculated as 0.3 times the volume of the cylinder. See also Note 2 below.

  Note 1

  The schematic examples reflected in the Figure 10 are unlikely to represent all types of commercial solar thermal installations. Where necessary, and for more complex systems, an accredited dynamic simulation tool can be used.

  Note 2

The dedicated solar volume of a solar thermal installation varies depending on the control and timing strategy of the of the back-up system. To optimise the performance of the solar thermal system, the back-up system should be prevented from operating during and prior to the period of the day where the solar radiation is strong enough to contribute to the hot water requirements. Where it can be demonstrated that the dedicated solar volume should be calculated following a different approach to the guidelines given here, alternative calculations can be used as long as they are in agreement with the UK Micro Certification Scheme standards in effect at that time. The detail and justifications of the calculations undertaken will need to be submitted to the Building Control officer.

- Insulation type and thickness: specifies the type and thickness of the insulation of the solar storage tank.

If the hot water storage vessel is shared between the solar energy system and the back-up hot water system, then the storage losses are already accounted for in Section 12.3.1. If the solar system has a dedicated hot water storage vessel, then the storage losses are calculated using the same procedure as in 12.3.1.

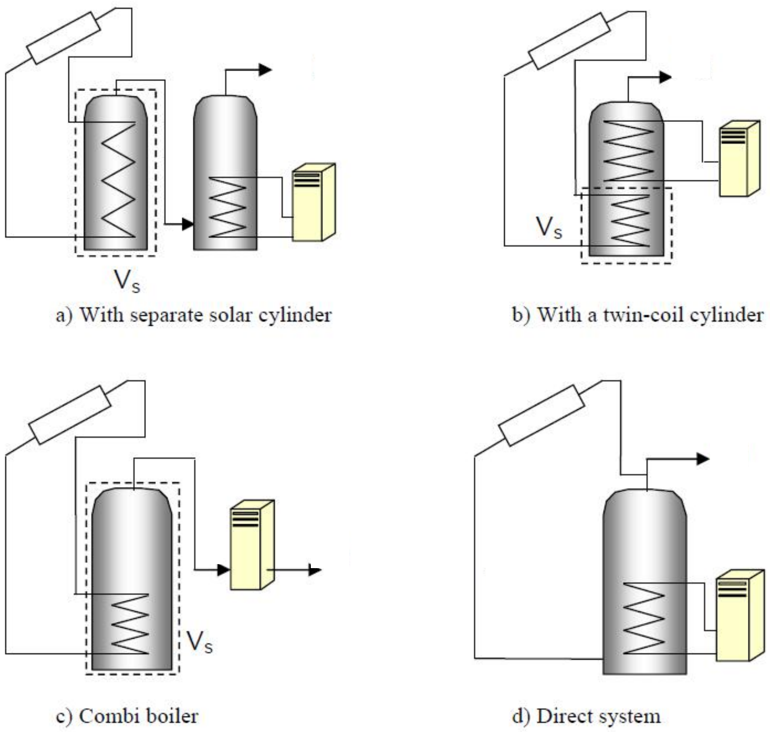


Figure 10: Arrangements for solar pre-heating (*these schematics are not intended to show safety measures and devices needed to make the systems safe - Adapted from SAP 2005.*

<u>Collector loop</u>

The solar loop refers to all elements located between the solar collector and the point where the back-up heating source supplies the hot water system with energy. The collector loop parameters are as follows:

- Heat transfer rate of the heat exchanger(s) in the solar loop, in W/K, $(U_{st})_{hx}$:

- For solar thermal direct systems in which the solar primary transmission fluid and the consumed water are the same (arrangement d in Figure 10) the option *there is no heat exchanger* should be chosen.
- For indirect systems where the primary circuit fluid is different to that of the secondary side of the system, there will be one or more heat exchangers in the storage vessel.

  In order to calculate the drop in system efficiency induced by the heat exchanger(s) in the solar loop, the heat transfer rate of the heat exchanger(s) needs to be entered by the user. If this value is not known, the default option should be used.

  - For small systems, the heat transfer rate of the heat exchanger in the solar loop value can be obtained from test results according to the standards *EN 12975-3 - Performance characterisation of stores for solar heating systems.*
  - For large systems, the value is taken from the heat exchanger performance data sheet provided by the manufacturer.
  - For systems with more than one heat exchanger, using an intermediary or tertiary arrangement such as with a thermal store, an equivalent heat transfer rate should be entered by the user (alternatively, dynamic simulation tools can be used).
- Overall heat loss coefficient of all pipes in the solar loop, $U_{loop,p}$: specifies the overall heat loss coefficient of all pipes in the solar loop, including pipes between collectors and array pipes and between collector array and the solar storage tank(s), in W/K
  - If the pipe and insulation for the solar loop are known, the overall heat loss coefficient of all pipes in the solar loop can be calculated accordingly - see for instance, *John A. Duffie and William A. Beckman: Solar Engineering of Thermal Process. Wiley-Interscience ed., 1991*.
  - If the pipe and insulation for the solar loop are not known, default values should be used.

Distribution losses

If there are pipes between the solar thermal system and the back-up heating system, the user needs to specify whether the distribution pipes between the solar energy system and the back-up heating source are insulated. This is used to estimate the thermal losses of the distribution between the thermal solar system and the back-up heater.

Auxiliary energy

The auxiliary energy parameters are as follows:

- Circulation system: specifies the type of circulation system that the solar system uses, i.e., either thermosiphon systems, forced circulation systems assisted with photovoltaics, or forced circulation systems using grid electricity for the circulation pump.
- Nominal power of pump(s): specifies the nominal input power of the circulation pump(s) in the solar loop, i.e., the power stated on the pump(s) label.

For a multi-stage pump, the power corresponding to the typical operation mode is chosen.

12.9.2. Definition of algorithms

Useful solar thermal output: $Q_{W,sol,use,mi}$, in KWh

The (monthly) useful contribution of the solar thermal system to the hot water requirements of the building is calculated as:

$Q_{W,sol,use,mi} = Q_{W,sol,out,mi} - Q_{sol,ls,mi}$, where

- o $Q_{W,sol,out,mi}$ is the heat output of the solar thermal system in month i, in kWh
- o $Q_{sol,ls,mi}$ are the thermal losses of the solar system in month i, in KWh

Solar thermal output system: $Q_{W,sol,out,mi}$

The output of the solar thermal system is calculated as:

$$Q_{W,sol,out,mi} = f \cdot Q_{W,sol,us,mi} = (aY_{w,mi} + bX_{w,mi} + cY_{w,mi}{}^2 + dX_{w,mi}{}^2 + eY_{w,mi}{}^3 + fX_{W,mi}{}^3) \cdot Q_{W,sol,us,mi}$$

where

- o $Q_{W,sol,us,mi}$ are the hot water requirements in month i, in kWh
- o X_{mi} is a value that depends on the collector loop heat loss coefficient and the temperature difference, but also on the storage tank volume by taking into account the storage tank capacity correction factor.

  $X_{m_i} = \dfrac{A \cdot U_{loop} \cdot \eta_{loop} \cdot \Delta T_{mi} \cdot f_{st} \cdot t_{mi}}{Q_{W,sol,us,m_i} \cdot 1000}$, where

  - o A is the collector area, in m^2.
  - o U_{loop} is the heat loss coefficient of the collector loop and is determined by the collector characteristics and the insulation of the pipes, in W/m^2K:

    $U_{loop} = a_1 + a_2 \cdot 40 + \dfrac{U_{loop,p}}{A}$, where

    - o $U_{loop,p}$ is the overall heat loss coefficient of all pipes in the solar loop, including pipes between collectors and array and pipes between collector array and solar storage tank(s), in W/K
      - § If pipe and insulation for the collector are known, formulas for insulated pipes can be used, or
      - § If collector characteristics are not known a default calculation is undertaken using $U_{loop,p} = 5 + 0.5 \cdot A$
  - o η_{loop} is the efficiency factor of the collector taking into account the influence of the heat exchanger calculated as:
    - o if the heat exchanger characteristics in the collector loop are known, then
      - § $\eta_{loop} = 1 - \Delta\eta$, where,

- $\Delta\eta = \frac{(\eta_o \cdot A \cdot a_1)}{(U_{st})_{hx}}$ and $(U_{st})_{hx}$ is the heat transfer rate of the heat exchanger(s) in the solar loop, in W/K
- For direct systems, $\Delta\eta = 0$

  - if the heat exchanger characteristics in the collector loop are not known, then η_{loop}=0.85
- ΔT_{mi} is the reference temperature difference in month i
  $\Delta T_{mi} = T_{ref,mi} - T_{e,avg,mi}$, where
  - $T_{ref,mi}$ is the reference temperature ion month i, in °C
    $T_{ref,mi}=11.6+1.18T_w+3.86T_{cw}-1.32T_{e,avg,mi}$
    - T_w is the desired hot water temperature taken as equal to 40°C
    - T_{cw} is the mains water supply temperature, taken as 10°C
    - $T_{e,avg,mi}$ is the monthly average outside temperature for each location
- f_{st} is the storage tank capacity correction factor, $f_{st} = (\frac{V_{ref}}{V_{sol}})^{0.25}$
  - V_{ref} is the reference volume equal to 75 litres per m^2 of collector
  - V_{sol} is the solar storage tank volume, in litres
- t_{mi} is the length of month i, in h
- $Q_{W(H),sol,us,mi}$ are the hot water requirements in month i, in kWh

- Y_{mi} is a value that depends on the collector data (zero-loss collector efficiency) and the solar irradiance on the collector plane

$$Y_{mi} = \frac{A \cdot IAM \cdot \eta_o \cdot \eta_{loop} \cdot I_{mi} \cdot t_{mi}}{Q_{sol,us,mi} \cdot 1000}$$, where

  - I_{mi} is the average solar irradiance on the collector plane during the month i, in W/m^2

- a,b,c,d,e are the correlation factors depending on the storage tank type as shown in Table 39. The values used are those calculated in the f-chart method (*John A. Duffie and William A. Beckman: Solar Engineering of Thermal Process. Wiley-Interscience ed., 1991*).

