

Technical Manual

SBEMie

SBEMie: Simplified Building Energy
Model for Ireland

For calculating and rating the energy performance of new and existing non-domestic buildings in the Republic of Ireland - Part of the Non-Domestic Energy Assessment Procedure (NEAP)

A Technical Manual for SBEMie

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Version history

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Key changes from the previous version of the manual

There have been no changes since the previous version.

This manual and the adaptation of the software tools described in it for the Republic of Ireland were developed by the BRE for Sustainable Energy Authority of Ireland (SEAI). This manual is a version specifically adapted for the Republic of Ireland based on both the UK's National Calculation Methodology (NCM) Modelling Guide for Buildings Other than Dwellings in England and the UK's SBEM Technical Manual.

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1. Introduction

1.1. Purpose

The purpose of this document is to record the details of the various calculation procedures adopted within SBEMie, generally comprising, for each:

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

1.2. Audience

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

- The SBEMie development team, as a reference document
- SEAI, as a record of the SBEMie 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 of the UK's version of SBEM, in the form of a BRE Information Paper¹, is available, but all users are expected to read and refer to the iSBEMie User Guide² if using iSBEMie as the interface. That User Guide contains all the information on the functioning of SBEMie needed to operate the tool effectively.

¹ IP 2/07: *SBEM for non-domestic buildings*

² Available for download from SEAI's website at www.seai.ie.

2. Background

The Non-Domestic Energy Assessment Procedure (NEAP) is the methodology for demonstrating compliance with specific aspects of the Technical Guidance Document - Part L of the Building Regulations in the Republic of Ireland. NEAP is also used to generate the Building Energy Rating (BER) certificate and advisory report for new and existing non-domestic buildings.

Having established the generalised content of the NEAP, SEAI sought software implementations of it. In particular, they required software which would handle the majority of buildings and could be made available free to users. They commissioned BRE to adapt for the Republic of Ireland the national calculation tool which BRE had developed for the UK's Ministry of Housing, Communities, and Local Government (MHCLG) to fulfil a similar role for non-domestic buildings in the UK.

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

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

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

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

2.1. European standards (CEN) used by SBEMie

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 standards³, which together form a calculation methodology.

In 2024, the European Council adopted the revised EPBD (Energy Performance of Buildings Directive, (EU) 2024/1275), introducing unified energy rating scales for all member states to compare buildings across borders.

SBEMie follows them as far as is practicable.

2.1.1. Summary of all CEN standards used by SBEMie

PG-N37 Standards supporting the Energy Performance of Buildings Directive

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

³ Published standards can be obtained online from the National Standards Authority of Ireland at www.nsai.ie.

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 Thermal performance of buildings - Transmission and ventilation heat transfer coefficients — Calculation method

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

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

3. The calculation process

3.1. Calculation overview

SBEMie takes inputs from the user of the software and various databases, and, by calculation, produces results in terms of the annual primary energy consumption and CO₂ emissions emanating from the energy used by the building's systems and its occupants. Some of the inputs are standardised to allow consistent comparisons for building regulations and energy ratings purposes in new and existing buildings.

SBEMie 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. SBEMie 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 the heating and cooling system efficiencies in order to determine the energy consumption. The energy used for lighting, ventilation, and hot water is also calculated.

Once the data has been input using the iSBEMie interface, the SBEMie calculation engine:

1. calculates the lighting energy requirements on a standardised basis, which takes into account the glazing area, glazing properties, light source, and lighting control systems;
2. establishes the standardised heat gains in each activity area, from the databases and input data;
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 required to maintain thermal conditions;
5. aggregates the delivered energy consumption by fuel source and converts it into the equivalent primary energy use and CO₂ emissions;
6. determines, on the same basis, the primary energy consumption and CO₂ emissions of a Reference building with the same geometry, usage, set-point temperatures, requirements for illuminance, hot water, and ventilation, and weather but with building component constructions, HVAC and lighting systems, set as per the Reference building's specifications for the relevant building regulations;
7. determines, on a similar basis, the primary energy consumption and CO₂ emissions of a Notional building, which has fixed ventilation, heating, and cooling conditions and space and water heating fuel.

Using the primary energy and CO₂ emissions results of the Actual building and Reference building, SBEMie then:

1. calculates the Energy Performance Coefficient (EPC) of the Actual building as the ratio of the primary energy consumption rate of the Actual building;
2. calculates the Carbon Performance Coefficient (CPC) of the Actual building as the ratio of the CO₂ emissions rate of the Actual building to that of the Reference building;
3. calculates the Renewable Energy Ratio (RER) of the Actual building as per the methodology specified in the NEAP Modelling Guide.

The primary energy and CO₂ emissions results of the Actual and Reference buildings are then handed over to the compliance checking module, BRIRL, to complete the assessment. BRIRL:

1. compares the EPC of the Actual building with the Maximum Permitted Energy Performance Coefficient (MPEPC) as specified in the relevant building regulations;
2. compares the CPC of the Actual building with the Maximum Permitted Carbon Performance Coefficient (MPCPC) as specified in the relevant building regulations;
3. compares the RER of the Actual building with the minimum permitted RER as specified in the relevant building regulations;
4. undertakes a compliance check on certain fabric and building services parameters drawn from information input using iSBEMie against the limiting standards as specified in the relevant building regulations;
5. generates a compliance output report to a standard format.

The primary energy and CO₂ emissions results of the Actual building are then handed over to the Building Energy Rating module, BERgen, to complete the assessment. BERgen:

1. Uses the results of the Actual building and f Zero Emission Building (ZEB) checks to determine an energy grade on an A0-G scale;
2. generates a BER Certificate to a standard format: showing the BER, energy grade, and CO₂ Emissions of the Actual building;
3. generates an Advisory report to a standard format, setting out recommendations for cost-effective improvements to the energy performance of the Actual building;
4. generates a BER XML file to a standard format required for lodgement onto the National BER Register.

The calculation of primary energy, CO₂ and other metrics for the BER differs from that used in generating compliance outputs (see NEAP modelling guide appendix C).

Some intermediate results produced by SBEMie are also generated to assist any diagnostic checks on the Actual building, including:

1. data reflection (to confirm data entry associated with results);
2. monthly profiles of energy use by each end use and by each fuel type;
3. total electricity and fossil fuel use (and generation by renewable energy sources, if applicable) and resulting primary energy and carbon dioxide 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 (weather at location);
- factors affecting fabric and ventilation heat losses, including insulation levels, thermal bridges, airtightness, deliberate natural ventilation, etc.;
- expected heat gains which are determined by the occupancy density, installed equipment (including lighting and IT), and solar heat gains which will depend on glazing areas, properties, and orientation, as well as the location of the building;
- information about the heating, cooling, lighting, and other building services systems.

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

The steps involved in the input are as follows:

- User defines the activities taking place and inputs the areas they occupy in the Actual (or proposed) building;
- Conditions in each of those areas are determined from a standard Activity Database;
- Durations of those conditions in each activity area are established from the Activity Database;
- User inputs the areas and constructions of the building components surrounding each activity area;
- User selects, from the standard weather database, a set of weather data relevant to the building location;
- User selects the HVAC and lighting systems and their control systems, and indicates which activity areas they serve;
- Provided that supporting evidence is available, the user is enabled to over-write default assumptions for construction and building services parameters;
- Finally, the interface enables the user to see reports on the primary energy consumption and CO₂ emissions comparisons and compliance check undertaken by the BRIRL module and/or the BER and energy band determined by the BERgen module.

