24/10/08

Technical Manual

SBEM

SBEM: Simplified Building Energy Model

Part of the National Calculation Methodology : SBEM for assessing the Energy Performance of Buildings

A Technical Manual for SBEM

24th October 2008

Communities and Local Government

Version history

Technical Manual Version	For SBEM Version
31st August 2007	2.0.c
10th December 2007	2.0.c
24th October 2008	3.0.b

Key changes from the previous version of the manual

- New Appendix A containing the basic logic for filtering recommendations for EPCs

This manual, together with the software tools described in it, were developed by the BRE for the Department for Communities and Local Government (CLG), under a contract managed for CLG by Faber Maunsell.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Purpose

The purpose of this document is to record the detail of the various calculation procedures adopted within SBEM, 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

1.2. Audience

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

- The SBEM development team, as a reference document
- CLG[1] and Faber Maunsell, 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[2], is available, but all users are expected to read and refer to the iSBEM User Guide[3] if using iSBEM as the interface. That Guide contains all the information on the functioning of SBEM needed to operate the tool effectively.

---

[1] Department for Communities and Local Government
[2] IP 2/07: *SBEM for non-domestic buildings*
[3] Available for download from http://www.ncm.bre.co.uk.

2. Background

This section of the manual looks at the requirement for a calculation methodology for the UK that complies with Article 3 of the EPBD, which has developed into the National Calculation Methodology. It describes which draft prEN and CEN standards have been used to develop a calculation procedure, and how one particular implementation (SBEM) has been designed to satisfy these requirements.

2.1. 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)

This Manual explains 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.

2.1.1. 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 UK response to this has been to develop the 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 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 on 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. Article 3 permits the use of CO_2 emissions as a means of comparison, rather than energy consumption, in the standard methodology.

2.2. The National Calculation Methodology (NCM)

The Building Act 1984 requires that all buildings constructed or refurbished should comply with the requirements of the current Building Regulations. As stated above, the EPBD calls for a calculation methodology on the energy performance of buildings to be established. The response to this by the UK Office of the Deputy Prime Minister (ODPM) - now the Department for Communities and Local Government (CLG) - was to state in the 2006 Building Regulations Part L for England and Wales:

17A - (1) The Secretary of State shall approve a methodology of calculation of the energy performance of buildings

(2) The methodology shall comply with the requirements of the Directive.

17B - The Secretary of State shall approve minimum energy performance requirements for new buildings in the form of CO_2 emission rates, which shall be based upon the methodology approved pursuant to regulation 17A.

The NCM has been developed to provide this calculation. This manual deals with the calculation methodologies and compliance checking procedures that form the NCM.

The EPBD permits the inclusion of a CO_2 emission factor in the standard methodology. For Building Regulations compliance in the UK, it has been decided to base compliance on CO_2 emissions, rather than on delivered or primary energy, in order to:

- avoid confusion over definitions of delivered and primary energy
- allow comparison of energy from disparate sources and of different costs
- avoid having to set different targets where there is the option of using electricity or other fuels for a given end use
- remind users that the overall objective for the UK is carbon management in order to meet international treaty obligations.

Following on from the Article 3 requirement of the EPBD, the 2006 Building Regulations call for a proposed building to be assessed by comparing its expected annual carbon dioxide emissions with a target, on a consistent, calculated basis.

This marks a change from the optional means of demonstrating compliance with previous Building Regulations which allowed either matching constructions with U-value requirements for particular elements, limits to glazing areas, etc., or achieving a calculated target. Previous calculation methods have been specified (e.g. CECM, as explained in CIBSE TM32) but these are not compliant with all the requirements of the EPBD, and there could potentially be difficulties in achieving consistent results.

To address these concerns, the National Calculation Methodology (NCM) has been established.

2.2.1. Comparison rather than absolute calculation

At the core of the NCM, the calculation process compares the carbon emissions of the proposed building with those of a “notional building”, (equivalent to the same building constructed to 2002 Building Regulations standards) subjected to a specified “improvement factor”. This constitutes setting the standards in order to satisfy the requirements of Article 4 of the EPBD.

The basis on a comparison minimises argument about how well the absolute carbon emissions are predicted by different NCM-compliant methods, because both the proposed and notional buildings are subject to the same calculation approach. Instead it concentrates on achieving improvements compared with the previous regulations.

The NCM 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
- Heating and cooling generator efficiencies

The reason for this is to encourage consistency between repeated evaluations of the proposals.

Standard databases are also available for
- Heating and cooling *system* efficiencies
- Building component parameters

These databases are described in more detail in Section 3.3

The NCM also requires that specific construction elements in the proposed building are checked for compliance with minimum performance standards specified in Part L (or equivalent in Scotland and Northern Ireland). 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.

2.2.2. 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 elsewhere in this document.

2.2.3. Parameters required to define building

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

- the zones in which identifiable, standardised activities take place
- the geometry of each zone; 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

2.2.4. Comparison with Notional Building

The performance requirement is for the proposed building to achieve carbon emissions less than a “Target Emissions Rate” (TER). This is derived from those of the Notional Building introduced above.

Briefly, for England and Wales the notional building has:

- The same geometry, orientation and usage as the evaluated building
- The same standard operating patterns
- The same weather data
- Building fabric, glazing type, air tightness and HVAC and lighting plant substituted by specified standard items. These generally just comply with 2002 Building Regulations
- Any service not covered by Part L (e.g. emergency escape lighting, specialist process lighting) is ignored in both the actual and notional building

For Scotland and Northern Ireland there are slight differences, but the philosophy is the same.

The NCM is used to calculate the energy consumption and hence carbon dioxide emissions of both the building being evaluated (its “Building Emissions Rate” or BER) and those of the notional building.

2.2.5. Target emissions rate

For the current Building Regulations the TER is calculated from three components:

1. the carbon dioxide emissions of a notional building ($C_{notional}$).
2. an improvement factor between the standards implicit in the 2002 regulations standards and those expected in the current regulations. This improvement factor depends on the system type; a greater improvement is expected in buildings with mechanical ventilation and/or air conditioning than those with natural ventilation and no mechanical cooling.

This is meant to encourage designers and building developers towards more passive solutions for providing comfort.
3. the Low/Zero Carbon benchmark, which is intended to encourage the application of the technologies listed in article 5 of the EPBD.

The TER is derived thus:

TER = ($C_{notional}$) x (1 – improvement factor) x (1 – LZC benchmark factor)

The check for compliance with the CO_2 performance requirements is that BER $\leq$ TER.

2.2.6. Compliance with Articles 5 & 6

EPBD Articles 5 & 6 require that it should be demonstrated that the minimum standard requirements applied to new and existing buildings have been met. The requirements are different for new and existing buildings; for instance for new buildings over 1000m^2 it must be shown that the technical, environmental and economic feasibility of alternative systems such as heat pumps or CHP has been considered before construction starts.

The articles 5 & 6 requirements for new buildings and refurbishments are effectively provided by a compliance checking module (BRUKL) which is incorporated into all implementations of the NCM, such as SBEM.

2.3. Brief from ODPM

Having established the generalised content of the NCM, the ODPM (now the Department of Communities and Local Government or CLG) 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 write a national calculation tool to fulfil this role.

This tool has been developed into SBEM (Simplified Building Energy Model) by BRE as the default calculation for non-domestic buildings in the UK, 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®.
- BRUKL, the compliance checking module
- Standardised databases
- Standardised report format

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

2.4. 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[4] both existing and those that are to be written, which together form a calculation methodology.

Although the UK 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.

2.4.1. 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

EN15316-3 Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – part 3 Domestic hot water systems

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

3. The calculation process

3.1. Calculation overview

SBEM takes inputs from the software user and various databases, and, by calculation, produces a result in terms of the annual 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 domestic 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 equivalent CO_2 emissions. This comprises the Building Energy Rating (BER).
6. determines, on the same basis, the CO_2 emissions of a notional building with the same geometry, usage, heat gains, temperature, lighting and ventilation conditions, and weather but with building component construction, HVAC and lighting systems which just meet the listed 2002 Building Regulation or deemed to satisfy requirements
7. applies an improvement factor to each zone within the notional building, which varies dependent on the HVAC system strategy employed in that zone. The resulting CO_2 emissions comprise the Target Energy Rating (TER).

The BER and TER calculations are then handed over to the compliance checking module, BRUKL, to complete the assessment. BRUKL:

1. compares the BER with the TER, and determines a pass or fail based on the relative performance of the proposed building
2. undertakes a compliance check on certain parameters drawn from information input using iSBEM.

Finally reports are prepared to the standard format to provide

1. comparison of BER & TER,
2. confirmation of the elemental compliance check

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 emissions

3.2. 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 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 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 CO2 emissions comparison and compliance check undertaken by the BRUKL module (or similar modules for Scotland and Northern Ireland)

Hence, the user interacts with user 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 energy performance certificate purposes, the software should draw information from the sources described below.

3.2.1. User input

The user identifies the zones suitable for the analysis, according to the zoning rules (see Section 3.4.1) 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.

3.2.2. 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 3.3.2 and 3.3.3).

3.2.3. 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 3.3.1). The external conditions come from the internal weather database determined by the user-selected location (see Section 3.3.4).

3.3. Databases

3.3.1. Activities

3.3.1.1. <u>Overview of the Activity Database – purpose and contents</u>

The NCM 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 the NCM website. The database contains a comprehensive list of building types (29 in total, see Table 1, for the full list), and the space types that might exist in each one (64 in total, see Table 2). Each building type has a selection of the 64 activity types to choose from.

The NCM 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 and notional buildings as with the choice of weather location. The need is to ensure that comparisons with the notional 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 1: 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 2: List of Activity areas with definitions (in some cases the definition will change slightly depending on building type)

3.3.1.2. Occupation densities and associated internal gains

An occupancy density, metabolic rate, and schedule of occupancy is 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.

3.3.1.3. Heating and cooling set points and set back temperatures

The heating and cooling setpoints 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.

3.3.1.4. Lighting standards

The database contains the lux levels 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. Details of the expected switching system is also included for the definition of the notional building.

3.3.1.5. 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 need 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).

3.3.1.6. Heat gains from equipment

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.

3.3.1.7. Humidity requirements

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

3.3.1.8. Domestic Hot Water requirements

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.

3.3.2. 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 each 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 is to be used in the calculation.

3.3.3. HVAC system efficiencies

3.3.3.1. Definitions

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 and pumps (and controls) is treated as a separate item denoted as “auxiliary energy”. The consequent definitions for system heating and cooling efficiency 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 Coefficient of Performance”, SCoP, 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, 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 Energy Efficiency Ratio” SEER: 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: 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.

3.3.3.2. 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 – 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.

EN15243[5] 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 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. EN15243 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 system 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.

3.3.3.3. Determination of system performance parameters from the mechanisms

The basic energy flow diagram of the HVAC calculation in SBEM is shown below in Figure 1. The basic philosophy is to provide a consistent set of parameters that address all the mechanisms in EN15243. 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.