Correlation factors for collector arrays connected to hot water storage tanks	
a	1.029
b	-0.065
c	-0.245

d	0.0018
e	0.0215
f	0

Table 39: Correlation factors - Adapted from EN 15316-4-4:2007

Calculation of auxiliary energy consumption: $W_{sol,aux,mi}$

The auxiliary energy consumption (electricity required by the circulation pumps) of the solar thermal system, in kWh, is calculated according to:

- For thermosiphon systems or forced circulation systems assisted with photovoltaics, $W_{sol,aux,mi}=0$
- For forced circulation systems using grid electricity,

  $W_{sol,aux,mi} = \frac{P_{aux,nom} \cdot t_{aux,mi}}{1000}$, where

  - Paux,nom is the nominal input power of the circulation pumps, in W.

    If $P_{aux,nom}$ is not known, $P_{aux,nom} = 25 + 2 \cdot A$

  - taux,mi is the operation time of the pump in month i, in h

    The annual operation time of the circulation pump is 2000h. The monthly operation time of the pump is determined by the distribution of the annual operation time corresponding to the monthly distribution of the solar irradiance (e.g., if January irradiation is 5% of annual irradiation, then January operation time of the pump is 5% of the annual operation time of the pump).

Thermal losses of the solar system: $Q_{sol,ls,mi}$

The thermal losses of the solar system are given by the addition of the storage tank heat losses $Q_{W,sol,st,ls,mi}$ plus the heat distribution losses between the thermal solar system and the back-up heater $Q_{bu,dis,ls,mi}$

$$Q_{sol,ls,mi} = Q_{W,sol,st,ls,mi} + Q_{bu,dis,ls,mi}$$, where

- Solar storage tank losses $Q_{W,sol,st,ls,mi}$
  - For combined cylinders, the solar storage tank losses are calculated as part of the hot water module calculations
  - For separate solar cylinder installations, the losses are calculated depending on the type and thickness of the insulation following the same calculation methodology as described for hot water cylinders.
- Distribution losses $Q_{bu,dis,ls,mi}$

  If there are pipes between the SES and the back-up system, this specifies whether the distribution pipes between the solar energy system and back-up heating source are insulated as follows:

  - If the pipes are insulated $Q_{bu,dis,ls,mi} = 0.02 \cdot (Q_{sol,out,mi} / Q_{sol,us,mi})$

§ If the pipes are not insulated $Q_{bu,dis,ls,mi} = 0.05 \cdot (Q_{sol,out,mi} / Q_{sol,us,mi})$

12.9.3. Outputs produced

SBEM deducts the useful hot water produced by the solar thermal energy system from the requirements to be met by the HWS to which the solar energy system is linked.

12.10. Photovoltaics

The energy yield given by the photovoltaic system (PV) is calculated according to the collector orientation and inclination. In order to calculate the radiation at the PV module, the hourly radiation data has been processed to yield values of global solar radiation for the orientations and inclinations shown in Table 36 and Table 37, respectively. The PV electricity generated is calculated by applying two factors to the solar resource at the collector plane: the module conversion of efficiency (whose value depends on the technology chosen) and the system losses (inverter losses, module shading, AC losses, module temperature, etc.).

12.10.1. Data requirements

- Type: refers to the photovoltaic technologies that are available in SBEM (mono-crystalline silicon, poly-crystalline silicon, amorphous silicon and other thin films). Each of these technologies is associated with a different efficiency of conversion as shown in Table 40.
- Area: specifies the area of the photovoltaic panels, excluding the supporting construction, in m^2.
- Orientation: specifies the orientation of the PV modules.
- Inclination: specifies the inclination of the PV modules in degrees from the horizontal where 0° stands for a horizontal surface and 90° for a vertical surface.
- PV module efficiency of conversion is limited to four generic technologies, Table 40.

Module type	Efficiency
Mono-crystalline silicon	15%
Poly-crystalline silicon	12%
Amorphous silicon	6%
Other thin films	8%

Table 40: Photovoltaic module efficiency of conversion

Inverter losses	7.5 %
Module shading	2.5 %
Module temperature	3.5%

Shading	2%
Mismatching and DC losses	3.5%
MPP mismatch error	1.5%
AC losses	3%
Other	1.5%
Total Losses	**25.0%**

Table 41: Photovoltaic system losses

12.10.2. Definition of algorithms

Photovoltaic electricity generation

$$Q_{PV} = I \bullet K_E \bullet (1 - K_S) \bullet A$$

where

Q_{PV} is the annual electricity produced by the photovoltaic modules, in kWh

I is the global solar radiation at the module surface, in kWh/m^2

K_E is the is the module efficiency of conversion, in % (Table 40)

K_S are the system losses, in % (Table 41).

A is area of the photovoltaic panels, excluding the supporting construction, in m^2

Carbon dioxide displaced by photovoltaic electricity

$$C_{PV} = Q_{PV} \bullet c_D$$

where

C_{PV} is the annual carbon dioxide emissions displaced by the electricity generated by the photovoltaic modules, in $kgCO_2$

c_D is the amount of carbon dioxide displaced by each unit of electricity produced by the PV modules and is the emission factor, in $kgCO_2/kWh$, for displaced electricity from Table 8.

12.10.3. Outputs produced

- Annual electricity produced by the photovoltaic system.
- Carbon dioxide displaced due to the electricity generated by the photovoltaic system.

12.11. Wind generators

The methodology followed to calculate the electricity generated by wind turbines is based on the Average Power Density Method. Electricity produced by the wind turbine is obtained by estimating the average power density of the wind throughout a year using the hourly

ASHRAE data and by applying a turbine efficiency of conversion. Correction of the wind resource due to turbine height and terrain type is allowed for.

12.11.1. Data requirements

- Terrain type: Specifies the type of terrain where the wind generator is installed from smooth flat country (no obstacles), farm land with boundary hedges, suburban or industrial area, or urban with average building height bigger than 15 m
- Diameter: specifies the wind turbine rotor diameter, in m
- Hub height: specifies the wind turbine hub height, in m
- Power: Specifies the wind turbine rated power (electrical power at rated wind speed), in kW - this information is used to assign an efficiency of conversion to the wind turbine. For SBEM purposes, this efficiency is considered to change with the monthly wind speed and turbine rated power according to Table 43.

Terrain type	K_R terrain factor	z_O (m) roughness length
Open Flat Country	0.17	0.01
Farm Land with boundary hedges, occasional small farm structures, houses or trees	0.19	0.05
Suburban, industrial areas and permanent forests	0.22	0.3
Urban areas in which at least 15% of surface is covered with buildings of average height exceeding 15m	0.24	1

Table 42: Terrain categories and related parameters (CIBSE, 2002)

Mean annual wind speed (m/s)	Small turbines (<80 kW)	Medium turbines (≥80 kW)
[0,3]	0 %	0 %
[3,4]	20%	36%
[4,5]	20%	35%
[5,6]	19%	33%
[6,7]	16%	29%
[7,8]	15%	26%
[8,9]	14%	23%
>9	14%	23%

Table 43: Wind turbine efficiencies

12.11.2. Definition of algorithms

Wind turbine electricity generation

$$Q_{WT} = 0.5 \bullet r \bullet C_R(z) \bullet V^3{}_o \bullet A \bullet EPF \bullet K_{WT} / 1000 \text{ [kWh]}$$

where

Q_{WT} is the annual electricity produced by the wind turbine, in kWh

r is the air density ~1.225 kg/m^3

$C_R(z)$ is the roughness coefficient at height *z* calculated as:

$$C_R(z) = K_R \bullet \ln(z / z_0)$$

where

K_R is the terrain factor (Table 42)

z_o is the roughness length (Table 42)

z is the wind turbine hub height, in m.

V_o is the mean annual wind speed as taken from ASHRAE, in m/s

A is the turbine swept area, in m^2, calculated as:

$$A = p \bullet D^2 / 4$$

where

D is the wind turbine diameter, in m

EPF is the energy pattern factor calculated using the hourly wind speed data as taken from ASHRAE as:

$$EPF = \frac{APD}{0.5 \bullet r \bullet V^3{}_o}$$

where

APD: is the annual power density, in W/m^2, calculated as

$$APD = \frac{\sum_{i=1}^{8760} 0.5 \bullet r \bullet V^3{}_i}{8760}$$

where

V_i is the hourly average wind speed as taken from ASHRAE, in m/s

8760 are the number of hours in a year

K_{WT}: is the wind turbine efficiency of conversion, in %, as given in Table 43.