Hence, the user interacts with the interface module, iSBEMie, 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, in order to support building regulations compliance checking or building energy rating purposes.

Further details on the sources from which the software draws information are 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 capacity for the building envelope elements, the HVAC systems efficiencies, and lighting data and controls by either selecting options from the internal databases, using the 'inference' procedures, or inputting values for these parameters directly (see Sections 3.3.2 and 3.3.3).

3.2.3. Locked databases

SBEMie also draws information from some 'locked' databases on activity parameters and weather data. These databases are 'locked' because the user cannot alter or override 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. Overview of the Activity Database – purpose and contents

The NEAP requires the activity definitions for a building to be defined by selecting from a set of standardised activities. For this purpose, an Activity Database has been prepared, and is available from SEAI's website. The database contains a comprehensive list of building types (see Table 1 for the full list), and the space types that might typically exist in each one (see Table 2 for the full list). Each building type has a selection of the activity types to choose from.

The NEAP divides up each building into a series of zones (following the zoning rules – see Section 3.4.1), 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 building 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 mainly:

- Heating and cooling set-point temperatures;
- 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, based on information supplied to SEAI by stakeholders such as, the Health Service Executive in relation to health-care activity types and the Department of Education and Skills in relation to education activity types.

Users should bear in mind that these data are used by the calculations for the proposed (Actual), Reference, and Notional buildings, as with the choice of weather location. The need is to ensure that comparisons with the Reference and other buildings are made on a standardised, consistent basis. For this reason, the energy and CO₂ emission calculations should not be regarded as predictions for the building in actual/real 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 SBEMie, or any other energy simulation software, are described below.

Building Type	Description
General Assembly and Leisure plus Night Clubs and Theatres	Cinemas, music and concert halls, bingo and dance halls, swimming baths, skating rinks, gymnasiums or sports arenas (except for motor sports or where firearms are used). This type also includes night clubs and theatres.
General Industrial and Special Industrial Groups	Used for the carrying on of an industrial process other than one falling within TCP Use class B1 and including those within TCP Use classes B3 to B7.
Hotels	Hotels, boarding and guest houses where no significant element of care is provided.
Non-residential Institutions - Community/Day Centre	Crèches, day nurseries and day centres.
Non-residential Institutions - Law Courts	Law courts
Non-residential Institutions - Libraries Museums and Galleries	Art galleries, museums, and libraries.
Non-residential Institutions – Post-primary Education	Non-residential post-primary education and training centres.
Non-residential Institutions - Primary Education	Non-residential primary education and training centres.
Non-residential Institutions - Primary Health Care Building	Non-residential clinics and health centres.
Offices and Workshop businesses	Offices, research and development, light industry appropriate in a residential area.
Others - Car Parks 24 hrs	Enclosed or underground car park reserved for parking cars with 24 hrs operation.
Others - Emergency services	Includes fire stations.
Others - Miscellaneous 24hr activities	Miscellaneous 24hr activities.
Others - Passenger terminals	Airport, Bus, Train and Sea Port passenger terminals.
Residential Institutions - Care Homes	Residential care homes and nursing homes.
Residential Institutions - Hospitals	Residential hospitals
Residential Institutions - Residential Post-primary schools	Residential post-primary boarding schools, residential colleges, and training centres. These follow a schedule of work similar to the schools' schedule (with similar working days, breaks, and holiday periods).
Residential Institutions - Residential primary schools	Residential primary boarding schools, residential colleges, and training centres. These follow a schedule of work similar to the schools' schedule (with similar working days, breaks, and holiday periods).
Residential Institutions - Universities and colleges	Universities and other residential campuses. These follow a schedule of work similar to the universities schedule (with similar working days, breaks and holiday periods).
Residential spaces	Residential spaces within non-domestic buildings not designed or altered for use as a separate dwelling.
Restaurant and Cafes/Drinking Establishments and Hot Food takeaways	For the sale of food and drink for consumption on the premises - restaurants, snack bars and cafes. Public houses, wine bars or other drinking establishments (but not night clubs). Also

	premises for the sale of hot food for consumption off the premises.
Retail and Financial/Professional services	Shops, retail warehouses, hairdressers, undertakers, travel and ticket agencies, post offices, pet shops, sandwich bars, showrooms, domestic hire shops, dry cleaners, and funeral directors. Banks, building societies, estate and employment agencies, professional and financial services, and betting offices. It also includes launderettes.
Secure Residential Institutions	Use for a provision of secure residential accommodation, including use as a prison, young offenders institution, detention centre, secure training centre, custody centre, short term holding centre, secure hospital, secure local authority accommodation or use as a military barracks.
Storage or Distribution	Used for storage or as a distribution centre.

Table 1: List of building types

Activity Type	Description
12hr Specialist Treatment Area	Treatment rooms that will predominantly be used during the day. Examples include: Day Case Theatre, Minor Procedure/Surgery Room, Local Anaesthetic.
24 hrs Consulting/treatment areas	For all A&E consulting/treatment/work areas, occupied and conditioned 24 hours a day.
24x7 Bedroom Unit	En suite bedrooms for patients with 24 hrs occupancy.
24x7 Circulation area (corridors and stairways)	For all 24x7 hrs circulation areas such as corridors and stairways.
24x7 Generic Office Area	Areas to perform 24 x7 hrs office work including offices and meeting rooms. It can include internal corridors providing access to the office spaces, tea making facilities or kitchenettes within the office space, areas for photocopiers and fax machines and staff lounges.
24x7 Reception	An area often containing a reception desk and reception staff with transient occupancy. It also includes patient waiting area.
24x7 Toilet	Any toilet areas. If toilets are subsidiary to changing/shower activities refer to Changing facilities with showers.
24x7 Warehouse storage	Large (warehouse sized) storage areas (unchilled) with 24 x 7 operation. If additional activities with 24x7 schedules are required (e.g. circulation, toilets) use the activities provided under building type "Others - Miscellaneous 24hr activities".
Assembly areas / halls	An area which can accommodate a large number of seated people. This could include a stage area.
Auditoria	Theatre auditoria spaces.
Bathroom	Contains a bath and/or shower and usually a basin and toilet. Also to be used for bathrooms for staff and relatives accommodation.
Bedroom	Bedroom
Bedroom Only	Guest bedroom without a bathroom.
Bedroom Unit	En suite bedrooms with no occupancy during day time, mainly for relatives or staff. Also for nursing home bedrooms. For patient private bedroom units with 24hr occupancy use activity "24x7 Bedroom Unit".
Car Park	Area designated for parking cars (enclosed or underground)
Cell (police/prison)	A room which accommodates one or more prisoners.
Changing facilities with showers	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, use the Generic Office Space.
Circulation area (corridors and stairways)	For corridors and stairways when these are separated from Office spaces, e.g. stairwells for access to other parts of the building.
Circulation area (corridors and stairways) - non public	For all non-public corridors and stairways. For public circulation spaces select Eating/drinking area.
Circulation area (corridors and stairways) - non-public/restricted	For restricted circulation areas such ward & department circulation, corridor sub-waiting, and domestic circulation (staff accommodation).
Classroom	For areas used for teaching/seminars which are not lecture theatres.
Common circulation areas	For all common circulation areas such as corridors and stairways outside the dwelling.
Computer lab	High density desk based work space with correspondingly dense IT.