---

[5] CEN EN15243 Ventilation for Buildings – Calculation of room temperatures and of load and energy for buildings with room conditioning systems.

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.

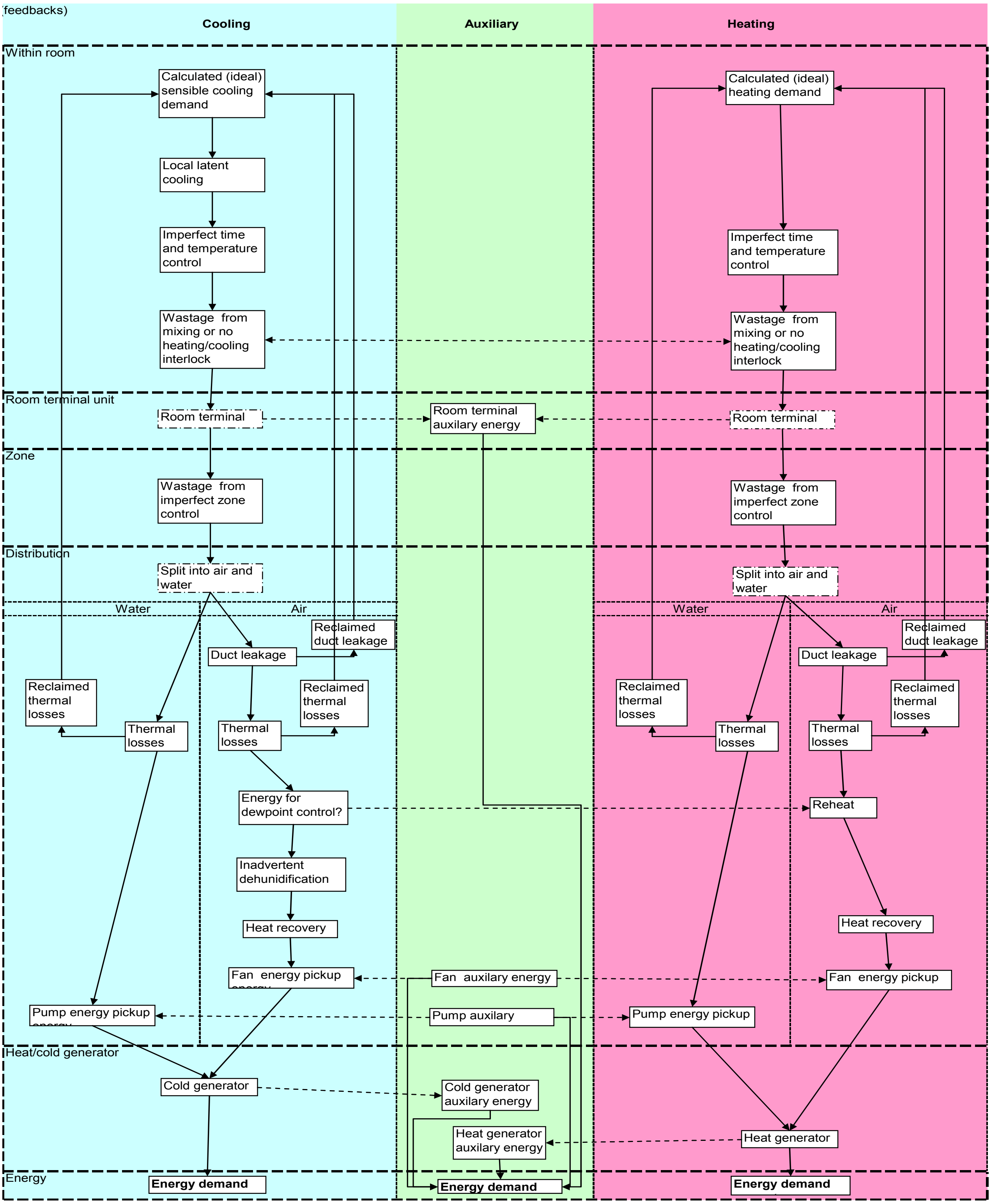


Figure 1: Basic energy flow diagram of the HVAC calculation in SBEM

3.3.3.4. The Mechanisms

The tables below, Table 3 and Table 4, list the mechanisms and summarises key points about them. Table 5 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 3: 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: auxilary 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 4: 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 wa	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 calcu	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 5: Parameter list

3.3.3.5. Calibration process

As can be seen from Table 3, 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 2.

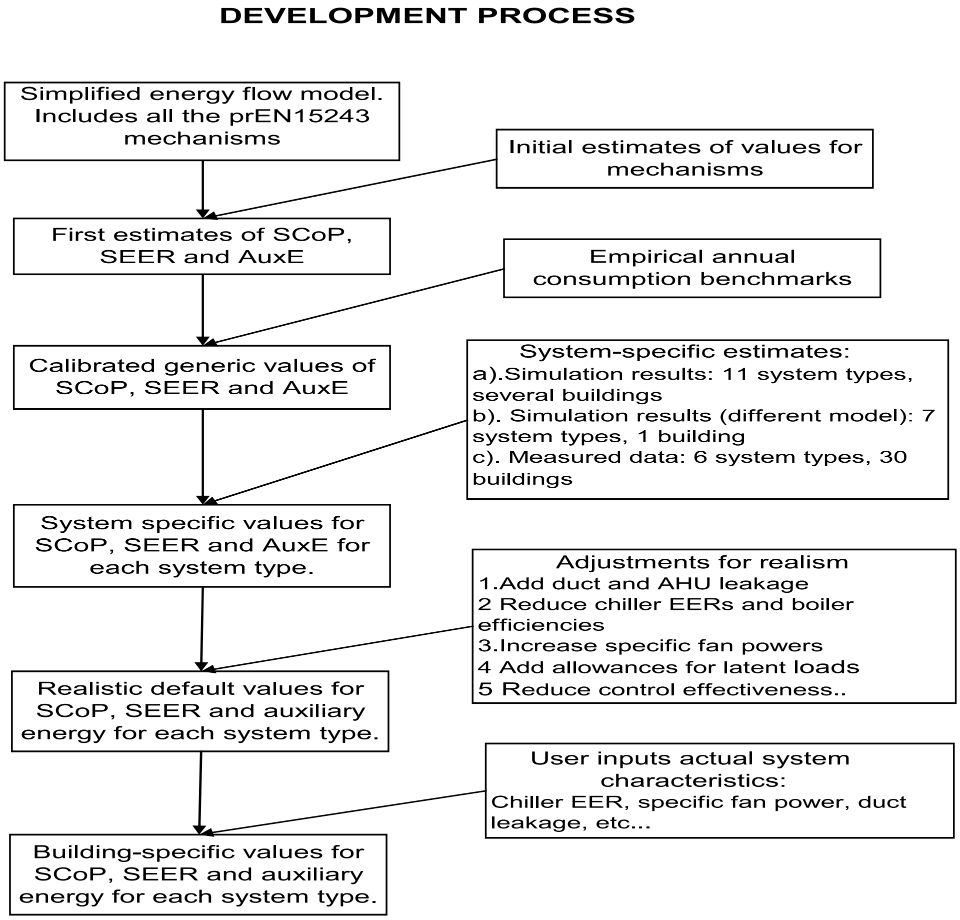


Figure 2: HVAC Model Development Process

We first produced initial estimates of typical values of the flow sheet parameters and calculated initial figures of the three performance parameters (auxiliary energy, SCoP, SEER) . With some relatively small adjustments to the initial assumptions, the consumption figures that these implied were brought into in 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[6], to develop a set of system-specific values for SCoP, SEER and auxiliary

[6] 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.

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.

3.3.3.6. 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 1.5m above 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 temperature

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

So 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 3m, this correction is very small

From GPG 303, typical values of grad are

Radiant heating	0.3
Radiators	1.5
Convector heaters	2.3

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

Radiant heating	1.1 deg C
Radiators	5.3 deg C

Convector heaters 8.1 deg C

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.

3.3.3.7. 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 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 tc is expressed as the arithmetic mean of air and mean surface temperature, ta and ts, respectively, we have

tc = I*a*r + (ta+ts)/2

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

Radiant intensity

For heat emitters such 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 Qt* ηr / ηt

Where Qt is the total heat output, ηr is the radiant efficiency and ηt 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 $I = d*Qt*\eta r / (\eta t*A)$

Correction factor

The heating requirement for the space is

$Qt = (ti-to)*(U+V) - dt*V$

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

to 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 Qt, for brevity set dt = k*Qt

Substituting and rearranging, we obtain

$Qt = (ti - to)*(U+V)/(1+k)$

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

Valuing k

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

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

And roomvolume/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).

$k = 0.00438*N*h*\eta r / \eta t$

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

$\eta r / \eta t$ 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 ηt 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 $\eta r / \eta t$ term simply represents the proportion of the output that is radiant.

Suggest the following values:

Emitter	ηr / ηt	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%

3.3.3.8. Energy Use Calculation for DHW in SBEM

The basic calculation scheme is straightforward:

- DHW demand is taken from the activity area 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 length are added. (as in SAP)
- Energy consumption is calculated using the heat generation efficiency
- Carbon emissions are calculated depending on the fuel source
- Additionally, if there is a secondary circulation system, auxiliary energy and the consequent carbon 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 assumptions are provided.

- storage volume
- heat loss per litre of stored hot water
- length of secondary pipework
- heat loss per metre of pipework
- secondary pump power
- heat generation efficiency

3.3.3.9. 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[7,8].

---

[7] 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.
[8] CEN EN 15243 Appendix I.

3.3.4. Weather

In order to calculate the reaction of the building and systems to the variable loads imposed by the external environment, the NCM needs an input of weather data. 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 accredited NCM 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, standard weather sets have been adopted as the only weather data sets to be used as part of the NCM. These equate to the 2006 CIBSE Test Reference Years. The available sites are: Belfast, Birmingham, Cardiff, Edinburgh, Glasgow, Leeds, London, Manchester, Newcastle, Norwich, Nottingham, Plymouth, Southampton, and Swindon. Thus the only option to be made available to the NCM user is to choose a weather location closest to the actual site of the project.

3.4. 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 3.4.1.
- 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 3.4.3.
- 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 the defined in Section 3.4.3) which need to be defined.

3.4.1. 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 NCM defines zoning rules that should be applied when assessing a building for Building Regulations compliance.

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:

- The Activity attached to it

- The HVAC system which serves it
- The lighting system within it
- The access to daylight (through windows or rooflights).

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

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

- 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.
- Attribute just one Activity to each resulting area.
- Divide each resulting area into Zones receiving significantly different amounts of daylight, defined by boundaries which are:
    - At a distance of 6m from an external wall containing at least 20% glazing.
    - At a distance of 1.5 room heights beyond the edge of an array of rooflights whose area is at least 10% of the floor area.
- Merge any contiguous areas which are served by the same HVAC and lighting systems, and which have the same Activity within them (e.g., adjacent hotel rooms, cellular offices, etc.) unless there is a good reason not to.
- If any resulting Zone is less than 3m wide, absorb it within surrounding zones.
- If any resulting *Zones* overlap, use your discretion to allocate the overlap to one or more of the *Zones*.