Note for vertical axis wind turbines

In order to define a vertical axis wind turbine, an equivalent turbine diameter D_e, needs to be defined:

$$A_{VAWT} = \frac{p \bullet D_e{}^2}{4}$$

where

A_{VAWT} is the swept area of the vertical axis wind turbine, in m^2

D_e vertical axis wind turbine equivalent diameter used for the calculations

Carbon dioxide displaced by wind turbines

$$C_{WT} = Q_{WT} \bullet c_D$$

C_{WT} is the annual carbon dioxide emissions displaced by the electricity generated by the wind turbine, in $kgCO_2$

c_D: is the amount of carbon dioxide displaced by each unit of electricity produced by the wind turbine and is the emission factor, in $kgCO_2$/kWh, for displaced electricity from Table 8.

12.11.3. Outputs produced

- Annual electricity produced by the wind turbine.
- Carbon dioxide emissions displaced by the electricity displaced by the wind turbine.

12.11.4. Commentary on accuracy

- Wind speed is taken from ASHRAE. Variations in the local wind resource from the one used by SBEM are unavoidable.
- Generic wind turbine efficiencies have been assumed which means that turbines with the same diameter will yield the same energy yield over a year without allowing for differences among different turbine makes.

12.12. CHP generators

12.12.1. Data requirements

- Fuel type: specifies the fuel type used for the CHP generator
- Heat seasonal efficiency: is the total annual useful heat supplied by the CHP plant divided by the total annual fuel energy input (using the gross calorific value).
- Power seasonal efficiency: is the total annual power generated by the CHP plant divided by the total annual fuel energy input (using the gross calorific value)
- Building space heating supplied: specifies the percentage of the building space heating demand supplied by the CHP generator
- Building hot water supplied: specifies the percentage of the hot water demand supplied by the CHP generator.
- Building space cooling supplied: specifies the percentage of the building space cooling demand supplied by the trigeneration plant
- Chiller seasonal energy efficiency ratio: is the seasonal efficiency of the heat fired chiller (typically an absorption chiller), calculated as the ratio of the useful cooling output to the energy input over the cooling season.

Note: the CHPQA Quality index is input in iSBEM for information purposes only. This value is not used in the calculations

12.12.2. Definition of algorithms

Amount of fuel used by the CHP plant

$$F = \frac{H_{SH} \bullet p_{SH} + H_{HW} \bullet p_{HW} + \frac{H_{SC} \bullet p_{SC}}{SEER}}{h_{TH}}$$

where

F is the fuel requirements by the CHP plant, in kWh

H_{SH} is the annual space heating demand of the building, in kWh

p_{SH} is the annual proportion (fraction) of the space heating demand supplied by the CHP plant

H_{HW} is the annual hot water demand of the building, in kWh

p_{HW} is the annual proportion (fraction) of the hot water demand supplied by the CHP plant

H_{SC} is the annual space cooling demand of the building, in kWh

p_{SC} is the annual proportion (fraction) of the space cooling demand supplied by the heat fired chillers

SEER is the heat-fired chiller seasonal energy efficiency ratio.

h_{TH} is the seasonal heat efficiency of the CHP plant defined as the total annual useful heat supplied divided by the total annual fuel energy input (using the gross calorific value).

Carbon dioxide generated by the CHP plant fuel requirements

$$F_C = F \bullet c$$

where

F_C is the annual carbon dioxide emission due to the fuel used by the CHP plant, in $kgCO_2$

F is the CHP plant fuel requirements, in kWh

c is the carbon emission rate of the fuel used by the CHP plant, in $kgCO_2$/kWh, from Table 8.

Electricity generated by the CHP plant

$$E = F \bullet h_E$$

where

E is the power (electricity) generated by the CHP plant, in kWh

h_E is the seasonal power efficiency of the CHP plant

Carbon dioxide displaced by the CHP plant

$$C_E = E \bullet c_D$$

C_E is the annual carbon dioxide emissions displaced by the electricity generated by the CHP plant, in $kgCO_2$

c_D is the amount of carbon dioxide displaced by each unit of electricity produced by the CHP plant and is the emission factor, in $kgCO_2$/kWh, for displaced electricity from Table 8.

12.12.3. Outputs produced

- Carbon dioxide emissions generated by the CHP plant fuel requirements
- Electricity produced by the CHP plant
- Carbon dioxide displaced due to the electricity generated by the CHP plant

13. Options for interfacing to SBEM

SBEM requires data to be presented in a standard format through an input interface. iSBEM (interface to SBEM) was commissioned by CLG and adapted for SEAI to fulfil the role of default interface. However, other approved interfaces to SBEM are available. These other interfaces are not discussed in this document.

13.1. iSBEM

The iSBEM input module acts as the interface between the user and the SBEM calculation. The user is guided towards appropriate databases as described earlier in this document, and the input is formatted so that data is presented correctly to the calculation engine, compliance checking module, and the BER module.

13.1.1. Logic behind iSBEM structure

iSBEM is structured as a series of forms in Microsoft Access®. This software was chosen as the platform for speed and convenience with programming in order to enable delivery within a limited timescale.

During the development of iSBEM, BRE has had extensive experience with operating the software and explaining it to users. This has enabled it to develop a detailed user guide with terms that most potential users can understand and follow.

13.1.2. How iSBEM collects the data for SBEM

The information gathering is arranged under a series of forms, tabs, and sub-tabs in order to structure the way the user collects and inputs the information. This structure is dealt with in full detail in the *iSBEM User Guide - Republic of Ireland Volume*[25], but, in summary, the forms deal with the following:

- General
    - Project and assessor details
    - File handling
- Project database - setting up the constructions used in the building
    - Walls
    - Roofs
    - Floors
    - Doors
    - Glazing
- Geometry - definition for each building element surrounding every zone:
    - Size
    - orientation

[25] Available for download from http://www.seai.ie/Your_Building/BER/Non_Domestic_Buildings/SBEM_Software_Download/.

    - construction
    - thermal bridges
    - links between elements
- Building services - setting up the systems used in the building
    - HVAC systems
    - Hot water generators including solar hot water
    - Photovoltaic systems
    - Wind generators
    - Combined heat and power
    - Lighting and its control
    - General issues relating to ventilation, power factor correction, etc
    - Allocation of systems to each zone
- Ratings - deals with the results in terms of ratings for the building
- Building Navigation – used to review entered data

Information is entered into the first four of these forms by the user and once the building description is complete, the calculation can be run. Results are then displayed in the Ratings form.

14. Planned developments

The initial versions of SBEM and iSBEM did not include all the features that users would find valuable or helpful, but the versions have evolved significantly since then. The many possible areas for extension and improvement include new options for energy systems and controls, and more diagnostic and error-checking information. The pace of, and priorities for, development will depend on the funding available and feedback from users and other stakeholders (including suppliers of systems and components).

Some upgrades are already under development and others have been agreed in principle as desirable. Several of these are currently being implemented. The following technical enhancements had been identified and agreed with CLG and are on the “waiting list” for funding:

First priority

- Add night ventilation strategies
- Add systems that provide enhanced thermal coupling to structure
- Add demand controlled ventilation
- Add additional HVAC controls
- Add automatic blind controls
- Add multi-boiler and chiller seasonal efficiency calculation

Second Priority

- Add explicit dehumidification calculation
- Provide user access to default HVAC parameters
- Develop better shading model
- Improve handling of air-handling luminaires
- Improve pump energy calculation
- Provide more chiller options
- Add embedded heat emitters
- Include provision for bivalent heating
- Add hot water conservation features (spray taps, etc.)
- Add provision for trace heating
- Improve duct leakage correction to be non-linear
- Add provision for energy piles
- Include ventilation efficiency correction

Third Priority

- Provide heating and cooling load indicators

- Provide more diagnostic information
- Explore more sophisticated inference rules for existing buildings
- Migrate to web-based implementation

Subsequent requests by users

- Add low-temperature heat emitters
- Distinguish heating systems by responsiveness
- Provide a route for highly simplified data input

15. References

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Paul Gipe. Wind Power. 2004. James & James (Science Publisher) Ltd. London. UK

Combined heat and power for buildings. Good Practice Guide GPG388. 2004

Small-scale combined heat and power for buildings. CIBSE Applications manual AM12: 1999

Non-Domestic Heating, Cooling and Ventilation Compliance Guide. Department for Communities and Local Government. May 2006. First Edition.

APPENDIX B: Basic Logic for Filtering Recommendations for BER Certificates

This appendix is a record of the structure and process of the filtering logic used to make an initial selection of recommendations to accompany BER certificates.

Content with a clear background describes the logic that is mandatory for the production of the formal Advisory Report in the Republic of Ireland.

Sections that have grey background are NOT a required element of the Advisory Report in the republic of Ireland. They are used in iSBEM to provide extra information to assessors. Other software may also make use of them, but this is not mandatory. Accreditation bodies may require additional information to be provided to assist auditing.