Data Centre	For data centres such as web hosting facilities, with 24hr high internal gains from equipment and transient occupancy.
Dept Store Sales area - chilled	A sales area in Department Stores designed to accommodate a considerable quantity of fridges/freezers such as a supermarket or food hall.
Dept Store Sales area - electrical	Sales areas in Department Stores designed to accommodate considerable electrical equipment loads such as lighting sales areas and IT/TV/Hi-fi sales areas.
Dept Store Sales area - general	All Sales areas in Department Stores which do not have a large concentration of fridges/freezers or electrical appliances.
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.
Display and Public areas	All public circulation areas where people are walking/sitting and where display items are exhibited / available normally using display lighting.
Display window	An area where display lighting is used to illuminate items with glazing onto the outside such as a shop window, but which is boxed/enclosed, separated from the main retail space.
Domestic Bathroom	An area specifically used for bathing/washing. Contains a bath and/or shower and usually a basin and toilet.
Domestic Bedroom	An area primarily used for sleep.
Domestic Circulation	For all circulation areas within the dwelling.
Domestic Dining room	An area which is primarily used for eating meals.
Domestic Kitchen	The area within the dwelling where food is prepared
Domestic Lounge	The main reception room of the home.
Domestic Toilet	An area containing a toilet and basin which is separate from the main bathroom
Dry sports hall	An area where indoor sports can be played.
Eating/drinking area	Areas where food or drink are consumed by staff and visitors, e.g. canteen or office restaurant sitting areas.
En suite bedroom	Guest bedroom unit including bedroom and on suite bathroom. Contains a bath and/or shower and usually a basin and toilet.
Fitness Studio	An area used for exercising/dance, usually with high person density but with no machines.
Fitness suite/gym	An area used for exercise containing machines.
Food preparation area	Areas where food or drinks are prepared for staff and visitors, e.g. kitchen in canteen or office restaurant.
Generic Checkin areas	Areas designated for check in, which may contain conveyer belts; security check areas, which may include equipment such as x ray machines; and baggage reclaim areas.
Generic Office Area	Areas to perform office work including offices and meeting rooms. It can include internal corridors providing access to the office spaces, tea making facilities or kitchenettes within the office space, areas for photocopiers and fax machines and staff lounges.
Generic Ward	For all areas containing beds which accommodate either single or multiple patients. It includes toilets, ward storage, staff accommodation, day patient accommodation and intensive care units.
Hall/lecture theatre/assembly area	An area which can accommodate a large number of seated people.
Heavy Plant Room	For heavy plant rooms with 24hr low-medium internal gains from equipment and transient occupancy.
Hydrotherapy pool hall	The area in which the hydrotherapy pool is contained.
Ice rink	An area which contains an ice rink.
Industrial process area	An area for industrial process work, usually involving large machinery or equipment.
Laboratory	A facility that provides controlled conditions in which scientific research, experiments, and measurement may be performed.
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 (eg a food preparation area).
Light plant room	Areas containing the main HVAC equipment for the building eg: boilers/air conditioning plant.
Lounges	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.

Office and consulting areas	Areas to perform management, office and administration work separated from standard customer/public areas. It can include internal corridors providing access to the office spaces, tea making facilities or kitchenettes within the office space and staff lounges.
Operating theatre	For the operating theatre suite, including anaesthetic, scrub & preparation rooms.
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.
Physiotherapy Studio	For all physiotherapy areas, e.g., Fitness Suite/Gym, activity area, Cardiac stress test area.
Post Mortem Facility	Post-Mortem Facility (including Observation room and body preparation area)
Public circulation areas	All public circulation areas such as a foyer. For non public spaces use "Circulation areas (corridors and stairways) - non public"
Reception	The area in a building which is used for entry from the outside, from other building storeys or in general waiting areas containing a reception desk.
Residents common rooms	TV lounges and other common spaces for use of residents. It may contain some hot drink facilities.
Residents kitchen	Common area kitchens used by residents, e.g. in residents' halls.
Retail Warehouse Sales area - chilled	A sales area in Retail Warehouses designed to accommodate a considerable quantity of fridges/freezers such as a supermarket or food hall.
Retail Warehouse Sales area - electrical	Sales areas in Retail Warehouses designed to accommodate considerable electrical equipment loads such as lighting sales areas and IT/TV/Hi-fi sales areas.
Retail Warehouse Sales area - general	All Sales areas in Retail Warehouses which do not have a large concentration of fridges/freezers or electrical appliances.
Sales area - general	All Sales areas which do not have a large concentration of fridges/freezers or electrical appliances.
Server Room	For areas such as computer server spaces with 24hr low-medium internal gains from equipment and transient occupancy. For an area with 24hrs high gains from equipment, use the 'Data Centre' activity.
Small Shop Unit Sales area - chilled	A sales area in Small Shop Units designed to accommodate a considerable quantity of fridges/freezers such as a supermarket or food hall.
Small Shop Unit Sales area - electrical	Sales areas in Small Shop Units designed to accommodate considerable electrical equipment loads such as lighting sales areas and IT/TV/Hi-fi sales areas.
Small Shop Unit Sales area - general	All Sales areas in Small Shop Units which do not have a large concentration of fridges/freezers or electrical appliances.
Specialist Care Ward	For all areas containing beds which accommodate either single or multiple patients and which require conditioned ventilation. Examples include: critical care, intensive care, high dependency, haematology/oncology. It includes toilets, ward storage, staff accommodation, day patient accommodation associated with these units.
Store Room	Areas for un-chilled goods storage with low transient occupancy.
Swimming pool	The area in which a swimming pool is contained. This activity should be used for the whole pool hall.
Teaching Areas	Teaching areas which include classrooms and corridors providing access to and between classrooms.
Teaching Areas DoES TGD033 2018	Teaching areas DoES TGD033 2018 which include classrooms and corridors providing access to and between classrooms.
Toilet	Any toilet areas. If toilets are subsidiary to changing/shower activities refer to Changing facilities with showers.
Waiting Rooms	Enclosed waiting spaces with no through flow of people e.g. in the transport terminal areas. For larger, more open waiting areas such as departure lounges and gate areas use "Lounges".
Warehouse storage	Large (warehouse sized) storage areas (unchilled).
Workshop - small scale	Area for sedentary light practical work, often containing some machinery, e.g. key cutting or shoe repairing. As per the definition, light industry appropriate in a residential area.

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

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

The heating and cooling set-points define the conditions which the selected HVAC system will be assumed to maintain for the period defined by the heating and cooling schedules. For the unoccupied period, if applicable, the system will be assumed to maintain the space at the set-back temperature defined in the database (not currently used by SBEMie).