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. SBEM will then assume no transfer of heat, coolth, or light across the boundary, in either direction. In the context of iSBEM, the building needs to be divided into separate *Zones* for each Activity area, subdivided where more than one HVAC system serves an Activity area.

3.4.2. 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 Envelope sub-tab, these links are established automatically.

Figure 3 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.

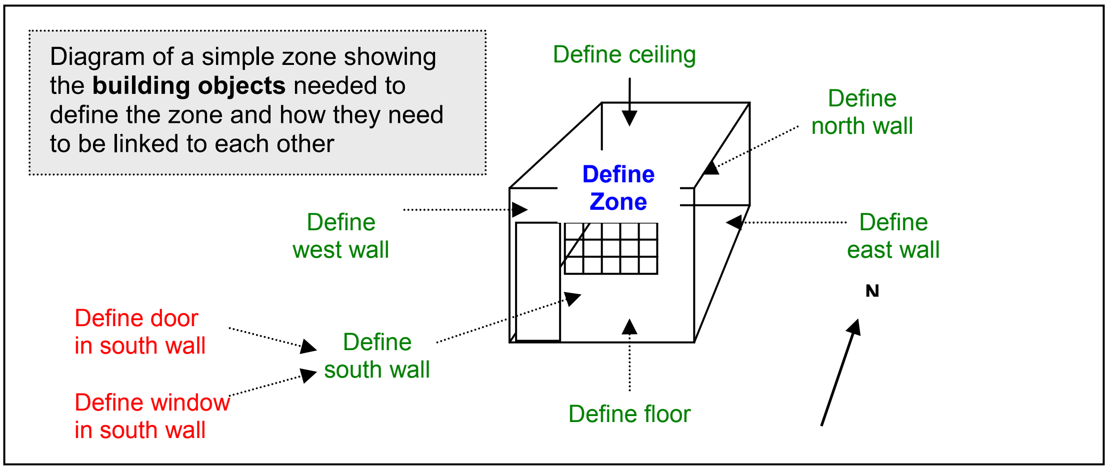


Figure 3: Diagram of building objects needed to define a simple zone

3.4.3. 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/m.K). SBEM contains a table of types of junctions and default linear thermal transmittance values for each of these types of junctions, Table 6. 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 6: 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/mK) 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 Psi values for junctions involving metal cladding are already compliant with the Metal Cladding and Roofing Manufacturers Association (MCRMA) standards.

Thermal bridging at junctions and around openings, which is not covered in Table 6, 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.

4. The calculation algorithms

The calculation methodology can in theory be based on any process which evaluates the energy consumption and hence CO_2 emissions of a building, as long as it complies with the following NCM 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 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 Standards 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 NCM in the UK, and that only one implementation of the monthly average calculation method will be accepted in the UK, 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

4.1. 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 carbon emissions for the building as a whole. The main structure of the calculation procedure is summarised in Table 7. 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 8.

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 heat and cooling production.
4	Combine the results for all zones and systems, to give building delivered energy totals.
5	Convert the totals into equivalent CO_2 emissions (this is not part of the CEN Standard – the conversion is described in ADL2A)

Table 7: 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 for 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	6.2, 6.3.2

		internal dimensions	
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 EN15242:2005	9.3.1
24	Differences in ventilation calculation between heating and cooling modes	Infiltration and heat recovery are currently ignored during cooling	9.3.2
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 schedules	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	Included in SBEM	10.3.2.5
35	Total solar heat sources	Equations 22 & 23 based on monthly average solar irradiance from weather data (see NCM Manual appendix I), 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 Cm values calculated according to EN ISO 13786:2005 in NCM Manual appendix J	12.3.1
43	Internal temperatures	Where heating or cooling is continuous	13.1

	used in energy calculations	during the whole heating period, use the set point temperature indicated by the activity area schedules (see NCM Manual appendix b). If not continuous, see below.	
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. This breakdown should be based on information in NCM Manual appendix G.	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.	Annex A

		Data should include the parameters 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 NCM	Annex I
61	Conventional input data (to be used in the absence of national data)	Not required for NCM – use activity area database	Annex J

Table 8: Options chosen in the CEN standard EN ISO 13790

4.1.1. 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 on 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.

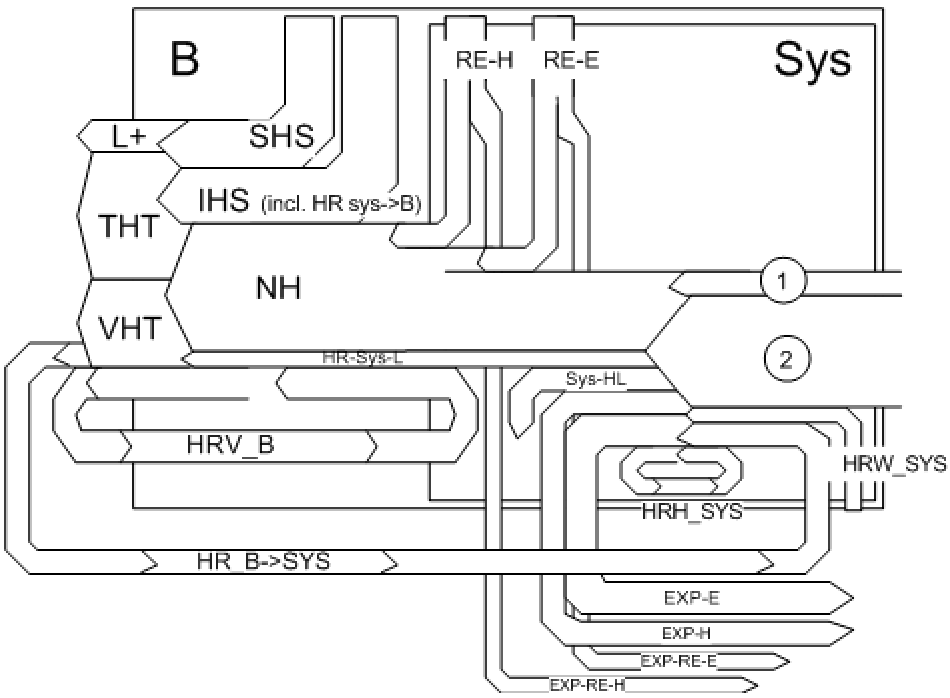
4.1.2. Overall energy balances for building and systems

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 4 and Figure 5, respectively.

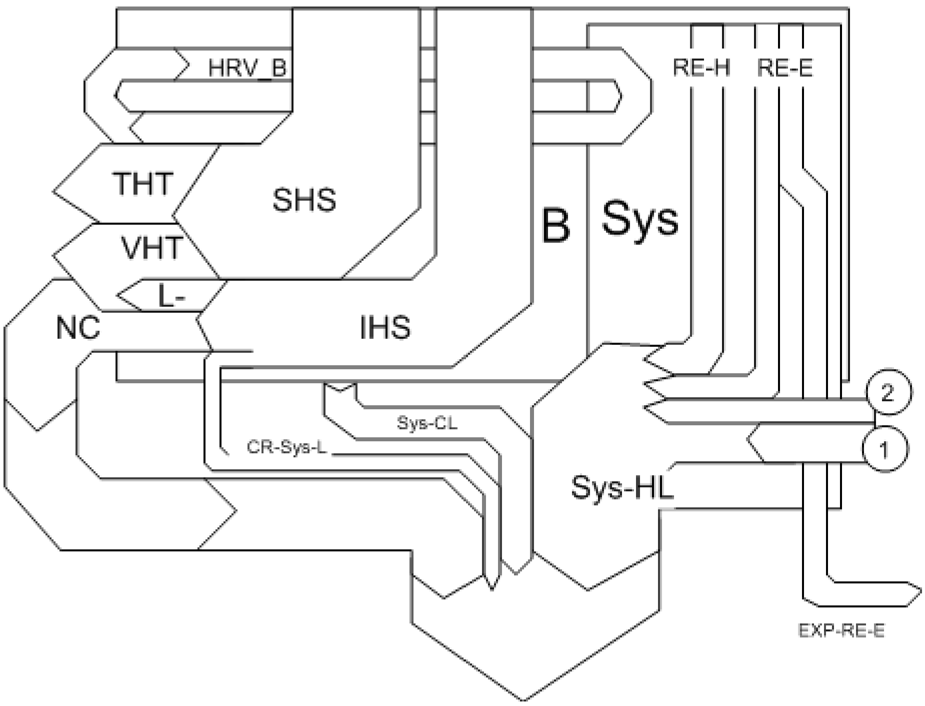


Key

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 4: 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 5: Energy balance of a building for space cooling

4.1.3. 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 heat flux from inside the building coincides with the overall internal dimensions.

4.1.4. 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.

4.1.5. 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

4.1.6. 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 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}.

4.1.7. Energy demand for heating

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

$Q_{NH} = Q_{L,H} - \eta_{G,H} \cdot Q_{G,H}$

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 for the heating mode, in MJ;

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

$\eta_{G,H}$ 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.

4.1.8. Energy demand for cooling

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

$Q_{NC} = Q_{G,C} - \eta_{L,C} \cdot Q_{L,C}$

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 for the cooling mode, in MJ;

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

$\eta_{L,C}$ 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.

4.1.9. Total heat transfer and heat sources

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.

4.1.10. Total heat transfer by transmission

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

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

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.

4.1.10.1. Transmission heat transfer coefficients

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 $W/(m^2{\cdot}K)$;

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 $W/(m{\cdot}K)$.

4.1.10.2. 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 3.4.3.

4.1.11. 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 4.2.

4.1.12. 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;

4.1.12.1. 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 4.4;

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.

4.1.12.2. 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 9;

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 0.75.

	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 9: 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 10 and Table 11.

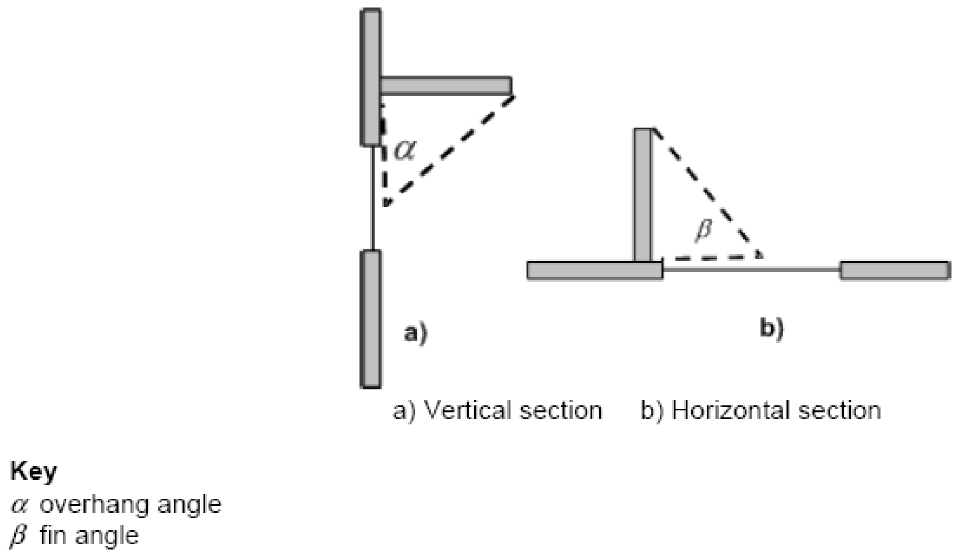


Figure 6: Overhang and fin: a) Vertical section b) Horizontal section

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 10: Partial shading correction factor for overhang, *Fo*

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 11: Partial shading correction factor for fins, *Ff*

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.