B1.0 Schematic logic of filtering process

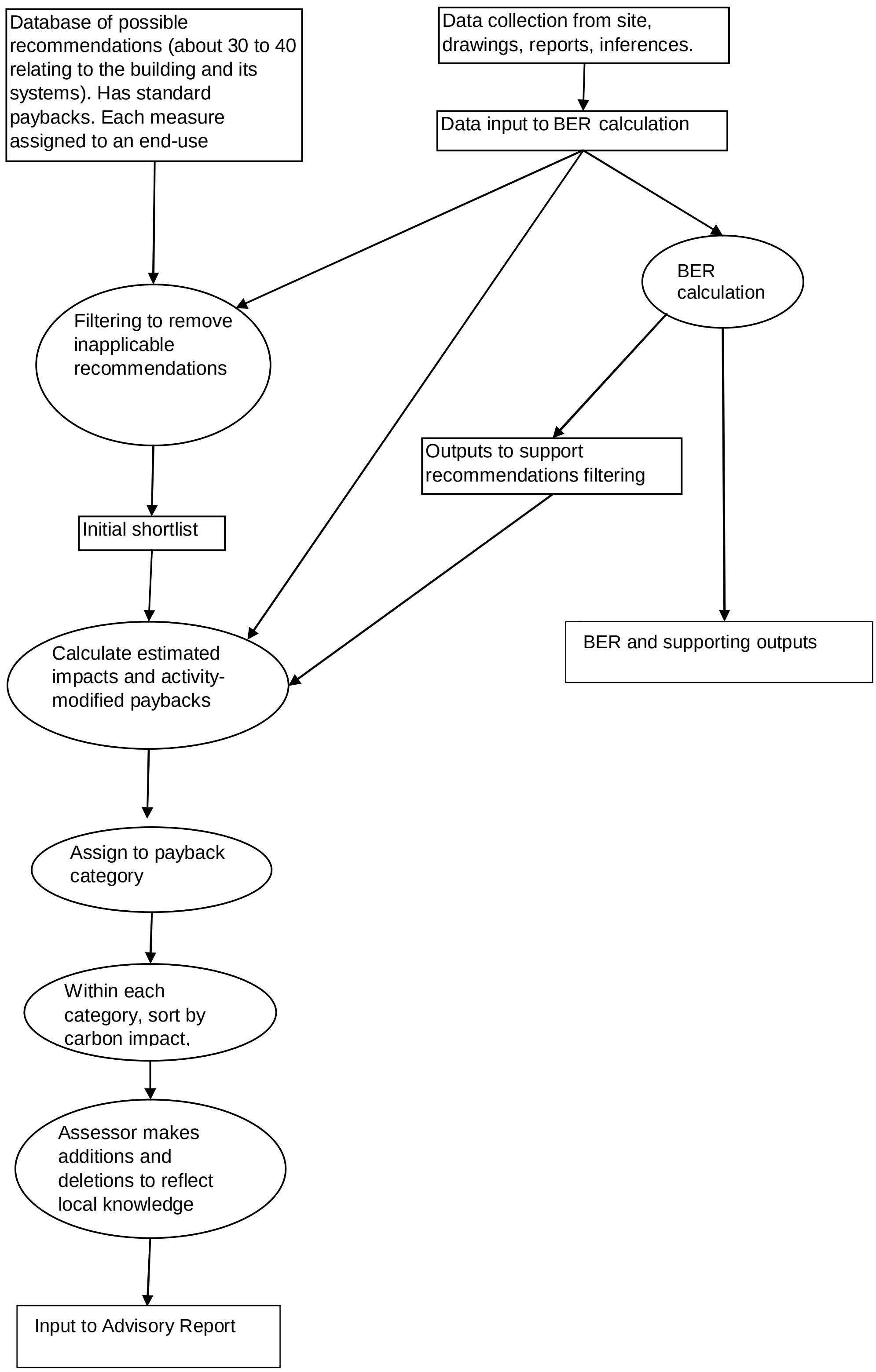

Figure 11: Schematic logic of recommendations filtering process

The initial list of potential recommendations is a subset of those collected by AECOM (formerly Faber Maunsell) for use with Display Energy Certificates (DEC) in the UK. Since the BER calculation contains no information on operation or maintenance, potential

recommendations relating to these aspects of energy efficiency have been omitted. On the other hand, the more detailed information available for the calculation has, in some cases, allowed the DEC recommendations to be refined. The basic payback information has also been taken from the DEC source. To retain some consistency over as wide a range of recommendations as possible, the paybacks for office applications have been used. (This application contains the largest number of recommendations). However, the paybacks are adjusted within the following logic to reflect the intensity and duration of use of the building being assessed.

The filtered and prioritised recommendations are intended to guide assessors, who have the final responsibility for them. Assessors are able to remove or add recommendations. With some software (for e.g., iSBEM), they may also comment on recommendations and provide justification for additions and removals.

B2.0 The logic, Step by Step

Note: It is important that all default values are set (or overwritten by the assessor, either directly or via the inference procedures).)

B2.1 Basic whole-building information

- From calculations already carried out for the BER, record Reference Building
    - Heating kWh/m^2, Cooling kWh/m^2, Lighting kWh/m^2, Hot water kWh/m^2, Auxiliary kWh/m^2
    - Heating $kgCO_2/m^2$, Cooling $kgCO_2/m^2$, Lighting $kgCO_2/m^2$, Hot water $kgCO_2/m^2$, Auxiliary $kgCO_2/m^2$
    - Identify which of these services are actually present in the building
    - Calculate % of carbon emissions attributable to each end-use

- From calculations already carried out for the BER, record Actual Building
    - Heating kWh/m^2, Cooling kWh/m^2, Lighting kWh/m^2, Hot water kWh/m^2, Auxiliary kWh/m^2
    - Heating $kgCO_2/m^2$, Cooling $kgCO_2/m^2$, Lighting $kgCO_2/m^2$, Hot water $kgCO_2/m^2$, Auxiliary $kgCO_2/m^2$
    - Calculate % of "energy" (price-weighted?) attributable to each end-use
    - Calculate % of carbon emissions attributable to each end-use

- From calculations already carried out for the BER, record Typical Building
    - Heating kWh/m^2, Cooling kWh/m^2, Lighting kWh/m^2, Hot water kWh/m^2, Auxiliary kWh/m^2
    - Heating $kgCO_2/m^2$, Cooling $kgCO_2/m^2$, Lighting $kgCO_2/m^2$, Hot water $kgCO_2/m^2$, Auxiliary $kgCO_2/m^2$

B2.2 Categorise end-uses as good/fair/poor

B2.2.1 Heating

- **For heating**, compare Actual **kWh/m^2** with Reference and Typical
    - If **Actual < Reference**, classify heating energy efficiency as "good"
    - If **Reference <= Actual < Typical**, classify heating energy efficiency as "fair"

- **Otherwise,** classify heating energy efficiency as “poor”

- **For heating**, compare Actual **$kgCO_2/m^2$** with Reference and Typical
  - If **Actual < Reference**, classify heating carbon efficiency as “good”
  - If **Reference <= Actual < Typical**, classify heating carbon efficiency as “fair”
  - **Otherwise,** classify heating carbon efficiency as “poor”

B2.2.2 Cooling

- **For cooling**, compare Actual **kWh/m^2** with Reference
  Note – We can’t use notional building as it is mixed-mode. Criteria are based on system efficiencies relative to that of the reference building, bearing in mind that the reference building system is a fairly run of the mill FC system.
  - If **Actual < 0.85 x Reference,** classify cooling energy efficiency as “good”
  - If **0.85 x Reference <= Actual < 1.5 x Reference**, classify cooling energy efficiency as “fair”
  - **Otherwise,** classify cooling energy efficiency as “poor”

- **For cooling**, compare Actual **$kgCO_2/m^2$** with Reference
  - But ignore virtual cooling (overheating is captured later)
  - If **Actual < 0.85 x Reference**, classify cooling carbon efficiency as “good”
  - If **0.85 x Reference <= Actual < 1.5 x Reference**, classify cooling carbon efficiency as “fair”
  - **Otherwise,** classify cooling carbon efficiency as “poor”

B2.2.3 Lighting

- **For lighting**, compare Actual **kWh/m^2** with Reference and Typical
  - If **Actual < Reference**, classify lighting energy efficiency as “good”
  - If **Reference <= Actual < Typical**, classify lighting energy efficiency as “fair”
  - **Otherwise,** classify lighting energy efficiency as “poor”

- **For lighting**, compare Actual **$kgCO_2/m^2$** with Reference and Typical
  - If **Actual < Reference**, classify lighting carbon efficiency as “good”
  - If **Reference <= Actual < Typical,** classify lighting carbon efficiency as “fair”
  - **Otherwise,** classify lighting carbon efficiency as “poor”

B2.2.4 Domestic Hot Water

- **For hot water**, compare Actual **kWh/m^2** with Reference and Typical
  - If **Actual < Reference**, classify hot water energy efficiency as “good”
  - If **Reference <= Actual < Typical**, classify hot water energy efficiency as “fair”
  - **Otherwise,** classify hot water energy efficiency as “poor”

- **For hot water**, compare Actual **$kgCO_2/m^2$** with Reference and Typical
  - **If Actual < Reference**, classify hot water carbon efficiency as “good”
  - If **Reference <= Actual < Typical**, classify hot water carbon efficiency as “fair”
  - **Otherwise,** classify hot water carbon efficiency as “poor”

B2.2.5 Auxiliary (Mechanical Ventilation)

- **For Auxiliary**, compare Actual **kWh/m^2** with Reference and Typical
  - If **Actual < Reference**, classify Auxiliary energy efficiency as “good”
  - If **Reference <= Actual < Typical**, classify Auxiliary energy efficiency as “fair”

- **Otherwise,** classify Auxiliary energy efficiency as “poor”

- **For Auxiliary**, compare Actual **$kgCO_2/m^2$** with Reference and Typical
  - If **Actual < Reference**, classify Auxiliary energy efficiency as “good”
  - If **Reference <= Actual < Typical**, classify Auxiliary energy efficiency as “fair”
  - **Otherwise,** classify Auxiliary energy efficiency as “poor”

B2.3 Recommendation triggered by system components

Notes:

- Boiler criterion is set to 0.7 rather than 0.65 in order to classify default boilers as poor
- “Potential impact” criteria have been pre-calculated using boiler efficiencies and rules taken from draft DEC thresholds of 4% and 0.5% of total building value.
- These are generally applied **both** at project and individual component level (there may be exceptions where only one is meaningful)
- Where recommendations are applied at project level**,** the assessment of impact assumes that for all systems/ components which trigger the recommendation, the recommendation is applied. The overall building energy (and CO_2) is then compared to the original building energy (and CO_2).