3.3.1.4. Lighting standards

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

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 needs to be heated or cooled to the required heating or cooling set-point. Whether or not the activity will include high pressure filtration is also defined in the database (such as hospital operating theatres), although it is possible for the user to override this flag in the iSBEMie interface.

3.3.1.6. Heat gains from equipment

Following a similar procedure to calculating heat gains from people, the database calculates the expected heat gains from equipment for each activity based on the equipment power density 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 and not currently used by SBEMie.

3.3.1.8. Hot Water requirements

A hot water demand is defined for all occupied spaces and is determined by the activity selected for the zone from the NEAP Activity Database, i.e., the hot water demand is associated with the occupied spaces rather than the spaces where the hot water is accessed/drawn-off. For example, there is a demand assumed to arise from the occupants of an office for activities such as washing hands and washing up cups. This demand is associated with the office rather than the toilet or tea room next door.

3.3.2. Constructions

The SBEMie user can specify the U-value and thermal capacity information for a particular wall, opaque door, roof, or floor (or the U-value, light transmittance, and solar transmittance for a particular window, rooflight, or glazed door) for which the construction is accurately known. Where the construction is less precisely known, the SBEMie user can make use of the NEAP Construction and Glazing Databases. These databases contain a library of constructions covering different regulation periods and different generic types of construction and glazing systems.

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 in their building. Once the user has selected the construction, the database provides a U-value and thermal capacity and, in the case of glazing, a U-value and solar and light transmittance. These values are then fed directly into the SBEMie calculation.

For cases where the SBEMie user has only minimal information, SBEMie 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 the building was constructed, and a description of the generic type of construction. SBEMie will then retrieve from the database 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 capacity value that are 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, pumps, and controls is treated as a separate item denoted as “auxiliary energy”. The consequent definitions for system heating and cooling efficiencies then become more straightforward - but are now different from the more familiar meanings that include the auxiliary energy.

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

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

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

sensible cooling, the definition may be extended to include allowances for deliberate or inadvertent latent loads.

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

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, i.e., perfect temperature controls, uniform air temperatures, etc., so the scope of the term “HVAC system” has to be sufficiently broad to encompass some factors that relate to the spaces themselves.

EN 15243⁴ is the EPBD standard that deals with the calculation of HVAC system efficiencies. It contains a number of informative annexes that illustrate different approaches, but it does not prescribe specific calculation procedures. It permits the HVAC system performance to be calculated either monthly or hourly.

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

In EN 15243, the mechanisms are mapped against 20 or so types of HVAC systems to show which mechanisms may apply to which system types. Any compliant calculation procedure is required to declare which system types it claims to cover, and how it addresses each of the applicable mechanisms. The standard does not prescribe how each mechanism should be handled (although there are “informative” suggestions). SBEMie includes all the mechanisms that were in the draft standard at the time the original UK’s 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 SBEMie is shown in Figure 1. The basic philosophy is to provide a consistent set of parameters that address all the mechanisms in EN 15243. The energy flow diagram is simplified in that some of the parameters are relatively aggregated - for example, heat pickup in chilled water distribution pipework is expressed as a percentage of the cooling energy flow handled.

Putting reliable values to each mechanism for any given system would be extremely difficult, unreliable, and difficult to check, especially for existing systems. SBEMie 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 and AHU leakage, and fuel. Corrections are then applied to the standard system performance parameters.

At present, system performance parameters and the correction routines are calculated outside SBEMie and inserted into look-up tables in the iSBEMie interface. Internalising the

⁴ CEN EN 15243 Ventilation for Buildings – Calculation of room temperatures and of load and energy for buildings with room conditioning systems.

calculation and providing the user with access to more of the mechanism values is a potential future upgrade.

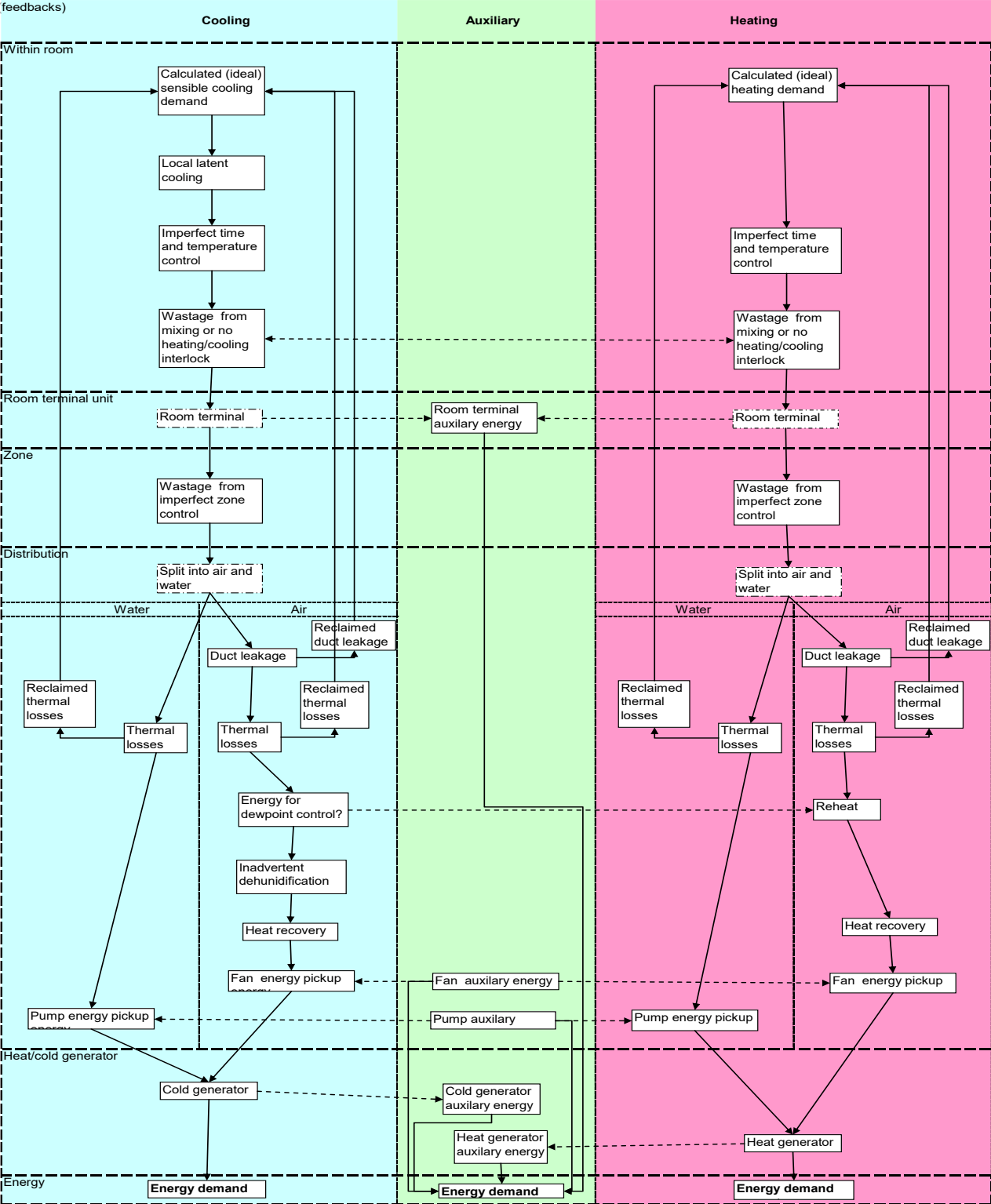


Figure 1: Basic energy flow diagram of the HVAC calculation in SBEMie

3.3.3.4. The Mechanisms

The next tables, Table 3 and Table 4, list the mechanisms and summarise key points about them. Table 5 contains a complete parameter list.