4.1.12.3. 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 for which 0.05 m^2K/W is taken.

$q_{sun,j}$ 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 areas of construction part j , in m^2.

4.1.13. 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 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, η_H is a function of the gain/loss ratio, γ_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)

η_{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 12;

τ_H is the time constant for heating of the building zone, in hours, determined according to Section 4.1.15;

$\tau_{0,H}$ is a reference time constant, from Table 12, 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 12: Values of the numerical parameter $a_{0,H}$ and reference time constant $\tau_{0,H}$ 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.

4.1.14. Loss utilisation factor for cooling

The loss utilisation factor for cooling, η_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

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

where (for each month and each building zone)

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

λ_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, τ_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 13;

τ_C is the time constant for cooling of the building zone, in hours; determined according to Section 4.1.15.

$\tau_{0,C}$ is a reference time constant, from Table 13, 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 13: Values of the numerical parameter $a_{0,H}$ and reference time constant $\tau_{0,H}$ 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.

4.1.15. 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 4.1.15.1;

$H_{L,H}$ 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 4.1.15.1;

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.

4.1.15.1. <u>Effective thermal capacity of the building zone</u>

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;

χ_j is the internal heat capacity per area of the building element j, in kJ/(m^2·K);

A_j is the area of the element j, in m^2;

ρ_{ij} is the density of the material of the layer i in element j, in kg/m^3;

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 14, 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 14: Maximum thickness to be considered for internal heat capacity

4.1.16. 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;

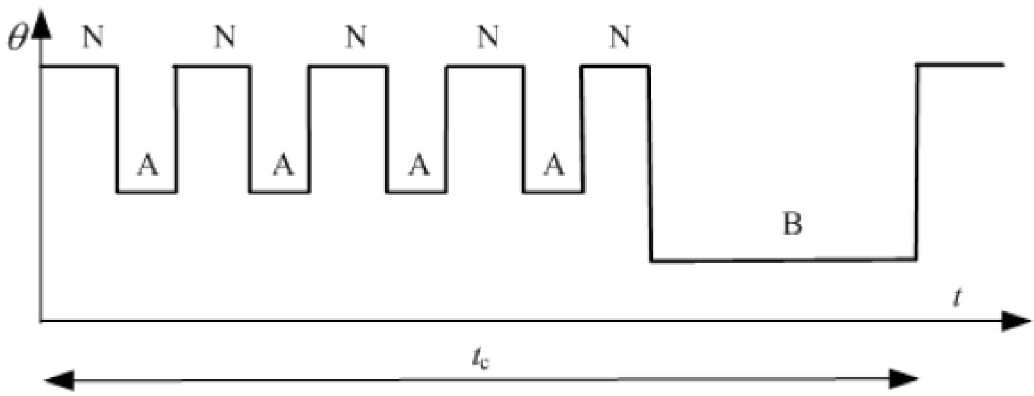
A) the time constant of the building is greater than three times the duration of the longest reduced period: in this case, the normal set-point temperature may be used for all periods;

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 7, 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	N	normal heating period
t	time	A	reduced heating period mode A
t_c	calculation period	B	reduced heating period mode B

Figure 7: Example of intermittence pattern

4.1.17. Set points and corrections for intermittency, cooling mode

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

NOTE: This implies that a thermostat setback 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;

$Q_{C,B}$ is the energy demand for cooling, assuming for all days of the month the control and thermostat settings for the intermittency 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);

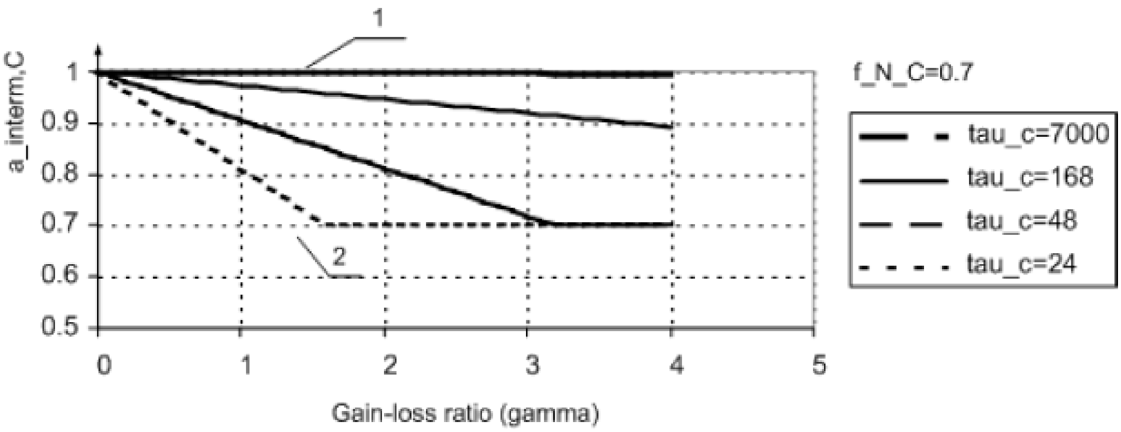
$b_{interim,C}$ is an empirical correlation factor; value $b_{interim,C}$ = 3;

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

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

λ_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 8: Example of intermittence factor for cooling

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

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

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

where

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

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

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

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

4.1.19. 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:

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

where

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

$Q_{NH,yr,z}$ 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.

4.1.20. 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.

4.1.21. 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.

4.2. Ventilation demand

4.2.1. Heat transfer by ventilation, heating mode

For every month, the heat transfer by ventilation Q_V is calculated as

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

where

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

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

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)

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

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

0.0864 conversion factor

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

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

where

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

$\rho_a \bullet c_a$ is the specific air heat capacity ~ 1.2 kJ/m^3

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

A is the zone floor area, in m^2

4.2.1.2. Ventilation air flow rate

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

where

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

u_{v-inf} air flow rate through the condition space due to infiltrations, in l/sm^2 floor area

η_{HR} efficiency of the heat recovery system. The default values are shown in Table 15

$u_{v,m,heat}$ 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.

$u_{v,n,heat}$ 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.

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

Table 15: Default efficiency of the heat recovery systems

4.2.2. Heat transfer by ventilation, cooling mode

For every month, the heat transfer by ventilation Q_V is calculated as

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

where

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

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

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)

θ'_e is the modified external air temperature as appearing in Table 16;

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

0.0864 conversion factor

Month	θ'_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 16: Values used for the temperature of the supply air for the calculation of monthly ventilation losses for cooling demand

4.2.2.1. Ventilation heat loss coefficient

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

where

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

$\rho_a \bullet c_a$ is the specific air heat capacity ~ 1.2 kJ/m^3

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

A is the zone floor area, in m^2

4.2.2.2. Ventilation air flow rate

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

where

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

u_{v-inf} air flow rate through the conditioned space due to infiltrations, in l/sm^2 floor area

$u_{v,m}$ 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.

4.2.3. 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 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:

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

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 cubic metres per hour) that passes through unit area of the building envelope (in square metres) 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 17, 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 17: Examples of leakages characteristics

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

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

$$u_{v-inf-wind} = 0.0769 \bullet Q4Pa \bullet (\Delta C_p \bullet V_{site}^{\,2})^{0.667} \text{ [m}^3\text{/hm}^2 \text{ outer envelope]}$$

where:

Q4Pa 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 ±60 to the external wall axis (orientation) for roofs: wind speed considering all wind sectors

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

Calculate the resulting air flow, qv-sw, for each zone using the following equation:

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

where:

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

$u_{v\text{-}inf\text{-}wind}$ 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, $u_{v\text{-}inf}$, can be defined using the following equation:

$$u_{v-inf} = (\max(0, u_{v-diff}) + u_{v-sw} \quad [m3/hm2 \text{ outer envelope}]$$

where:

$u_{v\text{-}diff}$ 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:

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

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

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

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.

4.2.4. 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.

4.3. Hot water demand

Demand for each zone is calculated as:

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

where

Database demand	= l/m^2 (per month), from the Activity database.
ΔT	= temp difference (deg K that water is heated up), taken as 50°K.
4.18 /1000	= specific heat capacity of water in MJ/kgK
zone AREA	= m^2

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

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

distribution loss = 0.17* Demand

where

0.17 is the default monthly DHW distribution loss (MJ/month) per monthly DHW energy demand (MJ/ month)

For each DHW generator:

- Carry out calculations for each solar energy system serving the DHW generator to calculate SES contribution to DHW, used to reduce DHW demand.
- Evaluate DHW demand, area, and distribution losses for DHW generator:
- Sum monthly demand for all zones served by DHW generator
- Sum monthly distribution losses for all zones served by DHW generator
- Sum area of all zones served by DHW generator
- Evaluate earliest start time and latest end time for any zone served DHW generator;
- Account for contribution from solar energy system (up to the maximum of half of DHW demand), Section 4.8, if applicable;
- Account for contribution from CHP, if applicable.

4.3.1. DHW storage

If the DHW system includes storage, then the storage volume is calculated as:

Storage volume (litres) = Daily demand (MJ/day) * 36

where

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

36 is a computational value – storage volume is 36 litres per MJ of daily demand

Storage losses are calculated as

Storage losses (MJ/month) = 0.1*(Storage volume5)$^{1/3}$ *(365/12)*(Storage volume)$^{2/3}$ * 3.6

where

0.1 is a computational value – storage losses are 0.1 kWh per litre of storage per day for storage vessel with inefficient insulation.

Storage volume5 is the storage volume, in litres, if the annual DHW demand were 5 MJ/m^2.

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 storage volume, in litres, as calculated above.

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

4.3.2. Secondary circulation

If the DHW system includes a secondary circulation, then 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 DHW generator, 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;

Loop length is the secondary circulation loop length in m;

Hours of operation number of hours of daily operation of the DHW system;

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

The secondary circulation pump power 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 DHW system.

4.4. 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 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

4.4.1. Calculate lighting power in the actual and notional buildings, P_j

<u>For the actual building</u>

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

    1. Find the notional illuminance in each space.
    2. Obtain the installed power by multiplying by the standard factor from Table 23 for that particular lighting system type and by the floor area of the space.