B2.3.1 Heating

B2.3.1.1 Heating efficiency

- **Check if using default heating efficiency – if yes trigger EPC-H4**

Note: Assessing impact of recommendation **EPC-H4** is done similarly to that for recommendation **EPC-H1** shown overleaf.

- If heat generator efficiency > **0.88**, classify heat generator efficiency as “good”

If **0.88** >= heat generator efficiency > **0.70**, classify heat generator efficiency as “fair”

§ If fuel is gas, oil or LPG,
- trigger recommendation **EPC-H3** (condensing boiler)

Note: If hot water is provided by the space heating boiler, hot water is included in the energy and carbon proportions below.

Fuel	Price Factor (with respect to gas)
gas	1
LPG	2.74
Biogas	1.48
oil	1.72
coal	0.61
Anthracite	1.07
Smokeless fuel (inc coke)	0.61
Dual fuel appliances (mineral + wood)	1.48
biomass	1.48
electricity	3.43
Waste heat	0.2

Table 44: Fuel Price factors

- § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate new heating (and, if appropriate HWS) energy as ratio between actual efficiency and **0.89**. Determine % change in total building energy
    - If change in total energy is > 4% potential impact is “high”
    - If 4% > = change in total energy > 0.5%, potential impact is “medium”
    - Otherwise change in total energy potential impact is “low”
- § Assess likely scale of carbon impact from proportion of total carbon. Calculate new heating (and, if appropriate HWS) carbon emissions as ratio between actual efficiency and **0.89**. Determine % change in total building carbon emissions
    - If change in total carbon is > 4% potential impact is “high”
    - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
    - Otherwise change in total carbon, potential impact is “low”

o If 0.70 >= heat generator efficiency, classify heat generator efficiency as “poor”

- § Trigger recommendation **EPC-H1** (high efficiency boiler) **and if fuel is gas, oil or LPG trigger EPC-H3 (condensing boiler) - assessed as above**
- § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate new heating (and, if appropriate HWS) energy as ratio between actual efficiency and 0.81. Determine % change in total building energy
    - If change in total energy is > 4% potential impact is “high”
    - If 4% > = change in total energy > 0.5%, potential impact is “medium”
    - Otherwise change in total energy potential impact is “low”
- § Assess likely scale of carbon impact from proportion of total carbon. Calculate new heating (and, if appropriate HWS) carbon emissions as ratio between actual efficiency and 0.81. Determine % change in total building carbon emissions
    - If change in total carbon is > 4% potential impact is “high”
    - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
    - Otherwise change in total carbon, potential impact is “low”

o If heating fuel is electricity, check heat generator efficiency, if less than 2, trigger recommendation **EPC-R1** (consider GSHP) and **EPC-R5** (consider ASHP)

Note: CoP of 2 is the worst allowable in the HVAC guide. But the air-source default in iSBEM is 2.2 – which is used below.

- § **For EPCR5**
- § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate new heating (and, if appropriate HWS) energy as ratio between actual efficiency and 2.2. Determine % change in total building energy
    - If change in total energy is > 4% potential impact is “high”
    - If 4% > = change in total energy > 0.5%, potential impact is “medium”
    - Otherwise change in total energy potential impact is “low”
- § Assess likely scale of carbon impact from proportion of total carbon. Calculate new heating (and, if appropriate HWS) carbon emissions as ratio between actual efficiency and 2.2. Determine % change in total building carbon emissions
    - If change in total carbon is > 4% potential impact is “high”
    - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
    - Otherwise change in total carbon, potential impact is “low”

- § **For EPCR1**
- § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate new heating

(and, if appropriate HWS) energy as ratio between actual efficiency and 3.1. Determine % change in total building energy

- If change in total energy is > 4% potential impact is “high”
- If 4% > = change in total energy > 0.5%, potential impact is “medium”
- Otherwise change in total energy potential impact is “low”

§ Assess likely scale of carbon impact from proportion of total carbon. Calculate new heating (and, if appropriate HWS) carbon emissions as ratio between actual efficiency and 3.1. Determine % change in total building carbon emissions

- If change in total carbon is > 4% potential impact is “high”
- If 4% > = change in total carbon > 0.5%, potential impact is “medium”
- Otherwise change in total carbon, potential impact is “low”

B2.3.1.2 Heating controls

- **Does the heating system have centralised time control**?
  - If not trigger recommendation **EPC-H2**
    - § Improve heating efficiency by 1 percentage point and
    - § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above),
      - If total energy cost for building changes by more than 4%, impact is “high”
      - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is “medium”
      - Otherwise impact is “low”
    - § Assess likely scale of carbon impact from proportion of total carbon
      - If total carbon emissions from the building change by more than 4%, impact is “high”
      - If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
      - Otherwise impact is “low”

- **Does the heating system have room by room time control?**
  - If not trigger recommendation **EPC-H5**
    - § Improve heating efficiency by 1 percentage point and
    - § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above),
      - If total energy cost for building changes by more than 4%, impact is “high”
      - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is “medium”
      - Otherwise impact is “low”
    - § Assess likely scale of carbon impact from proportion of total carbon
      - If total carbon emissions from the building change by more than 4%, impact is “high”
      - If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
      - Otherwise impact is “low”

- **Does the heating system have room by room temperature control?** If not trigger recommendation **EPC-H6**
    - § Improve heating efficiency by 2 percentage points and
    - § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above),

        - If total energy cost for building changes by more than 4%, impact is "high"
        - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
        - Otherwise impact is "low"
    - § Assess likely scale of carbon impact from proportion of total carbon
        - If total carbon emissions from the building change by more than 4%, impact is "high"
        - If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
        - Otherwise impact is "low"

- **Does the heating system have optimum start and stop control?**
    - o If not trigger recommendation **EPC-H7**
    - § Improve heating efficiency by 2 percentage points and
    - § Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above),
        - If total energy cost for building changes by more than 4%, impact is "high"
        - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
        - Otherwise impact is "low"
    - § Assess likely scale of carbon impact from proportion of total carbon
        - If total carbon emissions from the building change by more than 4%, impact is "high"
        - If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
        - Otherwise impact is "low"

Does the heating system have weather compensation controls? If not trigger recommendation **EPC-H8**

- § Improve heating efficiency by 1.5 percentage points and
- § Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above),
    - If total energy cost for building changes by more than 4%, impact is "high"
    - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
    - Otherwise impact is "low"
- § Assess likely scale of carbon impact from proportion of total carbon
    - If total carbon emissions from the building change by more than 4%, impact is "high"
    - If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
    - Otherwise impact is "low"

B2.3.2 Cooling

B2.3.2.1 Cooling Efficiency

- **Check if using default cooling efficiency – if yes trigger EPC-C1**

Note: Assessing impact of recommendation **EPC-C1** is done similarly to that for recommendation **EPC-C2** shown below.