HVAC parameters used in SBEM					
<i>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</i>					
<i>Note: some values are arbitrary but the overall impact of all assumptions is consistent with simulation results.</i>					
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 commissioning 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	SBEMie 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 (<i>and risk of condensation</i>)	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 <i>Includes AHUs and other air-handling components</i>	Fixed percentage loss assumed with no useful contribution to loads
Duct system air leakage <i>Includes AHUs and other air-handling components</i>	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 (<i>includes dew-point control plus reheat</i>)	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 <i>Typically CO2 controlled – total air flow unchanged</i>	Not included explicitly but possible to approximate in input parameters
Impact of air-side free cooling	Provided as an option
Distribution systems: auxiliary energy	
Auxiliary energy use by fans and pumps (other than in terminals)	Calculated according to system type, hours of use and (for fans) SFP
Cold and Heat Generation	
Cold generator (chiller) part-load performance (including multiple installations)	Calculated externally and provided to software
Water-side free-cooling	Can be included in external calculation of seasonal performance
Thermosyphon operation	May in principle be included in external calculation of seasonal performance
Impact on chiller performance of central heat rejection equipment <i>Includes cooling towers, dry coolers etc. Included in overall performance of packaged systems</i>	May in principle be included in external calculation of seasonal performance
Auxiliary energy use by central heat rejection equipment <i>Included in overall performance of packaged systems</i>	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 <i>Includes gas boosters, fuel pumps, etc. Included in overall performance of packaged systems</i>	Not included
Energy use for humidification	Not included
Bivalent systems <i>Includes boiler + CHP, condensing boiler + non-condensing boiler, heat pump + top-up, evaporative cooling + chiller.....</i>	Not included explicitly but possible to approximate in input parameters

Table 4: Summary of how SBEMie 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 to energy 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 system dependent	
	Cooling-air and w	Cooling-air	Cooling-air	Cooling-air	Cooling-air	Cooling-air	Heating-water	Cooling-air	Auxiliary	Cooling-air	
Parameter	Proportion of load handled by air sub-system	Duct leakage	Reclaimed leakage losses	Duct heat pickup	Reclaimed cold losses	Central latent load	Reheat energy	Heat recovery or economiser	Specific fan power	Fan energy pickup factor	
Description	Can vary from all air to no air	Can be substantial	Some of the lost coolth may be useful	Heat transfer through duct walls	Some of the lost coolth may be useful	May be inadvertent operation below dewpoint or humidity control	For dewpoint control	Airside free cooling or heat recovery wheel (etc) can reduce net loads	Used to determine fan energy. Both supply and extract	Most of fan energy is transferred to air as heat gain	
Application	factor	Leakage factor - think about the algebra when applying!	factor applied to the duct loss figure	factor	factor applied to the duct heat pickup figure	factor, but be careful with the algebra!	factor, but result is added to heating load	factor applied to room cooling demand		Proportion of fan energy is transferred to air as heat gain - but remember that fan also runs in non-cooling modes	
Units	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	dimensionless	kWhpa/m2	dimensionless	W/s	kWhpa/m2	
Comment	system dependent	Depends on quality of ducts and AHUs	Depends on location of ductwork	Depends on extent and insulation of ductwork	Depends on location of ductwork	System dependent	System dependent	System dependent	System dependent	System dependent	
	Auxiliary	Intermediate calc	Cooling-water	Cooling-water	Cooling-water	Intermediate calc	Auxiliary	Cooling generation	Cooling generation		
Parameter	Fan run hours	Fan energy	Pipe heat pickup	Reclaimed cold losses	Cooling pump pickup factor	Cooling pump power	Cooling pump energy	Chiller performance	Chiller Ancillaries		
Description	All services. Same figure used for terminals	All services	Heat transfer through pipe walls	Some of the lost coolth may be useful	Most pump energy is transferred to water as heat gain		Depends on pressure drop	Seasonal value - also applied to room units	May need to add cooling towers etc		
Application	Depends on controls	Based on 10 l/s m2 for all-air systems, proportioned to % cooling by air. SIP 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 calculation	Heating Demand	Heating Demand	Heating-air and w	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 as 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 system 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	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.

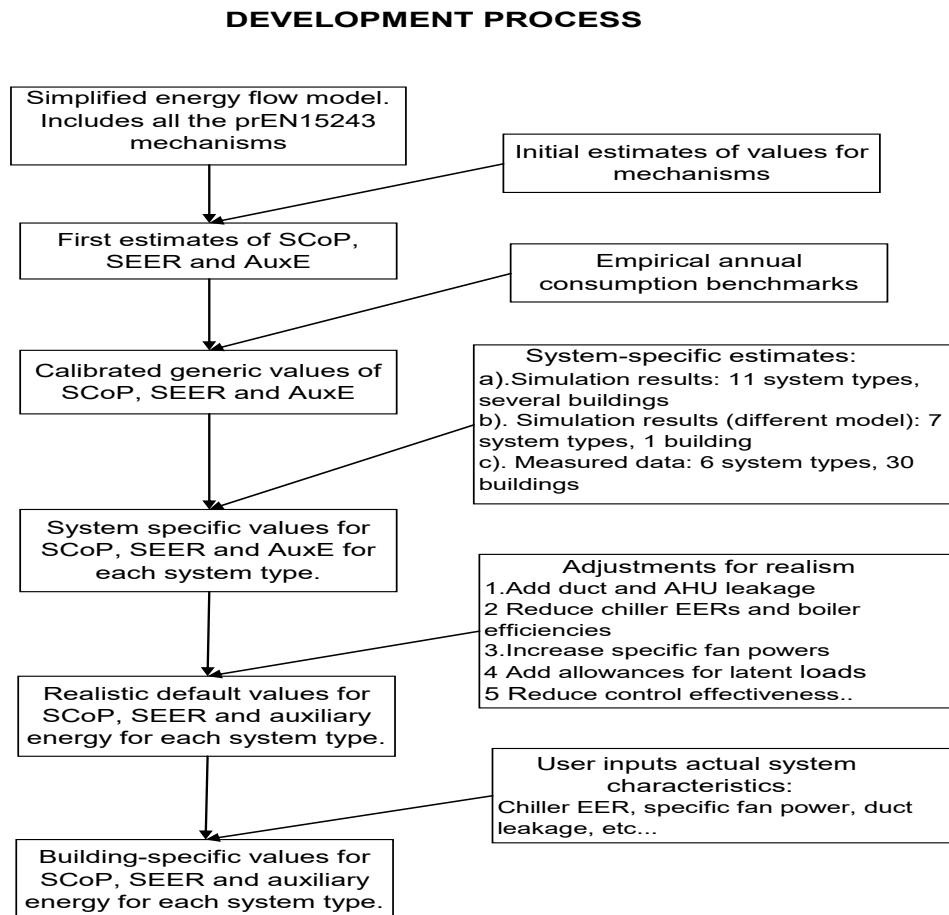


Figure 2: HVAC Model Development Process

We first produced initial estimates of typical values of the flow sheet parameters and calculated initial figures of the three performance parameters (auxiliary energy, SSEFF, and SSEER). With some relatively small adjustments to the initial assumptions, the consumption figures that these implied were brought into general alignment with empirical benchmarks, notably ECG 019⁵. 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

⁵ Energy Efficiency - Best Practice Programme (EEBPP) - Energy Consumption Guide 019: Energy Use in Offices.

system types⁶ to develop a set of system-specific values for SSEFF, SSEER, and auxiliary energy. For each system type, we then adjusted the spreadsheet parameters until the spreadsheet generated the same figures.