- **Where a full lighting design has been carried out, including verification that illuminances meet the standard levels:**

    1. Use the actual lighting circuit wattage 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 notional building (see below).
2. Multiply by 50, and divide by the average lamp and ballast efficacy (in lamp lumens per circuit Watt).

For the notional building

1. Find the notional illuminance in each space.
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.

4.4.2. Calculate display lighting power in the actual and notional buildings, P_{dj}

For the actual building

1. Take the same installed power as the notional 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 notional building

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

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

4.4.3. 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 = 1 W/m^2, default for stand alone sensors = 0.3 W/m^2. Or user can specify value for system used.
- Occupancy sensing – parasitic power will be extended to occupancy sensing in a future version of SBEM.
- Emergency lighting (although this is exempt from Part L) = 1 W/m^2. Currently this is not considered in SBEM for either lighting heat gain or electrical load.

4.4.4. Calculate daylight correction factor, F_{Dji}

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

4.4.4.1. Daylight penetration

This is expressed in terms of the average daylight factor. It also can be used with rooflights too. The average daylight factor can be **input by the user, or (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 and 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.

4.4.4.2. Photoelectric control

Photoelectric switching **– calculate equiv ext illum, E_{ext}:**

In side-lit spaces:

At the front of the room:
E_{ext} = 1.5 E 100 / (5 DF/3) /1000 = 0.09 E/DF kilolux

At the back of the room:
E_{ext} = 1.5 E 100 / (DF/3) /1000 = 0.45 E/DF kilolux

For each month, F_D in each half of the room is given by the fraction of day E_{ext} is not exceeded, per month(Table 19). If there is no photoelectric control in the back half of the room F_D in that half equals 1.

F_D = (F_D in front half of room + F_D in back half of room) /2

In roof lit spaces and those with windows in opposite sides, or a combination of windows and rooflights, the external illuminance in kilolux is given by:

E_{ext} = 1.5 E 100 / (0.75 DF) /1000 = 0.2 E/DF kilolux

For each month, F_D in the whole room is given by the fraction of day E_{ext} is not exceeded (Table 19).

Photoelectric dimming **– calc equiv ext illuminance, E_{ext}:**

E_{ext} is found in the same way as for photoelectric switching.
F_D is given by
F_D = [1 - Savings from ideal dimmer x $(1-R_w)/(1-R_f)$]
Savings from ideal dimmer are in Table 20
Typical values of R_f and R_w are 0.125 and 0.33 respectively for the longer established form of dimmer.

[In normal operation their residual light output and power consumption will occur throughout working hours even if the daylight illuminance exceeds the target value E_s; unless (future modifications to SBEM) the circuit is switched off by the occupants, an occupancy sensor or time switch.]

4.4.4.3. Manual switching

This only applies where there is **local manual switching**:

- 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

In SBEM, the user specifies the type of control

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:

1. **Calculate minimum working plane internal illuminance:**

$E_{in} = 2.6\ E_{ext}\ DF$ lux

where E_{ext} is the external horizontal diffuse illuminance (Table 21) and DF is the average daylight factor (in %)

2. **F_D is then calculated from**

$$F_D = -0.0175 + 1.0361/(1+\exp(4.0835(\log_{10} E_{in} - 1.8223)))$$

If $\log_{10} E_{in} \leq 0.843$ $F_D = 1$

$\log_{10} E_{in} \geq 2.818$ $F_D = 0$

F_D is then assumed to remain constant until an hour when the external illuminance E_{ext} drops below what it was at the start of the occupancy period. Then a new F_D is calculated using the equation above. This process is repeated each hour that E_{ext} drops. This is intended to simulate late afternoon switching.

4.4.4.4. Manual plus photoelectric control

F_D is calculated for each control separately. Then the minimum of the two F_Ds is taken.

4.4.5. 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.

4.4.5.1. Local occupancy sensing

$F_{Oi} = F_{OC}$ (i means for each hour in the calculation)

In these expressions F_{OC} is given in Table 22, System types are defined in the CEN statndard.

4.4.6. 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:
tsunrise and tsunset 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 18: tsunrise and tsunset

E_{ext} kilolux	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.472	0.291	0.206	0.160	0.130	0.183	0.159	0.168	0.197	0.282	0.384	0.496	0.261
10	0.772	0.570	0.389	0.338	0.260	0.300	0.279	0.281	0.334	0.449	0.649	0.828	0.454
15	0.946	0.776	0.594	0.521	0.367	0.397	0.373	0.389	0.493	0.666	0.895	0.985	0.616
20	0.995	0.916	0.736	0.617	0.571	0.466	0.436	0.559	0.631	0.833	0.984	0.999	0.728
25	1.000	0.977	0.876	0.738	0.654	0.622	0.594	0.646	0.770	0.940	0.998	1.000	0.817
30	1.000	0.998	0.950	0.847	0.749	0.731	0.706	0.752	0.883	0.987	1.000	1.000	0.883
35	1.000	1.000	0.989	0.928	0.838	0.822	0.804	0.850	0.960	0.998	1.000	1.000	0.932
40	1.000	1.000	0.997	0.974	0.915	0.896	0.877	0.917	0.990	1.000	1.000	1.000	0.964
45	1.000	1.000	0.999	0.991	0.956	0.945	0.938	0.966	0.997	1.000	1.000	1.000	0.983
50	1.000	1.000	1.000	0.996	0.984	0.973	0.974	0.990	0.999	1.000	1.000	1.000	0.993
55	1.000	1.000	1.000	1.000	0.996	0.989	0.993	0.998	1.000	1.000	1.000	1.000	0.998
60	1.000	1.000	1.000	1.000	0.998	0.997	0.997	1.000	1.000	1.000	1.000	1.000	0.999
65	1.000	1.000	1.000	1.000	1.000	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
70	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 19: Fraction of day (sunrise to sunset) external diffuse illuminance not exceeded at Kew

E_{ext} kilolux	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	0.764	0.855	0.897	0.920	0.935	0.909	0.920	0.916	0.902	0.859	0.808	0.752	0.870
10	0.571	0.712	0.800	0.835	0.870	0.834	0.851	0.846	0.818	0.747	0.646	0.545	0.756
15	0.428	0.584	0.703	0.747	0.809	0.773	0.792	0.785	0.741	0.646	0.507	0.394	0.659
20	0.328	0.476	0.611	0.668	0.740	0.722	0.743	0.720	0.665	0.547	0.395	0.298	0.576
25	0.263	0.392	0.527	0.599	0.669	0.669	0.691	0.656	0.592	0.460	0.318	0.238	0.507
30	0.219	0.328	0.454	0.534	0.607	0.611	0.634	0.597	0.522	0.389	0.265	0.199	0.447
35	0.188	0.282	0.393	0.474	0.550	0.556	0.579	0.540	0.459	0.335	0.227	0.170	0.397
40	0.164	0.246	0.345	0.421	0.497	0.504	0.526	0.487	0.405	0.293	0.199	0.149	0.354
45	0.146	0.219	0.307	0.376	0.449	0.457	0.478	0.439	0.360	0.261	0.177	0.132	0.317
50	0.131	0.197	0.276	0.339	0.407	0.415	0.435	0.398	0.325	0.234	0.159	0.119	0.287
55	0.120	0.179	0.251	0.308	0.371	0.379	0.397	0.362	0.295	0.213	0.145	0.108	0.261
60	0.110	0.164	0.230	0.282	0.340	0.348	0.364	0.332	0.270	0.195	0.133	0.099	0.239
65	0.101	0.152	0.213	0.261	0.314	0.322	0.336	0.306	0.250	0.180	0.122	0.092	0.221
70	0.094	0.141	0.197	0.242	0.292	0.299	0.312	0.285	0.232	0.167	0.114	0.085	0.205
75	0.088	0.131	0.184	0.226	0.272	0.279	0.291	0.266	0.216	0.156	0.106	0.079	0.192
80	0.082	0.123	0.173	0.212	0.255	0.261	0.273	0.249	0.203	0.147	0.099	0.074	0.180
85	0.077	0.116	0.163	0.199	0.240	0.246	0.257	0.234	0.191	0.138	0.094	0.070	0.169

90	0.073	0.110	0.154	0.188	0.227	0.232	0.243	0.221	0.180	0.130	0.088	0.066	0.160
95	0.069	0.104	0.145	0.178	0.215	0.220	0.230	0.210	0.171	0.123	0.084	0.063	0.151
100	0.066	0.099	0.138	0.169	0.204	0.209	0.218	0.199	0.162	0.117	0.080	0.060	0.144
105	0.063	0.094	0.132	0.161	0.194	0.199	0.208	0.190	0.155	0.112	0.076	0.057	0.137
110	0.060	0.090	0.126	0.154	0.186	0.190	0.199	0.181	0.148	0.107	0.072	0.054	0.131
115	0.057	0.086	0.120	0.147	0.177	0.182	0.190	0.173	0.141	0.102	0.069	0.052	0.125
120	0.055	0.082	0.115	0.141	0.170	0.174	0.182	0.166	0.135	0.098	0.066	0.050	0.120

Table 20: Savings from ideal dimmer (data from Kew, for period from sunrise to sunset)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Time												
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 21: External illuminances for manual switching. 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 22: F_{OC} values

Application and Lamp Type	Power Density Range (W/m2/100lux)
Commercial Application	
T12 Fluorescent - (halophosphate - low frequency control gear)	5.0
T8 Fluorescent - halophosphate - low frequency control gear	4.4
T8 Fluorescent - halophosphate - high frequency control	3.8

gear	
T8 Fluorescent - triphosphor - high frequency control gear	3.4
Fluorescent - compact	4.6
Metal Halide	5.5
High Pressure Mercury	7.6
High Pressure Sodium	4.5
GLS	28.0
T5	3.3
Industrial Application	
T12 Fluorescent - (halophosphate - low frequency control gear)	3.9
T8 Fluorescent - halophosphate - low frequency control gear	3.4
T8 Fluorescent - halophosphate - high frequency control gear	3.0
T8 Fluorescent - triphosphor - high frequency control gear	2.6
Metal Halide	4.1
High Pressure Mercury	5.7
High Pressure Sodium	3.3
T5	2.6

Table 23: Application, lamp type, and power density

4.4.7. Correction for Metering

Apply metering correction of 5% reduction to the lighting energy calculated, if applicable.

4.5. 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 4.1.7, 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). For heating, the "System Coefficient of Performance" of an HVAC system, SCoP, is the ratio of the total heating demand in that HVAC system divided by the energy input into the heat generator(s) as discussed in section 3.3.3.

The heating energy use for the HVAC system h_i (H_e) is then calculated by:

$H_e = H_d / SCoP$

The building heating energy use will be the addition of the heating energy use of all the HVAC systems included in the building.

4.5.1. Correction for Metering

Apply metering correction of 5% reduction to the heating energy calculated, if applicable.

4.6. 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 4.1.8, 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). For cooling, the “System Energy Efficiency Ratio” of an HVAC system, SEER, is the ratio of the total cooling demand in that HVAC system divided by the energy input into the cold generator(s) as discussed in section 3.3.3.