- **Find cold generator efficiency**
  - o If cold generator efficiency > 2.4, classify cold generator efficiency as "good"
  - o If 2.4 > = cold generator efficiency > 2.0 , classify cold generator efficiency as "fair"
    - § Trigger recommendation **EPC-C2**
    - § Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above). Calculate new cooling energy as ratio between actual efficiency and 2.5. Determine % change in total building energy
      - If change in total energy is > 4% potential impact is "high"
      - If 4% > = change in total energy > 0.5%, potential impact is "medium"
      - Otherwise change in total energy potential impact is "low"
    - § Assess likely scale of carbon impact from proportion of total carbon. Calculate new cooling carbon emissions as ratio between actual efficiency and 2.5. Determine % change in total building carbon emissions
      - If change in total carbon is > 4% potential impact is "high"
      - If 4% > = change in total carbon > 0.5%, potential impact is "medium"
      - Otherwise change in total carbon, potential impact is "low"
  - o If 2.0 > cold generator efficiency, classify cold generator efficiency as "poor"
    - § Trigger recommendation **EPC-C2 as above**

B2.3.2.2 Duct and AHU leakage

- o If the HVAC system is VAV (including packaged cabinet), fan coil, induction, constant volume, multizone, terminal reheat, dual duct, chilled ceiling or chilled beam (with displacement ventilation), or active chilled beams,
- o Extract duct and AHU leakage for Actual Building
- o If duct and AHU leakage < 5% classify duct leakage as "good"
- o If 5% < = duct and AHU leakage < 10%, classify duct leakage as "fair"
  - § Trigger recommendation **EPC-C3** and calculate impact
  - § Reduce cooling energy by P% where P is
    - VAV, constant volume, multizone, terminal reheat, dual duct P=5%
    - Fan coil, induction P = 2%
    - Chilled ceiling, chilled beam P= 0.5%
  - § Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above),
    - If total energy cost for building changes by more than 4%, impact is "high"
    - If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
    - Otherwise impact is "low"
  - § Assess likely scale of carbon impact from proportion of total carbon
    - If total carbon emissions from the building change by more than 4%, impact is "high"

- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

- If 10% < = duct and AHU leakage, classify duct leakage as “**poor”**
  - Trigger recommendation **EPC-C3 – as above** and calculate impact - this time reducing cooling energy by P% where P is
    - VAV, constant volume, multizone, terminal reheat, dual duct P=10%
    - Fan coil, induction P = 4%
    - Chilled ceiling, chilled beam P= 1%

B2.3.3 Hot Water

B2.3.3.1 Hot water generator efficiency

- If hot water is NOT provided by the space heating heat generator
- If heat generator efficiency > 0.79, classify heat generator efficiency as “good”
- If 0.79 > = heat generator efficiency > 0.7, classify heat generator efficiency as “fair”
  - And trigger recommendation **EPC-W1**
  - Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate new hot water energy as ratio between actual efficiency and 0.8. Determine % change in total building energy
    - If change in total energy is > 4% potential impact is “high”
    - If 4% > = change in total energy > 0.5%, potential impact is “medium”
    - Otherwise change in total energy potential impact is “low”
  - Assess likely scale of carbon impact from proportion of total carbon. Calculate new cooling carbon emissions as ratio between actual efficiency and 0.8. Determine % change in total building carbon emissions
    - If change in total carbon is > 4% potential impact is “high”
    - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
    - Otherwise change in total carbon, potential impact is “low”
- If 0.7 > = heat generator efficiency, classify heat generator efficiency as “poor”
  - And trigger recommendation **EPC-W1 – as above**
  - Assess likely scale of impact as above

- **If HWS efficiency is “poor”**
  - Trigger recommendation **EPC-W2**
    - Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate reduction in hot water energy as ratio between actual HWS efficiency and 0.75. Determine % change in total building energy
      - If change in total energy is > 4% potential impact is “high”
      - If 4% > = change in total energy > 0.5%, potential impact is “medium”
      - Otherwise change in total energy potential impact is “low”
    - Assess likely scale of carbon impact from proportion of total carbon. Calculate reduction in hot water energy as ratio between actual HWS efficiency and 0.75. Determine % change in total building carbon emissions

- If change in total carbon is > 4% potential impact is “high”
- If 4% > = change in total carbon > 0.5%, potential impact is “medium”
- Otherwise change in total carbon, potential impact is “low”

B2.3.3.2 Hot water storage

- o Check whether there is hot water storage
- o If storage heat loss > default value* 0.9 trigger recommendation **EPC-W3**
  - § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate reduction in hot water energy as 50% of storage losses. Determine % change in total building energy
    - If change in total energy is > 4% potential impact is “high”
    - If 4% > = change in total energy > 0.5%, potential impact is “medium”
    - Otherwise change in total energy potential impact is “low”
  - § Assess likely scale of carbon impact from proportion of total carbon. Calculate reduction in hot water energy as 50% of storage losses. Determine % change in total building carbon emissions
    - If change in total carbon is > 4% potential impact is “high”
    - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
    - Otherwise change in total carbon, potential impact is “low”

B2.3.3.3 Secondary HWS circulation

- If there is secondary HWS circulation and there is no time control
  - o Trigger recommendation **EPC-W4**
    - § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above). Calculate reduction in hot water energy as 30% of total hot water energy. Determine % change in total building energy
      - If change in total energy is > 4% potential impact is “high”
      - If 4% > = change in total energy > 0.5%, potential impact is “medium”
      - Otherwise change in total energy potential impact is “low”
    - § Assess likely scale of carbon impact from proportion of total carbon. Calculate reduction in hot water energy as 30% of total hot water energy. Determine % change in total building carbon emissions
      - If change in total carbon is > 4% potential impact is “high”
      - If 4% > = change in total carbon > 0.5%, potential impact is “medium”
      - Otherwise change in total carbon, potential impact is “low”

B2.3.4 Fuel Switching

Note: The potential impact calculations are the same process for each of the fuel-switching recommendations – only the fuel carbon contents and prices differ.

- o If coal, trigger recommendations **EPC-F2**, **EPC-F3**, **EPC-F6**

If hot water is provided by the space heating boiler, include hot water in energy and carbon proportions below

- § Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above), for **EPC-F2** (coal to gas)

Note: For simplicity, assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is "high"
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

§ Assess likely scale of carbon impact for **EPC-F2** from proportion of total carbon

- If total carbon emissions from the building change by more than 4%, impact is "high"
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

§ Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above), for **EPC-F3** (coal to biomass)

Note: For simplicity assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is "high"
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

§ Assess likely scale of carbon impact for **EPC-F3** (from proportion of total carbon

- If total carbon emissions from the building change by more than 4%, impact is "high"
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

§ Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above), for **EPC-F6** (coal to oil)

Note: For simplicity assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is "high"
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

§ Assess likely scale of carbon impact from proportion of total carbon

- If total carbon emissions for **EPC-F6** from the building change by more than 4%, impact is "high"
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is "medium"
- Otherwise impact is "low"

o If heating fuel is oil or LPG trigger recommendations **EPC-F1**, **EPC-F4**

If hot water is provided by the space heating boiler, include hot water in energy and carbon proportions below

§ Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 44 above), for **EPC-F1** (oil to gas)

Note: For simplicity assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is “high”
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

§ Assess likely scale of carbon impact for **EPC-F1** from proportion of total carbon

- If total carbon emissions from the building change by more than 4%, impact is “high”
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

§ Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above), for **EPC-F4** (oil to biomass)

Note: For simplicity assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is “high”
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

§ Assess likely scale of carbon impact for **EPC-F4** from proportion of total carbon

- If total carbon emissions from the building change by more than 4%, impact is “high”
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

o If heating fuel is gas, trigger recommendation **EPC-F5** (gas to biomass)

§ Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 44 above), for **EPC-F5** (gas to biomass)

Note: For simplicity assume no change in boiler efficiency – savings are due to fuel price only

- If total energy cost for building changes by more than 4%, impact is “high”
- If total energy cost for building changes by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

§ Assess likely scale of carbon impact for **EPC-F5** from proportion of total carbon

- If total carbon emissions from the building change by more than 4%, impact is “high”
- If total carbon emissions from the building change by less than or equal to 4% but more than 0.5%, impact is “medium”
- Otherwise impact is “low”

B2.3.5 Lighting

Note: Survey should require lamp type to be completed or inferred

o Check whether any spaces have T12 lamps

§ If they do, trigger recommendation **EPC-L1**

§ Assess likely impact on energy (assumed price weighted)

        - Impact is assessed by changing all T12 lamps to T8 lamps and assessing the % change in energy for the project
    - Assess likely impact on carbon
        - Impact is assessed by changing all T12 lamps to T8 lamps and assessing the % change in CO_2 for the project

- Check whether any spaces have T8 lamps
    - If they do, trigger recommendation **EPC-L5**
    - Assess likely impact on energy (assumed price weighted)
        - Impact is assessed by changing all T8 lamps to T5 lamps and assessing the % change in energy for the project
    - Assess likely impact on carbon
        - Impact is assessed by changing all T8 lamps to T5 lamps and assessing the % change in CO_2 for the project

- Check whether any spaces have GLS lamps
    - If they do, trigger recommendations **EPC-L2**
    - Assess likely impact on energy (assumed price weighted)
        - Impact is assessed by changing all GLS lamps to CFL (**EPC-L2**) and assessing the % change in energy for the project
    - Assess likely impact on carbon
        - Impact is assessed by changing all GLS lamps to CFL (**EPC-L2**) and assessing the % change in CO_2 for the project

- Check whether any spaces (with fluorescent lamps) have mains frequency ballasts
    - If they do, trigger recommendation **EPC-L7**
    - Assess likely impact on energy (assumed price weighted)
        - Impact is assessed by changing all T8 lamps with mains frequency ballast to T8 lamps with high frequency ballast and assessing the % change in energy for the project
    - Assess likely impact on carbon
        - Impact is assessed by changing all T8 lamps with mains frequency ballast to T8 lamps with high frequency ballast and assessing the % change in CO_2 for the project

- Check whether any spaces have high-pressure mercury discharge lamps
    - If they do, trigger recommendations **EPC-L3** and **EPC-L6**
    - Assess likely impact on energy (assumed price weighted)
        - Impact is assessed by changing all HP mercury to SON replacements (HP sodium) and assessing the % change in energy for the project. Note that the paybacks will be different for **EPC-L3** and **EPC-L6** although the energy impact will be the same.
    - Assess likely impact on carbon
        - Impact is assessed by changing all HP mercury to SON replacements (HP sodium) and assessing the % change in CO_2 for the project. Note that the paybacks will be different for **EPC-L3** and **EPC-L6** although the CO_2 impact will be the same.