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

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

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 effects 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 at the time but possibly prEN 14335 section 5.1.3).

Assume that there is a linear temperature gradient, with the required comfort temperature, t_c , maintained at 1.5 m above the floor. At this height, air temperature is $t_{1.5}$.

Average air temperature is:

$$t_{av} = t_{1.5} + \left[grad \times \left(\frac{h}{2} - 1.5 \right) \right]$$

where h is the room height, in m, and $grad$ is the air temperature gradient, in K/m.

Assume that surface temperatures are unaffected.

Design operative temperature is:

$$\frac{(t_r + t_{1.5})}{2}$$

where t_r is the mean radiant temperature, so the nominal heat loss is:

$$U \times \left[\frac{(t_r + t_{1.5})}{2} - t_o \right]$$

where U is the total conductance associated with the fabric elements enveloping the space (i.e., the sum of U -value \times envelope area terms), and t_o is the outdoor air temperature.

Ignoring how losses vary between floors, walls, and roof, the actual heat loss is:

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.

$$U \times \left[\frac{(t_r + t_{av})}{2} - t_o \right]$$

Valuing “*grad*”

Actual heat loss should be based on a temperature that is higher than design value by:

$$grad \times \left(\frac{h}{2} - 1.5 \right)$$

For room heights around 3 m, this correction is very small.

From GPG 303⁷, typical values of *grad* are:

Type of heating	<i>grad</i>
Radiant heating	0.3 K/m
Radiators	1.5 K/m
Convactor heaters	2.3 K/m

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

Type of heating	<i>grad</i>
Radiant heating	1.1°C
Radiators	5.3°C
Convactor heaters	8.1°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 SBEMie, 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

⁷ GPG 303: The designer's guide to energy efficient buildings for industry.

replace the mean radiant temperature by the mean internal surface temperature of the space and to ignore direct radiation from the heating system.

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

Reduction in air temperature

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

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

$$t_c = (I \times a \times r) + \left(\frac{t_a + t_s}{2}\right)$$

and the reduction in air temperature due to direct radiation is:

$$2 \times I \times a \times r = dt.$$

Radiant intensity

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

$$Q_t \times \frac{\eta_r}{\eta_t}$$

where Q_t is the total heat output, η_r is the radiant efficiency, and η_t is the total efficiency of the system.

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

Therefore, the radiant intensity on the occupied area is:

$$I = d \times Q_t \times \left(\frac{\eta_r}{\eta_t \times A}\right)$$

Correction factor

The heating requirement for the space is:

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

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

t_o is the outdoor air temperature

U is the total conductance associated with the fabric (i.e., the sum of U -value \times envelope area terms), W/K

V is the ventilation conductance, W/K

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

However, we know that dt is proportional to Q_t .

For brevity, set $dt = k \times Q_t$.

Substituting and rearranging, we obtain:

$$Q_t = \frac{(t_i - t_o) \times (U + V)}{(1 + k)}$$

That is, the conventional heat demand is multiplied by a factor $\frac{1}{(1+k)}$.

Valuing "k"

V , the ventilation conductance is $0.33 \times N \times \text{room volume}$ where N is the ventilation rate in ac/h.

So

$$k = 2 \times a \times r \times d \times 0.33 \times N \times \text{room volume} \times \left(\frac{\eta_r}{\eta_t \times A} \right)$$

And $\frac{\text{room volume}}{A}$ is equal to room height, h .

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

RADIANT HEATING SYSTEMS:

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

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

$$k = 0.00438 \times N \times h \times \frac{\eta_r}{\eta_t}$$

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

$\frac{\eta_r}{\eta_t}$ 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 η_t to obtain the 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 $\frac{\eta_r}{\eta_t}$ term simply represents the proportion of the output that is radiant.

The following values are suggested:

Emitter	$\frac{\eta_r}{\eta_t}$	d
Radiator	0.56	0.25 (includes 50% straight to wall behind radiator)
Heated floor	0.55	0.60

Chilled ceiling	0.55	0.40
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The corrections are smaller but typically in the range 5% to 10%.

3.3.3.8. Energy Use Calculation for Hot Water in SBEMie

The basic calculation scheme is straightforward:

- Hot water demand is taken from the NEAP Activity Database. It is expressed per unit of floor area, but this reflects the occupancy density and the nominal consumption per person for the activity in question;
- Heat losses from storage and distribution are added (if they are present);
- Heat losses associated with residual hot water in distribution pipes of more than 3 metres in length are added;
- Delivered energy consumption is calculated using the heat generation efficiency;
- Primary energy consumption and CO₂ emissions are calculated depending on the fuel source;
- Additionally, if there is a secondary circulation system, the auxiliary delivered energy, and the consequent primary energy and CO₂ emissions, are calculated.

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

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

- monthly storage losses (derived from heat loss per litre of stored hot water);
- storage volume;
- insulation type and thickness on storage vessel;
- length of secondary pipework;
- heat loss per metre of secondary pipework;
- secondary pump power;
- heat generation efficiency.

3.3.3.9. Heat and Cold generator seasonal efficiency

These values should be provided by the user to over-write the pessimistic default values in the software. 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^{8,9}.

⁸ 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.

⁹ 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 NEAP needs an input of weather data. In addition, information regarding weather data is necessary to calculate the energy yield by some renewable energy systems, such as solar and wind technologies.

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

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

In order to provide consistency of application, a standard weather dataset has been adopted for the NEAP, based on the Dublin IPCC Emission Scenario: High (RCP8.5), Mid sensitivity TRY Met Éireann¹⁰ weather file, which must be used for all Building Regulations compliance and BER calculations for non-domestic buildings in the Republic of Ireland.

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 surrounding 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/rooftlights or doors. The areas, types, shading systems, and constructions of windows and doors within each envelope element need to be entered;
- Similarly, within the windows/rooftlights and doors, there may be additional thermal bridges, (other than those 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 NEAP defines zoning rules that should be applied when assessing a building for building regulations compliance or energy rating certification.

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;

¹⁰ Obtained from the Irish National Meteorological Service at [Climate data for thermal modelling of buildings - Met Éireann - The Irish Meteorological Service](#).