The cooling energy use for the HVAC system h_i (C_e) is then calculated by:

$C_e = C_d$ / SEER

The building cooling energy use will be the addition of the cooling energy use of all the HVAC systems included in the building.

4.6.1. Correction for Metering

Apply metering correction of 5% reduction to the cooling energy calculated, if applicable.

4.7. Hot water energy use

As described in section 4.3, for each DHW generator, calculate:

- storage losses
- secondary circulation losses
- secondary circulation pump energy (added to auxiliary energy)

The monthly DHW distribution efficiency is calculated as:

Distribution efficiency = DHW demand (MJ/month) / [DHW demand (MJ/month) + Distribution losses (MJ/month) + Storage losses (MJ/month) + Secondary circulation losses (MJ/month)]

Total thermal efficiency for DHW system = Distribution efficiency * DHW generator efficiency

Calculate DHW energy consumption for the DHW generator as:

DHW energy consumption = DHW demand / total thermal efficiency for DHW system

4.8. Solar thermal contribution

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 has been processed to yield values of global solar radiation for the orientations and inclinations shown in Table 24 and Table 25, respectively. The system's energy yield is calculated by applying an annual efficiency of conversion to the solar resource at the collector plane.

For the purposes of SBEM calculations solar hot water is used to displace the fuel used by the domestic hot water (DHW) generator.

4.8.1. Data requirements

- DHW System which the solar energy system is serving: Specifies the name given by the user for the DHW generator to which the SES is connected. This parameter is needed for the software to know which is the primary fuel that is being displaced by the solar energy system.
- Area: Specifies the collector area of the solar energy system, excluding the supporting construction, 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 24: Orientations for which the solar radiation has been calculated

Inclinations
0
15
30
45
60
75
90

Table 25: Inclinations for which the solar radiation has been calculated

4.8.2. Definition of algorithms

$Q_{SES} = I \bullet K_S \bullet A$

where

Q_{SES} is the annual useful domestic hot water supplied by the solar energy system, in kWh

I is the global solar radiation at collector surface, in kWh/m^2

K_S is the annual system efficiency of conversion defined as the ratio between the useful domestic hot water delivered by the solar collectors and the solar radiation at the collector plane, in %. The value used by SBEM is 38%

A is the aperture area of collector, in m^2.

4.8.3. Outputs produced

SBEM deducts the useful hot water produced by the solar thermal energy system from the requirements to be met by the DHW generator to which the solar energy system has been linked.

4.8.4. Commentary on accuracy

- The algorithm used to predict the performance of the solar energy system has been adjusted in order to yield energy production values that match actual measured performance data
- SBEM does not allow the user to define customised collector efficiencies. This means the benefits given by a more efficient collector over another are not being retained in the calculations.
- SBEM does not consider the electricity consumed by the pump in the solar primary circuit.
- SBEM does not account for the influence that different solar pre-heating strategies can have in the overall output of the solar energy system.

4.9. 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 24 and Table 25, 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.).

4.9.1. 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 have associated a different efficiency of conversion as shown in Table 26.
- 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 26.

mono-crystalline silicon,	15 %
Poly-crystalline silicon,	12 %
Amorphous silicon	6%
Other thin films.	8%

Table 26: 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 27: Photovoltaic system losses

4.9.2. 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 26)

K_S are the system losses, in % (Table 27).

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} are 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 equal to 0.568 $kgCO_2$/kWh as taken from Approved Document L2A for the displaced electricity.

4.9.3. Outputs produced

- Annual electricity produced by the photovoltaic system.
- Carbon dioxide displaced due to the electricity generated by the photovoltaic system.

4.10. 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 CIBSE data and by applying a turbine efficiency of conversion. Correction of the wind resource due to turbine height and terrain type is allowed for.

4.10.1. 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 and suburban or industrial area to urban with average building height bigger than 15m
- 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 29.

	K_R terrain factor	z_O (m) roughness
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 28: 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 29: Wind turbine efficiencies

4.10.2. Definition of algorithms

Wind turbine electricity generation

$$Q_{WT} = 0.5 \bullet \rho \bullet C_R(z) \bullet V^3_o \bullet A \bullet EPF \bullet K_{WT} / 1000 \qquad [kWh]$$

where

Q_{WT} is the annual electricity produced by the wind turbine, in kWh

ρ 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 28)

z_o is the roughness length (Table 28)

z is the wind turbine hub height, in m.

V_o is the mean annual wind speed as provided by the CIBSE Test Reference year for each location, in m/s

A is the turbine swept area, in m^2, calculated as:

$$A = \pi \bullet D^2 / 4$$

where

D is the wind turbine diameter, in m

EPF is the energy pattern factor calculated using the hourly wind speed data as provided by the CIBSE test reference years as:

$$EPF = \frac{APD}{0.5 \bullet \rho \bullet V^3_o}$$

where

APD: is the annual power density, in W/m^2, calculated as

$$APD = \frac{\sum_{i=1}^{8760} 0.5 \bullet \rho \bullet V^3_i}{8760}$$ where

V_i is the hourly average wind speed as given by the CIBSE TRYs, 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 29.

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:

$$A_{VAWT} = \frac{\pi \bullet D_e^{\,2}}{4}$$ 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}: are the annual carbon dioxide emissions displaced by the electricity generated by the wind turbine, in kgCO2

c_D: is the amount of carbon dioxide displaced by each unit of electricity produced by the wind turbine and is equal to 0.568 $kgCO_2/kWh$ as taken from Approved Document L2A for the displaced electricity.

4.10.3. Outputs produced

- Annual electricity produced by the wind turbine.
- Carbon dioxide emissions displaced by the electricity displaced by the wind turbine.

4.10.4. Commentary on accuracy

- Wind speed is taken from the CIBSE test reference years. 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.

4.11. CHP generators

4.11.1. Data requirements

- Fuel type: specifies the fuel type used for the CHP generator

- Thermal seasonal efficiency: refers to the thermal seasonal efficiency of the CHP plant calculated as the annual useful heat supplied by the CHP engine divided by the annual energy of the fuel supplied (using the higher calorific power)
- Building space heating supplied: specifies the percentage of the building space heating demand supplied by the CHP generator
- Building DHW supplied: specifies the percentage of the DHW demand supplied by the CHP generator.
- Heat to power ratio: The heat to power ratio of the CHP plant is calculated for the annual operation as the annual useful heat supplied divided by annual electricity generated

4.11.2. Definition of algorithms

Amount of fuel used by the CHP plant

$$F = \frac{H_{spc} \bullet p_{spc} + H_{DHW} \bullet p_{DHW}}{\eta_{TH}}$$

where

F are the fuel requirements by the CHP plant, in kWh

H_{spc} is the annual space heating demand of the building, in kWh

p_{spc} is the annual proportion of the space heating demand supplied by the CHP plant, in%

H_{DHW} is the annual domestic hot water demand of the building, in kWh

p_{DHW} is the annual proportion of the domestic hot water demand supplied by the CHP plant, in %

η_{TH} is the seasonal thermal efficiency of the CHP plant defined as the annual useful heat supplied by the CHP plant divided by the energy content of the annual fuel requirements of the CHP plant

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 are the CHP plant fuel requirements, in kWh

c is the carbon emission rate of the fuel used by the CHP plant, in $kgCO_2/kWh$, as taken from Approved Document L2A

Electricity generated by the CHP plant

$$E = \frac{F \bullet \eta_{TH}}{R}$$

where

E is the electricity generated by the CHP plant, in kWh

R is the heat to power ratio of the CHP plant as entered by the user, and defined as $R = \frac{\eta_{TH}}{\eta_E}$ where

η_E is the electrical conversion efficiency of the CHP engine

η_{TH} is the thermal conversion efficiency of the CHP engine

Carbon dioxide displaced by the CHP plant

$$C_E = E \bullet c_D$$

C_E are 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 equal to 0.568 $kgCO_2$/kWh as taken from Approved Document L2A for the displaced electricity

4.11.3. Outputs produced

- Electricity produced by the CHP plant
- Carbon dioxide displaced due to the electricity generated by the CHP plant

5. Options for interfacing to SBEM

SBEM requires data to be presented in a standard format through an input interface. iSBEM (interface to SBEM) has been commissioned by DCLG to fulfil the role of default interface, however, other approved interfaces to SBEM are available. These other interfaces are not discussed in this document.

5.1. iSBEM

The iSBEM input module acts as the interface between the user and the SBEM calculation. The user is guided towards appropriate databases described above, and the input is formatted so that data is presented correctly to the calculation and compliance checking modules.

5.1.1. 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.

5.1.2. 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*[9], 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
    - construction
    - thermal bridges
    - links between elements

[9] Available from the www.ncm.bre.co.uk web site

- 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 tool can be run. Results are then displayed in the Ratings form.

6. Applications for SBEM

SBEM calculates the energy consumption and consequent carbon emissions for the heating, cooling, ventilation, lighting and hot water systems which serve a particular building. This can be used in a number of applications. In particular, the way it has been designed by BRE answers the needs of the EPBD, as described under the following headings

6.1. Building Regulations compliance

The call by the EPBD for minimum energy performance standards to be met for new buildings is being answered in the UK by the requirement to comply with the Building Regulations relevant to each part of the UK (England & Wales, Scotland and Northern Ireland). The regulations also distinguish between domestic and non-domestic buildings, and new and refurbished buildings. For England and Wales the relevant document for new build non-domestic buildings is Approved Document to Part L (ADL2A)[10], to which the reader should refer for definitive statements on how to achieve compliance. Similar formats apply for Scotland and Northern Ireland.

As outlined in Section 2, the performance requirement in the UK is for the proposed building to achieve carbon emissions of a “Building Emissions Rate” (BER) no worse than a “Target Emissions Rate” (TER). The TER is derived from the emissions of a “Notional Building” (roughly equivalent to 2002 standards[11]) with improvement factor and “low/zero carbon” factor (defined in the relevant Approved Document) to mandate advances beyond previous standards. Again, similar approaches are taken for Scotland and Northern Ireland, with minor alterations.

The check can be undertaken when the building design is first submitted for outline Building Regulations approval, although this is not obligatory.

However, the check must be undertaken when the “as built” parameters are confirmed prior to final Building Regulations approval. This allows for changes between the original conceptual and construction stages, and confirmation that parameters such as air tightness (which cannot be checked until the building is actually constructed) have been achieved. The result then provides the basis for the “Asset Rating” (see next section).

CLG have commissioned SBEM and iSBEM to be the default application to implement this Building Regulations compliance check for non-domestic buildings, including the generation of the notional building, the application of appropriate improvement and LZC factors, and the comparison between BER and TER. This application also contains the rules for zoning the building consistently.

The Building Regulations tab on the ratings form of iSBEM reports on the comparison between BER and TER, and whether the proposed building meets the CO_2 compliance check at each stage. Other checks are carried out in parallel by the BRUKL module, which draws on data recorded for SBEM to establish whether various elemental values comply with Approved Document (e.g., L2A) and their equivalents and with the *Non-domestic heating, cooling and ventilation compliance guide.*

---

[10] Available from http://www.planningportal.gov.uk/england/professionals/en/4000000000563.html
[11] The notional building is fully defined by DCLG in the NCM Modelling Guide.