B2.3.6 Renewables

- Is a wind turbine installed?
- If not trigger recommendation **EPC-R2**
    - Energy impact is (always?) low
    - Carbon impact is (always?) low

- Is solar thermal water heating installed?
- If not trigger recommendation **EPC-R3**
    - Energy impact is (always?) low
    - Carbon impact is (always?) low

- Is a photovoltaic system installed?
- If not trigger recommendation **EPC-R4**
    - Energy impact is (always?) low
    - Carbon impact is (always?) low

Note: Ideally we need a proper calculation to estimate impact, but generally the absolute impacts are likely to be low. The assessor can over-write this if the building merits special consideration.

B2.3.7 Envelope

Note: For envelope (and lighting) recommendations, guidance on impact is often very general. We can improve this in future, maybe looking at the gain loss ratio, etc.

Scale of Potential Impact			
Proportion of total energy or CO_2 accounted for by end-use	Overall consumption for end-use		
	Good efficiency	*Fair efficiency*	*Poor efficiency*
20% + energy or CO_2	Medium	Medium	High
5% to 20% energy or CO_2	Low	Medium	High
5% - energy or CO_2	Low	Low	Medium

Table 45: Scale of potential impact

Roofs
For pitched roofs with lofts
- If any have U value > 1.0, trigger recommendation **EPC-E6**
    - Assess likely impact on energy (assumed price weighted)
        - Use Table 45 applied to heating energy
    - Assess likely impact on carbon
        - Use Table 45 applied to heating carbon

Identify flat roofs
- If any have U value > 1.0, trigger recommendation **EPC-E2**
    - Assess likely impact on energy (assumed price weighted)
        - Use Table 45 applied to heating energy
    - Assess likely impact on carbon
        - Use Table 45 applied to heating carbon

Walls
Identify solid walls
- If any have U value > 1.0, trigger recommendation **EPC-E3**
    - Assess likely impact on energy (assumed price weighted)
        - Use Table 45 applied to heating energy
    - Assess likely impact on carbon
        - Use Table 45 applied to heating carbon

Identify cavity walls
- If any have U value > 1.0, trigger recommendation **EPC-E4**
    - Assess likely impact on energy (assumed price weighted)
        - Use Table 45 applied to heating energy

- o Assess likely impact on carbon
  - § Use Table 45 applied to heating carbon

Glazing
Identify all glazing

- If any have U value > 3.5 (assumed single glazed), trigger recommendation **EPC-E5**
  - o Assess likely impact on energy (assumed price weighted)
    - § Use Table 45 applied to heating energy
  - o Assess likely impact on carbon
    - § Use Table 45 applied to heating carbon
- And trigger recommendation **EPC-E8**
  - o Assess likely impact on energy (assumed price weighted)
    - § Use Table 45 applied to heating energy
  - o Assess likely impact on carbon
    - § Use Table 45 applied to heating carbon

Floors

- If any have U value > 1.0 trigger recommendation **EPC-E1**
  - o Assess likely impact on energy (assumed price weighted)
    - § Use Table 45 applied to heating energy
  - o Assess likely impact on carbon
    - § Use Table 45 applied to heating carbon

Airtightness

- If permeability > 14, trigger recommendation **EPC-E7**
  - o Assess likely impact on energy (assumed price weighted)
    - § Use Table 45 applied to heating energy
  - o Assess likely impact on carbon
    - § Use Table 45 applied to heating carbon

Overheating

- **Check whether any space in the building overheats**
  This is done by assessing if the solar gain limit according to the building regulations is exceeded in any zone in the building
  - o If yes, trigger recommendation **EPC-V1**
    - § Energy impact is (always?) medium
    - § Carbon impact is (always?) medium

B2.4 Next step: “Triggered” recommendations now need prioritising

To calculate **PAYBACK** for each recommendation, adjust standard paybacks (from Table 48) for building activities using the following:

- **For heating measures**
  - o Multiply payback by 140 and divide by **TYPICAL** building heating consumption (kWh/m^2.year)
- **For lighting measures**
  - o Multiply payback by 30 and divide by **TYPICAL** building lighting consumption (kWh/m^2.year)
- **For cooling measures relating to cold generators**
  - o Multiply payback by 30 and divide by **1.2*REFERENCE** building cooling consumption (kWh/m^2.year)
- **For cooling measures relating to mechanical ventilation**

- Multiply payback by 60 and divide by **REFERENCE** building auxiliary energy consumption (kWh/m^2.year)

- **For hot water measures**
  - Multiply payback by 10 and divide by **REFERENCE** building hot water energy consumption (kWh/m^2.year)

*Note: Standard paybacks are for offices and are derived by AECOM from an analysis of reported (expected) paybacks by CT surveys (in this case, in offices). (These surveys presumably are mostly in larger buildings). The adjustment scales the payback according to the ratio of **typical** building consumption to ECG019 (average of types 1 and 2, except cooling type 3) . (Note: need to choose suitable air-con adjustment!). Actual values are of secondary importance as the results are primarily used to rank measures.*

B2.5 Calculate Supporting information

To calculate **POUND PER CARBON SAVING** for each recommendation, use the following:

Apply financial payback adjustment

This adjusts the financial payback for existing fuels other than gas (or electricity). It is based on the relative prices of fuels. Multiply the payback by the value from Table 46.

Fuel	Factor
Natural gas	1
LPG	0.36
Biogas	0.68
Oil	0.58
Coal	1.64
Anthracite	1.64
Smokeless fuel (inc coke)	1.64
Dual fuel appliances (mineral + wood)	0.68
Biomass	0.68
Grid supplied electricity	1.22
Grid displaced electricity	0
Waste heat	0.1

Table 46: Financial payback adjustment

Label in terms of € spent per carbon saving
Good [index < 3], Fair [3 =< index < 5] or Poor [index >= 5]

Note: Based on DEC draft guidance advice – subsequently not used - that more than 4% of site energy is “high”, less than 0.5% is “low”, between these limits is “medium”. The current note assumes that energy is weighted by cost. It also uses information from an early DEC draft that suggests a rough indicator based on proportion of energy accounted for by end use: more than 20% “high”, less than 5% “low”, in between “medium”. This is extended in the table to reflect the “as found” performance. All these criteria will need to be reviewed in the light of early experience.

For fuel switching recommendations only
Adjust for the carbon content of different fuels by multiplying the financial payback by the relative carbon contents. (The financial payback has already been adjusted for fuel prices if the initial fuel is not gas). The adjustment depends on both existing and recommended fuel.

Multiply POUND PER CARBON SAVING value calculated above by relevant value from Table 47.

	From									
To	biomass	coal	LPG	oil	gas	biogas	anthracite	smokeless fuel	dual fuel	waste heat
biomass	1	0.09	0.11	0.09	0.13	1	0.08	0.06	0.13	1.39
coal	11.64	1	1.24	1.1	1.5	11.64	0.92	0.74	1.56	16.17
LPG	9.36	0.8	1	0.88	1.21	9.36	0.74	0.6	1.25	13
oil	10.6	0.91	1.13	1	1.37	10.6	0.84	0.68	1.42	14.72
gas	7.76	0.67	0.83	0.73	1	7.76	0.61	0.49	1.04	10.78
biogas	1	0.09	0.11	0.09	0.13	1	0.08	0.06	0.13	1.39
anthracite	12.68	1.09	1.35	1.2	1.63	12.68	1	0.81	1.7	17.61
smokeless fuel	15.68	1.35	1.68	1.48	2.02	15.68	1.24	1	2.1	21.78
dual fuel	7.48	0.64	0.8	0.71	0.96	7.48	0.59	0.48	1	10.39
waste heat	0.72	0.06	0.08	0.07	0.09	0.72	0.06	0.05	0.1	1

Table 47: Fuel switching recommendations adjustment to calculate POUND PER CARBON SAVING

- Sort “triggered” measures into rank order (lowest paybacks first)

- Offer this list to the assessor
  - Assessor can accept or reject selected recommendations, but must give reasons for rejection

- Select all recommendations with payback of less than (or equal to?) three years
  - Sort these by decreasing magnitude of carbon saving
  - If there are more than 15, select the first 15
  - These are the “recommendations with a short payback”

- Select all recommendations with payback of between three and seven years
  - Sort these by decreasing magnitude of carbon saving
  - If there are more than 10, select the first 10
  - These are the “recommendations with a medium payback”

- Select all recommendations with payback of more than seven years
  - Sort these by decreasing magnitude of carbon saving
  - If there are more than 5, select the first 5
  - These are the “recommendations with a long payback”

- Select recommendations added by assessor
  - Sort these by decreasing magnitude of carbon saving
  - If there are more than 10, select the first 10
  - These are the “other recommendations”

B3.0 Some caveats

These recommendations have been generated for the building and its energy systems operated according to standard schedules that are appropriate to the general activities in the building. The assessor should use his or her knowledge to remove inappropriate ones and possibly to add additional ones.

It is strongly recommended that more detailed assessments are carried out to quantify the benefits before making final decisions on implementation.