- 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:

1. Divide the floor into separate physical areas, bounded by physical boundaries, such as structural walls or other permanent elements;
2. If any part of an area is served by a different type of HVAC or lighting system, create a separate area bounded by the extent of those services;
3. If any part of an area has a different activity taking place in it, create a separate area for each activity;
4. Attribute just one *activity* to each resulting area;
5. Divide each resulting area into *zones* receiving significantly different amounts of daylight, defined by boundaries which are:
 - At a distance of 6 m from an external wall containing at least 20% glazing;
 - At a distance of 1.5 x room height beyond the edge of an array of rooflights whose area is at least 10% of the floor area;
 - If any resulting *zone* is less than 3 m 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*.
6. 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;
7. 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. SBEMie will then assume no transfer of heat, coolth, or light across the boundary, in either direction. In the context of iSBEMie, 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 iSBEMie 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, they will be prompted to link (or assign) it to a zone. Equally, when the user defines a window in the *Windows & Rooflights* main tab, they are prompted to link it to an envelope element. If the user creates the envelope element or window in the *Quick Envelopes* sub-tab of a particular zone, these links are established automatically by the software.

Figure 3 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's 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.

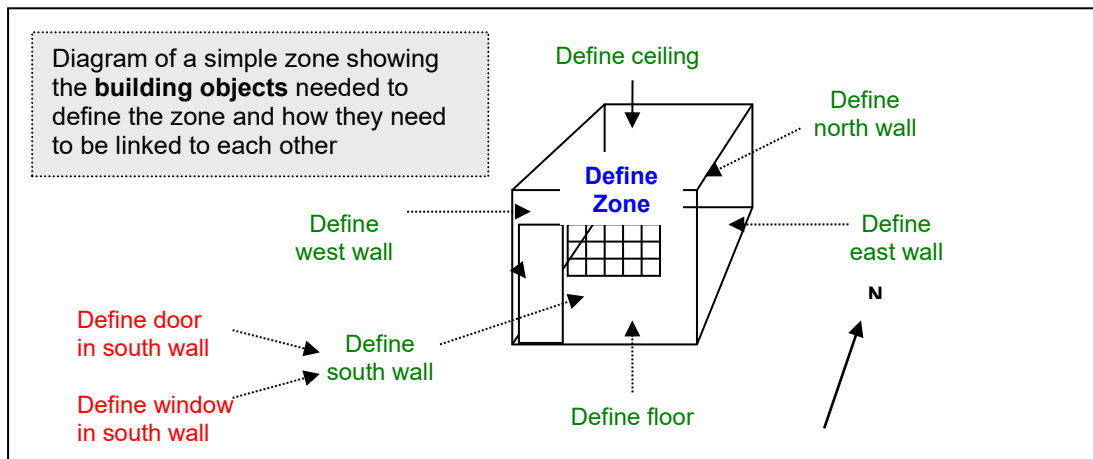


Figure 3: Diagram of building objects needed to define a simple zone

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 SBEMie is only concerned with those arising from junctions between envelope elements, windows, and doors which are in contact with the exterior. These types of junctions fall into two categories:

- Junctions involving metal cladding
- Junctions not involving metal cladding.

At these junctions between different building elements, there can be additional loss of heat from the building which is not attributed to the U-values and areas of the adjoining elements. The additional heat loss which is attributed to the junction is expressed as a linear thermal transmittance, Ψ (Psi) value, (expressed in W/mK). SBEMie contains a table of types of junctions and default linear thermal transmittance values for each of these types of junctions, shown in Table 6, (which are used unless overwritten by the user). 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* and then degraded by the greater of 0.04 W/mK or 50%, as defined in the NEAP Modelling Guide.

Type of junction	Metal cladding constructions	Non-metal cladding constructions
	Ψ (W/(m·K))	Ψ (W/(m·K))
Roof to wall	0.42	0.18
Wall to ground floor	1.73	0.24
Wall to wall (corner)	0.38	0.14
Wall to floor (not ground floor)	0.04	0.11
Lintel above window or door	1.91	0.45
Sill below window	1.91	0.08
Jamb at window or door	1.91	0.09

Table 6: SBEMie's default values for the linear thermal transmittance of thermal bridges, as defined in the NEAP Modelling Guide

For each type of junction, the user can either enter an Ψ (Psi) value (W/mK) or accept the default values in the software.

Additional thermal bridging at junctions and around openings, which are not covered in Table 6, can be defined by the user in iSBEMie 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 method in SBEMie mostly follows the CEN standard umbrella document PG-N37, which lists standards relevant to the implementation of the EPBD. The CEN umbrella document PG-N37 provides an outline of the calculation procedure for assessing the energy performance of buildings. It includes a list of the European standards 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 a monthly heat balance, and a simplified hourly calculation, and it also permits detailed simulation.

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

- Fixed lighting with different control systems
- Hot water for washing

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 primary energy use and CO₂ emissions for the building as a whole. The main structure of the calculation procedure is summarised in Table 7. The options chosen for SBEMie 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 heating and cooling production.
4	Combine the results for all zones and systems, to give the building's delivered energy totals.
5	Convert the totals into equivalent primary energy and CO ₂ emissions (this is not part of the CEN Standard – the conversion is described in the NEAP Modelling Guide).

Table 7: Summary of CEN standard calculation

	Issues/options	Chosen route	References in CEN standard prEN ISO 13790
1	Different types of calculation method: dynamic or quasi-steady state	Quasi-steady state, calculating the heat balance over a month	5.3
2	If steady state, how to take account of dynamic effects on heating	Determine utilisation factors for internal and solar heat sources using equations 31 & 32, to allow non-utilised heat which leads to an undesired increase in temperature above set-points to be ignored. This depends on the thermal capacity of the structure	5.4.2
3	Effects of thermal inertia in case of intermittent heating	Adjust set-point temperature as described in EN ISO 13790 (i.e., thermal capacity-dependent) using information in databases	13.2
4	How to take account of dynamic effects on cooling	Using equations 35 & 36, determine utilisation factors for internal and solar heat sources, to take account of that part which takes the temperature to a certain level, so only non-utilised heat beyond that level contributes to cooling needs. This depends on the thermal capacity of the structure	12.2.1
5	Effects of thermal inertia in case of intermittent cooling	Adjust set-point temperature using information in databases.	13.2
6	Energy balance at system level	Includes energy needs at zone level; from renewables; generation, storage, distribution, emission and control losses; input to space heating and cooling systems; energy outputs e.g., from CHP; energy recovered within the system	5.5; see also figs 3a&c in the section for all energy flows
7	Relationship with unconditioned spaces	The boundary of the building is the elements between the conditioned and unconditioned spaces, including exterior. Heat transfer between conditioned spaces is ignored.	6.2
8	Dimension system for calculating areas	Internal dimensions of each zone's structural elements, so that the area presented to the heat flux from inside the building coincides with the overall internal dimensions	6.2, 6.3.2
9	Thermal zones	Building is partitioned into several zones, taking no account of thermal coupling between zones	6.3.1, 6.3.3.2
10	Calculation procedure for multi-zone	Regard as a series of single zone calculations, but with boundary conditions and input data coupled when zones share same heat/cooling system.	6.3.5