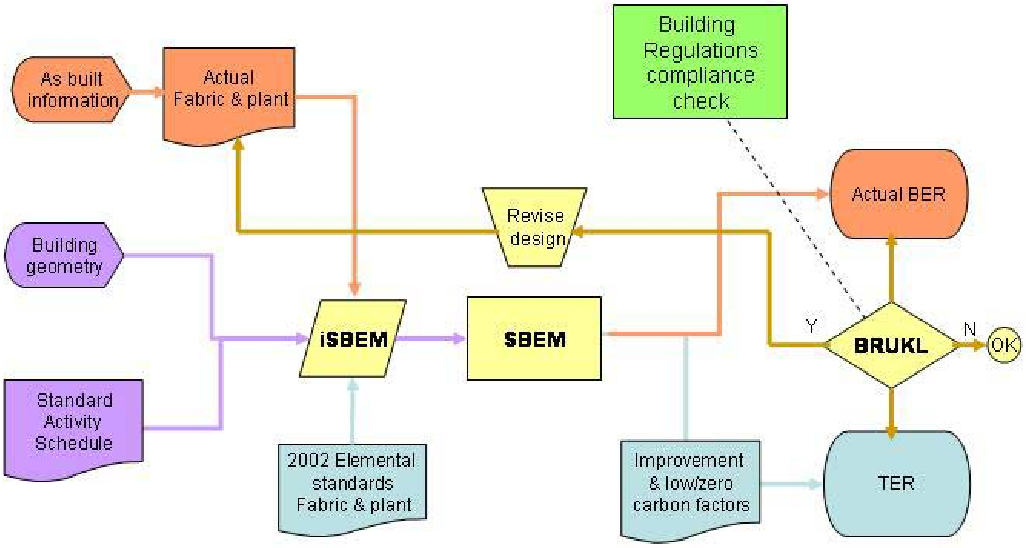


Figure 9: Inputs, calculations and comparisons involved in Building Regulations compliance checking procedures in SBEM

Further buttons on this tab provide intermediate results from the SBEM calculation, and data reflection to allow auditing against information on the proposed building.

BRE has collaborated with other software providers to enable them to develop alternative interfaces to SBEM, including links with other design software[12].

6.2. Asset rating

The EPBD calls for new and existing buildings to have an energy performance certificate available after construction and whenever they change hands through sale or let. The certificate should report on the intrinsic, as-built energy performance based on standardised operating patterns and internal conditions for the mix of activities taking place in the building. This is called the “asset rating” in the UK. This rating enables buildings with similar uses to be compared on a like-for-like basis for their potential to be operated efficiently. The asset rating will be presented in the form of an “Energy Performance Certificate (EPC)” to help non-technical buyers and tenants to understand the relative performance of buildings.

The formal EPCs will be issued by an accredited energy assessor, on the basis of calculations carried out using SBEM or an alternative approved dynamic simulation model. A central register of building ratings will be maintained so that government can report to the EU on the carbon efficiency of the building stock. In addition to the certificate, a list of recommendations for improvement will be generated and given to the building user or potential purchaser/tenant.

[12] The list of approved interfaces is available at www.ncm.bre.co.uk

The asset rating will be based on a comparison between the standardised emissions of the building (the BER as calculated for Building Regulations compliance) and those of a “reference” building. The reference building will be equivalent to the notional building, but with a fixed mixed mode HVAC system so that air conditioned and heated-only buildings can be rated on the same scale.

The description of the reference building and the EPC rating scale are defined in the NCM Modelling Guide. The EPC will also display the numerical value on which the rating is based, to aid differentiation within rating bands.

SBEM is capable of working out the intrinsic energy and carbon performance of buildings against the standardised operating patterns required for the asset rating; this process is the same as that required for checking Building Regulations compliance.

For a new building, producing the EPC would be undertaken using the data collected for the compliance check, by pressing another tab.

For an existing building which has not gone through the compliance check, the actual construction and system parameters are input instead of those which might be needed to achieve Building Regulation compliance. It is appreciated that some of this information may be difficult to acquire for existing buildings – for instance drawings and schedules of the current construction may no longer be available. Default values for constructions, HVAC, HWS and lighting system parameters based on age, generic appearance, etc are provided. Procedures for simplifying the collection and input of geometry and activity information are being developed.

7. Planned developments

The initial versions of SBEM and iSBEM do not include all the features that users would find valuable or helpful. 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. As of mid -2007, 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

- Provide daylight data for 14 sites
- Add explicit dehumidification calculation (if/when required by Asset rating calculation)
- Provide user access to default HVAC parameters
- Develop better shading model
- Improve handling of air-handling luminaires
- Add variable speed pumping
- Improve pump energy calculation
- Provide more chiller options
- Add embedded heat emitters
- Include provision for bivalent heating
- Add DHW 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

8. References

NEN 2916:1998 Energy performance of non-residential buildings. Determination method. ICS 91.120.10 November 1999

Energy performance of buildings — Calculation of energy use for space heating and cooling. CEN/TC 89. 2006 EN 13790

PG-N37 Standards supporting the Energy Performance of Buildings Directive (EPBD)

Ventilation for buildings — Calculation methods for the determination of air flow rates in buildings including infiltration. CEN/TC 156. 2006. EN 15242

CIBSE Guide J. Weather, solar and illuminance data. January 2002. The Chartered Institution of Buildings Services Engineers London.

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.

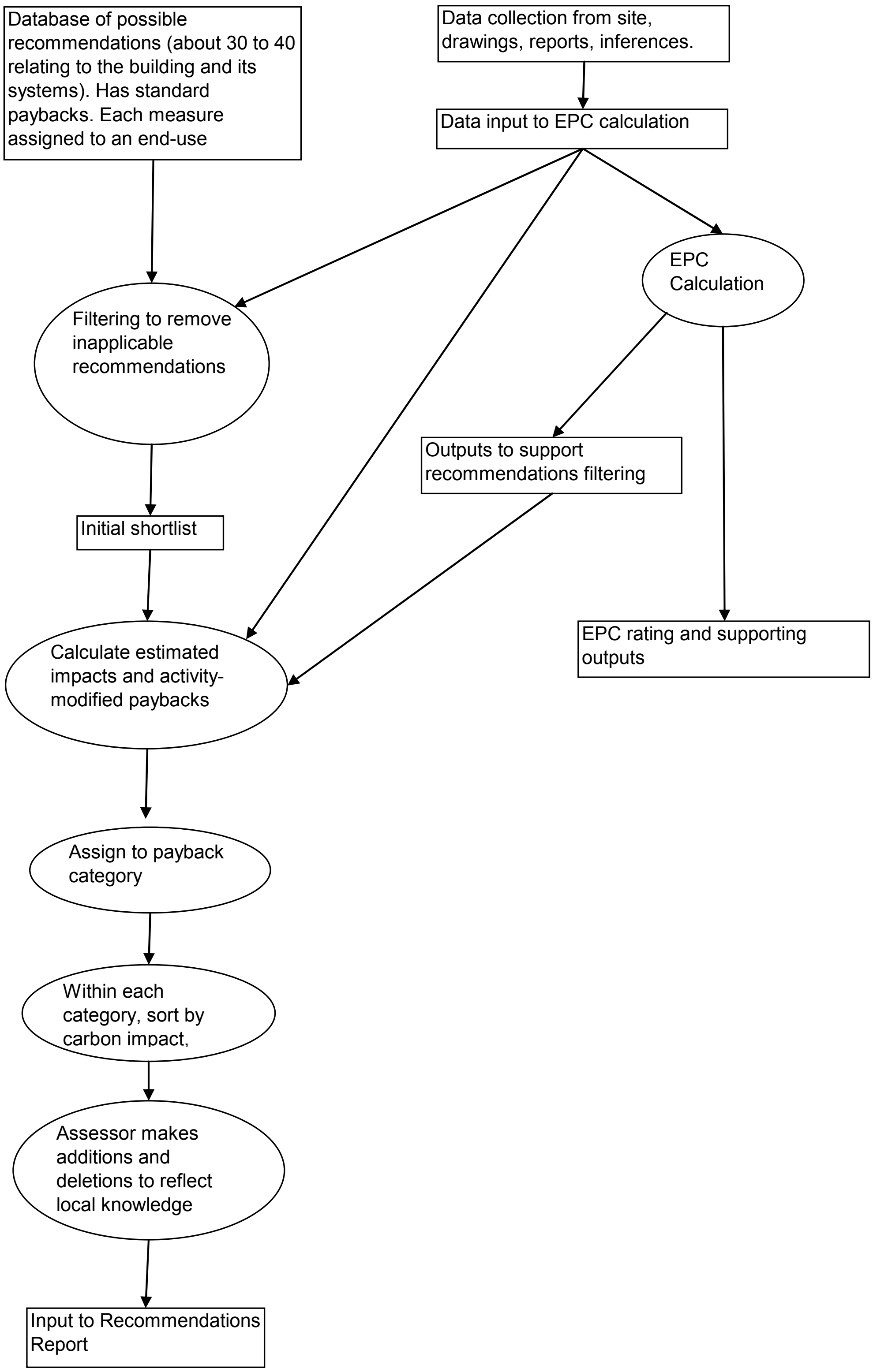
APPENDIX A: Basic Logic for Filtering Recommendations for EPCs

This appendix is a record of the structure and process of the filtering logic used to make an initial selection of recommendations to accompany EPCs.

Content with a clear background describes the logic that is mandatory for the production of the formal Recommendations Report in England and Wales.

Sections that have grey background are NOT a required element of the Recommendations Report in England and Wales. They are used in iSBEM to provide extra information to assessors. Other software may make also use them , but this is not mandatory. Accreditation bodies may require additional information to be provided to assist auditing.

A1.0 Schematic logic of filtering process



The initial list of potential recommendations is a subset of those collected by Faber Maunsell for use with Display Energy Certificates. Since the EPC calculation contains no information on operation or maintenance, potential recommendations relating to these aspect 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 applications 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 example iSBEM) they may also comment on recommendations and provide justification for additions and removals.

A2.0 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).)