If the BER calculation has made extensive use of default values, some of the recommendations may be based on uncertain assumptions.

The replacement of systems or building elements when they reach the end of their useful life, or during refurbishment, offers economic opportunities beyond those listed here. Where this list of recommendations has identified a system, building element or end-use energy or carbon performance as being “poor”, the opportunities for improvement will be especially high. In most cases, new elements and systems will also need to comply with building regulations performance standards.

These recommendations do not cover the quality of operation or maintenance of the building and its systems. There are frequently significant opportunities for energy and carbon savings in these areas and a full “energy audit” to identify them is strongly recommended.

B4.0 Report Formats

The Format of the Recommendations Report is described in a separate template.

According to the information provided, for this building:	Typical payback	Carbon saved per £ spent	Potential impact on energy use	Potential impact on carbon emissions
Heating accounts for 35% of the carbon emissions				
The overall energy efficiency for heating is *fair*				
The carbon efficiency for heating is *fair*				
The heating system efficiency is *good*				
The heat generator efficiency is *good*				
The worst insulation level of some windows is *poor*				
** Recommendation: Replace/improve glazing i.e. install double glazing*	*Medium*	*Medium*	*Medium*	*Medium*
The worst insulation level of walls is *fair*				
The worst insulation level of roofs is *poor*				
** Recommendation: Install/improve roof insulation*	*Poor*	*Poor*	*High*	*High*
The worst insulation level of floors is *fair*				
Cooling accounts for 30% of the carbon emissions				
The overall energy performance for cooling is *poor*				
The carbon efficiency for cooling is *poor*				
The cooling system efficiency is *poor*				
** Recommendation: pressure test and seal ductwork*	*Good*	*Good*	*Medium*	*Medium*
The cold generator efficiency is *fair*				
** Recommendation: when next replacing the chiller, select a high performance model*	*Good*	*Good*	*Medium*	*High*
The demand for cooling is *poor*				
** Recommendation: reduce solar gain by use of shading devices or reflective film*	*Good*	*Good*	*Low*	*Medium*
(If no cooling system is installed in a space, the overheating risk can be checked and reported:				
Some spaces in this building have a significant risk of overheating				
Recommendation: reduce solar gain by use of shading devices or reflective film	*Good*	*Good*	*Low*	*Medium*
Lighting accounts for 25% of carbon emissions				
The overall energy performance of lighting is *good*				
The carbon efficiency of lighting is *good*				
The energy efficiency of the worst lighting systems in this building is *poor*				
** Recommendation: replace tungsten GLS lamps with CFLs*	*Good*	*Good*	*Potentially medium but requires more assessment*	*Potentially medium but requires more assessment*
Hot water provision accounts for 10% of carbon emissions				
The energy performance of hot water provision is *fair*				
The carbon efficiency of hot water provision is *poor*				
Mechanical ventilation accounts for 5% of carbon emissions				
The energy efficiency of mechanical ventilation is *poor*				
The carbon efficiency of mechanical ventilation is *poor*				
** Recommendation: consider replacing extract fans*	*Medium*	*Good*	*Medium*	*Good*

Figure 12: Example format for optional additional information

B5.0 Working list of BER recommendations

Note: Wording of recommendations to be reviewed

CODE	DESCRIPTION	CATEGORY	PAYBACK Currently using an average of FAIR and POOR values
EPC-C1	default chiller efficiency	COOLING	3
EPC-C2	install high efficiency chiller	COOLING	3.5
EPC-C3	Inspect and seal ductwork	COOLING	7.5
EPC-W1	High efficiency water heater	HOT-WATER	4.15
EPC-W3	DHW storage insulation	HOT-WATER	3.8
EPC-W4	DHW secondary circulation time control	HOT-WATER	4.5
EPC-W2	DHW point of use system	HOT-WATER	8
EPC-E1	insulate floor	ENVELOPE	15
EPC-E2	insulate roof	ENVELOPE	25
EPC-E3	insulate solid walls	ENVELOPE	6.5
EPC-E4	cavity wall insulation	ENVELOPE	3.7
EPC-E5	secondary glazing	ENVELOPE	4.6
EPC-E6	insulate loft	ENVELOPE	5.6
EPC-E7	pressure test	ENVELOPE	7
EPC-E8	improve glazing	ENVELOPE	9.3
EPC-F1	Oil or LPG to natural gas (heating)	FUEL-SWITCHING	1.08
EPC-F2	Coal to natural gas (heating)	FUEL-SWITCHING	3.75
EPC-F3	Coal to biomass (heating)	FUEL-SWITCHING	3.81
EPC-F4	Oil or LPG to biomass (heating)	FUEL-SWITCHING	6.7
EPC-F5	gas to biomass (heating)	FUEL-SWITCHING	6.72
EPC-F6	Coal to oil (heating)	FUEL-SWITCHING	8.4
EPC-H2	heating central time control	HEATING	1.8
EPC-H5	local time control	HEATING	5.8
EPC-H6	Room temperature control	HEATING	4.8
EPC-H7	Heating optimum start and stop control	HEATING	2.5
EPC-H8	heating weather compensation controls	HEATING	5
EPC-H1	install high efficiency boiler	HEATING	2.3
EPC-H3	install condensing boiler	HEATING	6.6
EPC-H4	default heat generator efficiency	HEATING	3
EPC-L1	T12 to T8	LIGHTING	0.6
EPC-L2	GLS to CFL	LIGHTING	0.85
EPC-L3	HP mercury to SON replacements	LIGHTING	1.8
EPC-L5	T8 to T5	LIGHTING	2.8
EPC-L6	HP mercury to SON	LIGHTING	3.5
EPC-L7	Mains to HF ballast	LIGHTING	5.7
EPC-V1	overheating	OVERHEATING	1.7
EPC-R1	consider GSHP	RENEWABLES	11.7
EPC-R2	install wind turbine	RENEWABLES	15.9
EPC-R3	install solar thermal water heating	RENEWABLES	20.2
EPC-R4	install PV system	RENEWABLES	44.7
EPC-R5	consider ASHP	RENEWABLES	9.8

Table 48: Working list of BER recommendations

CODE	TEXT
EPC-C1	The default chilller efficiency is chosen. It is recommended that the chiller system be investigated to gain an understanding of its efficiency and possible improvements.
EPC-C2	Chiller efficiency is low. Consider upgrading chiller plant.
EPC-C3	Ductwork leakage is high. Inspect and seal ductwork
EPC-W1	Install more efficient water heater
EPC-W3	Improve insulation on DHW storage
EPC-W4	Add time control to DHW secondary circulation
EPC-W2	Consider replacing DHW system with point of use system
EPC-E1	Some floors are poorly insulated – introduce/improve insulation. Add insulation to the exposed surfaces of floors adjacent to underground, unheated spaces or exterior.
EPC-E2	Roof is poorly insulated. Install/improve insulation of roof.
EPC-E3	Some solid walls are poorly insulated – introduce/improve internal wall insulation.
EPC-E4	Some walls have uninsulated cavities - introduce cavity wall insulation.
EPC-E5	Some windows have high U-values - consider installing secondary glazing
EPC-E6	Some loft spaces are poorly insulated - install/improve insulation. (reworded)
EPC-E7	Carry out a pressure test, identify and treat identified air leakage. Enter result in EPC calculation
EPC-E8	Some glazing is poorly insulated. Replace/improve glazing and/or frames. (reworded)
EPC-F1	Consider switching from oil or LPG to natural gas
EPC-F2	Consider converting the existing boiler from coal to natural gas
EPC-F3	Consider switching from coal to biomass
EPC-F4	Consider switching from oil or LPG to biomass
EPC-F5	Consider switching from gas to biomass
EPC-F6	Consider switching from coal to oil
EPC-H2	Add time control to heating system
EPC-H5	Add local time control to heating system
EPC-H6	Add local temperature control to the heating system
EPC-H7	Add optimum start/stop to the heating system
EPC-H8	Add weather compensation controls to heating system
EPC-H1	Consider replacing heating boiler plant with high efficiency type
EPC-H3	Consider replacing heating boiler plant with a condensing type
EPC-H4	The default heat generator efficiency is chosen. It is recommended that the heat generator system be investigated to gain an understanding of its efficiency and possible improvements.
EPC-L1	Replace 38mm diameter (T12) fluorescent tubes on failure with 26mm (T8) tubes
EPC-L2	Replace tungsten GLS lamps with CFLs: Payback period dependent on hours of use
EPC-L3	Replace high-pressure mercury discharge lamps with plug-in SON replacements
EPC-L5	Consider replacing T8 lamps with retrofit T5 conversion kit. (reworded)
EPC-L6	Replace high-pressure mercury discharge lamps with complete new lamp/gear SON (DL)
EPC-L7	Introduce HF (high frequency) ballasts for fluorescent tubes: Reduced number of fittings required
EPC-V1	In some spaces, the solar gain limit in criterion 3 of ADL2A 2010 is exceeded, which might cause overheating. Consider solar control measures such as the application of reflective coating or shading devices to windows.
EPC-R1	Consider installing a ground source heat pump
EPC-R2	Consider installing building mounted wind turbine(s)
EPC-R3	Consider installing solar water heating
EPC-R4	Consider installing PV
EPC-R5	Consider installing an air source heat pump

Table 49: Text for BER recommendations