A2.1 Basic whole-building information

- From calculations already carried out for EPC rating, record Notional Building
  - Heating kWh/m2, Cooling kWh/m2, Lighting kWh/m2, DHW kWh/m2, Auxiliary kWh/m2,
  - Heating kgCO2/m2, Cooling kgCO2/m2, Lighting kgCO2/m2, DHW kgCO2/m2, Auxiliary kgCO2/m2,
  - 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 EPC rating, record Actual Building
  - Heating kWh/m2, Cooling kWh/m2, Lighting kWh/m2, DHW kWh/m2, Auxiliary kWh/m2,
  - Heating kgCO2/m2, Cooling kgCO2/m2, Lighting kgCO2/m2, DHW kgCO2/m2, Auxiliary kgCO2/m2,
  - Calculate % of “energy” (price-weighted?) attributable to each end-use
  - Calculate % of carbon emissions attributable to each end-use
    - Perhaps with pie chart

- From calculations already carried out for EPC rating, record Typical Building
  - Heating kWh/m2, Cooling kWh/m2, Lighting kWh/m2, DHW kWh/m2, Auxiliary kWh/m2,
  - Heating kgCO2/m2, Cooling kgCO2/m2, Lighting kgCO2/m2, DHW kgCO2/m2, Auxiliary kgCO2/m2,

A2.2 Categorise end-uses as good/fair/poor

A2.2.1 Heating

- **For heating**, compare Actual **kWh/m2** with Notional and Typical
  - If **Actual < Notional**, classify heating energy efficiency as “good”
  - If **Notional <= Actual < Typical**, classify heating energy efficiency as “fair”
  - **Otherwise,** classify heating energy efficiency as “poor”

- **For heating**, compare Actual **kgCO2/m2** with Notional and Typical
  - If **Actual < Notional**, classify heating carbon efficiency as “good”
  - If **Notional <= Actual < Typical**, classify heating carbon efficiency as “fair”
  - **Otherwise,** classify heating carbon efficiency as “poor”

A2.2.2 Cooling

- **For cooling**, compare Actual **kWh/m2** with Notional
  Note – We can’t use reference or typical as they are mixed mode. Criteria are based on system efficiencies relative to that of the notional building, bearing in mind that the notional building system is a fairly run of the mill FC system.
  - If **Actual < 0.85 x Notional,** classify cooling energy efficiency as “good”
  - If **0.85 x Notional <= Actual < 1.5 x Notional**, classify cooling energy efficiency as “fair”
  - **Otherwise,** classify cooling energy efficiency as “poor”

- **For cooling**, compare Actual **kgCO2/m2** with Notional
  - But ignore virtual cooling (overheating is captured later)
  - If **Actual < 0.85 x Notional**, classify cooling carbon efficiency as “good”
  - If **0.85 x Notional <= Actual < 1.5 x Notional**, classify cooling carbon efficiency as “fair”
  - **Otherwise,** classify cooling carbon efficiency as “poor”

A2.2.3 Lighting

- **For lighting**, compare Actual **kWh/m2** with Notional and Typical
  - If **Actual < Notional**, classify lighting energy efficiency as “good”
  - If **Notional <= Actual < Typical**, classify lighting energy efficiency as “fair”
  - **Otherwise,** classify lighting energy efficiency as “poor”

- **For lighting**, compare Actual **kgCO2/m2** with Notional and Typical
  - If **Actual < Notional**, classify lighting carbon efficiency as “good”
  - If **Notional <= Actual < Typical,** classify lighting carbon efficiency as “fair”
  - **Otherwise,** classify lighting carbon efficiency as “poor”

A2.2.4 Domestic Hot Water

- **For hot water**, compare Actual **kWh/m2** with Notional and Typical
  - If **Actual < Notional**, classify hot water energy efficiency as “good”
  - If **Notional <= Actual < Typical**, classify hot water energy efficiency as “fair”
  - **Otherwise,** classify hot water energy efficiency as “poor”

- **For hot water**, compare Actual **kgCO2/m2** with Notional and Typical
  - **If Actual < Notional**, classify hot water carbon efficiency as “good”
  - If **Notional <= Actual < Typical**, classify hot water carbon efficiency as “fair”
  - **Otherwise,** classify hot water carbon efficiency as “poor”

A2.2.5 Auxiliary (Mechanical Ventilation)

- **For Auxiliary**, compare Actual **kWh/m2** with Notional and Typical
  - If **Actual < Notional**, classify Auxiliary energy efficiency as “good”
  - If **Notional <= Actual < Typical**, classify Auxiliary energy efficiency as “fair”
  - **Otherwise,** classify Auxiliary energy efficiency as “poor”

- **For Auxiliary**, compare Actual **kgCO2/m2** with Notional and Typical
    - If **Actual < Notional**, classify Auxiliary energy efficiency as “good”
    - If **Notional <= Actual < Typical**, classify Auxiliary energy efficiency as “fair”
    - **Otherwise,** classify Auxiliary energy efficiency as “poor”

A2.3 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).

A2.3.1 Heating

A2.3.1.1 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 DHW is provided by the heating boiler, DHW 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
elec	3.43
Waste heat	0.2

Table A1– Fuel Price factors

- Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 1 above). Calculate new heating (and, if appropriate DHW) 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 DHW) 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"

○ 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 1 above). Calculate new heating (and, if appropriate DHW) 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 DHW) 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"

○ 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 HCVC guide. But the air-source default in SBEM 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 1 above). Calculate new heating (and, if appropriate DHW) 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 DHW) 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 1 above). Calculate new heating (and, if appropriate DHW) 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 DHW) 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"

A2.3.1.2 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 1 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 1 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 1 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?**
    - 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 1 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 1 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"

A2.3.2 Cooling

A2.3.2.1 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**
    - If cold generator efficiency > 2.4, classify cold generator efficiency as "good"
    - If 2.4 > = cold generator efficiency > 2.0 , classify cold generator efficiency as "fair"
        - Trigger recommendation **EPC-C2** (was A4)
        - Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 1 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"

    - If 2.0 > cold generator efficiency, classify cold generator efficiency as "poor"
        - Trigger recommendation **EPC-C2 as above** (was A3)

A2.3.2.2 Duct and AHU leakage

- 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,
- Extract duct and AHU leakage for Actual Building
- If duct and AHU leakage < 5% classify duct leakage as "good"

- If 5% < = duct and AHU leakage < 10%, classify duct leakage as "fair"
    - Trigger recommendation **EPC-C3 – was EPCA6** 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 1 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, was EPCA5** 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%

A2.3.3 DHW

A2.3.3.1 Hot water generator efficiency

- If DHW is NOT provided by the 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 – was EPCW2**
    - Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 1 above). Calculate new DHW 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 DHW efficiency is "poor"**
  - Trigger recommendation **EPC-W2, was EPCW5**
    - Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 1 above). Calculate reduction in DHW energy as ratio between actual DHW system 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 DHW energy as ratio between actual DHW system 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"

A2.3.3.2 Hot water storage

  - Check whether there is hot water storage
  - 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 1 above). Calculate reduction in DHW 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 DHW 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"

A2.3.3.3 Secondary DHW circulation

- If there is secondary DHW circulation and there is no time control
  - Trigger recommendation **EPC-W4**
    - Assess likely scale of energy impact from proportion of total "energy" (assumed to be price-weighted using factor from Table 1 above). Calculate reduction in DHW energy as 30% of total DHW 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 DHW energy as 30% of total DHW 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"

A2.3.4 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.

- If coal, trigger recommendations **EPC-F2**, **EPC-F3**, **EPC-F6**

.If DHW is provided by the heating boiler, include DHW 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 1 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 1 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 1 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"

- If heating fuel is oil or LPG trigger recommendations **EPC-F1**, **EPC-F4**

.If DHW is provided by the heating boiler, include DHW 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 1 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 1 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"

- 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 1 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”

A2.3.5 Lighting

Note: Survey should require lamp type to be completed or inferred

- 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** and **EPC-L4**
  - Assess likely impact on energy (assumed price weighted)
    - Impact is assessed by changing all GLS lamps to CFL (EPC-L2) or LV tungsten halogen (EPC-L4) 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) or LV tungsten halogen (EPC-L4) 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 impact will be the same.

A2.3.6 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.

A2.3.7 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 A2– Scale of potential impact

Roofs
For pitched roofs with lofts

- If any have U value > 1.0, trigger recommendation **EPC-E6 was EPCH6**
    - Assess likely impact on energy (assumed price weighted)
        - Use *Table* applied to heating energy
    - Assess likely impact on carbon
        - Use *Table* applied to heating carbon

Identify flat roofs

- If any have U value > 1.0, trigger recommendation **EPC-E2** , **was EPCH11**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Walls
Identify solid walls
- If any have U value > 1.0, trigger recommendation **EPC-E3**, **was EPCH12**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Identify cavity walls
- If any have U value > 1.0, trigger recommendation **EPC-E4, was EPCH2**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Glazing
Identify all glazing
- If any have U value > 3.5 (assumed single glazed), trigger recommendation **EPC-E5, was EPCH5**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon
- And trigger recommendation **EPC-E8, was EPCH9**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Floors
- If any have U value > 1.0 trigger recommendation **EPC-E1, was EPCH10**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Airtightness
- If permeability > 14, trigger recommendation **EPC-E7, was EPCH8**
  - Assess likely impact on energy (assumed price weighted)
    - Use *Table* applied to heating energy
  - Assess likely impact on carbon
    - Use *Table* applied to heating carbon

Overheating
- **Check whether any space in the building overheats**
  (This will have been done in order to calculate virtual cooling)
  - If there is overheating, trigger **general warning** on certificate This is still to be confirmed
  - If yes, trigger recommendation **EPC-V1**

- Energy impact is (always?) medium
- Carbon impact is (always?) medium

A2.4 Next step: "Triggered" recommendations now need prioritising

To calculate **PAYBACK** for each recommendation, adjust standard paybacks (from Table A) for building activities using the following:

- **For heating measures**
  - Multiply payback by 140 and divide by **TYPICAL** building heating consumption (kWh/m2.year)
- **For lighting measures**
  - Multiply payback by 30 and divide by **TYPICAL** building lighting consumption (kWh/m2.year)
- **For cooling measures relating to cold generators**
  - Multiply payback by 30 and divide by **1.2*NOTIONAL** building cooling consumption (kWh/m2.year)
- **For cooling measures relating to mechanical ventilation**
  - Multiply payback by 60 and divide by **NOTIONAL** building auxiliary energy consumption (kWh/m2.year)
- **For hot water measures**
  - Multiply payback by 10 and divide by **NOTIONAL** building DHW consumption (kWh/m2.year)

*Note: Standard paybacks are for offices and are derived by FM 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.*

A2.5 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 .

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 A3– 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 4.

	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 A4– 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”

A3.0 Some caveats

These recommendations have been generated for to the building and its energy systems operated according to standard schedules 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 Energy Performance Rating 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.

A4.0 Report Formats

The Format of the Recommendations Report is described in a separate template.

Example format for optional additional information

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*

A5.0 Working list of EPC 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 efficency chiller	COOLING	3.5
EPC-C3	Inspect and seal ductwork	COOLING	7.5
EPC-W1	High efficiency water heater	DHW	4.15
EPC-W3	DHW storage insulation	DHW	3.8
EPC-W4	DHW secondary circulation time control	DHW	4.5
EPC-W2	DHW point of use system	DHW	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-L4	GLS to LV tungsten halogen	LIGHTING	2.5
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 A5– Working list of EPC 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-L4	Replace tungsten GLS spotlights with low-voltage tungsten halogen: Payback period dependent on hours of use
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	Some spaces have a significant risk of 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 A6– Text for EPC recommendations