		Zones are aggregated when served by the same heating/cooling system.	
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 SBEMie – heat is available whenever monthly calculation demands it.	7.2.1.3
14	Length of cooling season	Not calculated in SBEMie – 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 1 st iteration	Not done in SBEMie	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 SBEMie - physical characteristics of building do not change	
20	Nocturnal insulation	Not implemented in SBEMie	8.3.2, 8.4.2
21	Special elements	Optional; if applied, comply with 8.4.3	8.4.3
22	Total heat transfer by ventilation	Equation 13	9.2
23	Ventilation heat transfer coefficients	Determine according to section 9.3.1, using volume flow rate based on NEN 2916:1998 methodology section 6.5.2.1. Infiltration based on section 7.1.3.2 of EN 15242:2005	9.3.1
24	Differences in ventilation calculation between heating and cooling modes	The stack effect in infiltration is currently ignored during cooling calculation in SBEMie.	9.3.2
25	Ventilation heat recovery	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. Can be bypassed during cooling.	
26	Night-time ventilation for free cooling	Optional in cooling calculation in SBEMie.	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 SBEMie, but heat dissipated is included in system efficiency adjustment factors	10.3.1
30	Heat gain from people and appliances	Determined from activity area database	10.3.2.1
31	Heat gain from lighting	Determined using method described in this manual	10.3.2.2
32	Heat to/from washing water and sewerage	Ignored in SBEMie	10.3.2.3
33	Heat dissipated from or absorbed by heating, cooling and ventilation systems	Determined from efficiency factors	10.3.2.4
34	Heat from processes or goods	Determined from activity area database	10.3.2.5
35	Total solar heat sources	Equations 22 & 23 based on monthly average solar irradiance from weather data	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 SBEMie	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.	11.3.3, 11.4.5
39	Gain utilisation factor for heating	Equations 31, 32, 33 & 34 using reference numerical parameter for monthly calculation from Table 8 based on building type and calculated building time constant (see below)	12.2.1.1
40	Loss utilisation factor for cooling	Equations 35, 36, 37, 38 & 39 using reference numerical parameter for monthly calculation from Table 9 based on building type and calculated building time constant (see below)	12.2.1.2
41	Building time constant	Equations 40 (heating) and 41 (cooling) using internal heat capacity of building	12.2.1.3
42	Internal heat capacity of building	Sum of internal capacities of all building elements, using C_m values calculated according to EN ISO 13786:2005	12.3.1
43	Internal temperatures used in energy calculations	Where heating or cooling is continuous during the whole heating period, use the set-point temperature indicated by the activity area database. If not continuous, see below.	13.1
43	Correction for holiday periods	SBEMie 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	13.2.1

		above) and difference in set-point temperature between normal and reduced heating periods	
45	Correction for intermittent cooling	Equations 44 & 45, which need input of building time constant (calculated above) and set-point temperatures for normal cooling and intermittent periods.	13.3
46	Annual energy need for heating and cooling per building zone	Sum of heating and cooling needs in each month; as equation 47	14.1
47	Annual energy need for heating and cooling, per combination of systems	Sum of heating and cooling needs served by the same combination of systems, then sum of needs of all systems; as equation 48	14.2
48	Total system energy use, including system losses	Use option b in section 14.3.1, in order to present auxiliary energy separately from system losses, for each energy carrier.	14.3.1
49	System losses	SBEMie 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	SBEMie's tabulated output reports	14.3.3
51	Additional annual energy by ventilation system	Calculated as section 14.3.4, in accordance with EN 15241. For HVAC systems involving ventilation, auxiliary energy comes from method in appendix G. Where ventilation comes from individual fans, use EN 13779.	14.3.4
52	Reporting of building and systems evaluation	Results broken down for the whole building, each zone and each month, with heating and cooling heat transfer and energy needs as in section 15.3.1. Input data reflection (as section 15.2) is available on screen but is not printed automatically, to reduce paper consumption prior to final version.	15.2, 15.3.1, 15.3.2
53	Climate related data	Hourly climatic data are needed, even though the calculation is monthly based, in order to prepare the monthly values. Data should include the parameters required in CEN standard annex A.	Annex A
54	Multi-zone calculation with thermal coupling between zones	Not implemented in SBEMie	Annex B
55	Alternative formulation for monthly cooling method	Not implemented in SBEMie	Annex D
56	Heat loss of special envelope elements (e.g., ventilated walls)	Not implemented in SBEMie	Annex E
57	Solar gains of special elements (e.g.,	Not implemented in SBEMie.	Annex F

	unconditioned sunspaces, opaque elements with transparent insulation, ventilated walls)		
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 SBEMie	Annex H
60	Accuracy of the method	Not required for NEAP	Annex I
61	Conventional input data (to be used in the absence of national data)	Not required for NEAP – use activity area database	Annex J

Table 8: Options chosen in the CEN standard prEN ISO 13790:2005

4.1.1. Calculation method

SBEMie 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 gain 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 heating set-point temperature or a correction to the calculated heat demand.

For cooling: (mirror image of the approach for heating) a utilisation factor for the transmission and ventilation heat transfer takes account of the fact that only part of the transmission and ventilation heat loss 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 to the cooling set-point temperature or a correction to the calculated cooling needs.

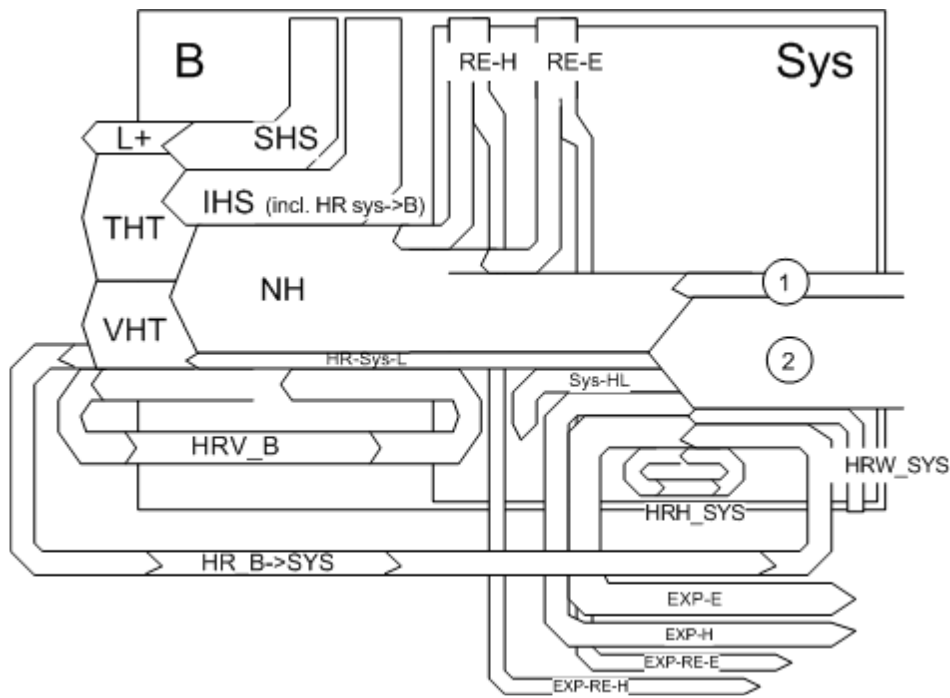
4.1.2. Overall energy balances for building and systems

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.

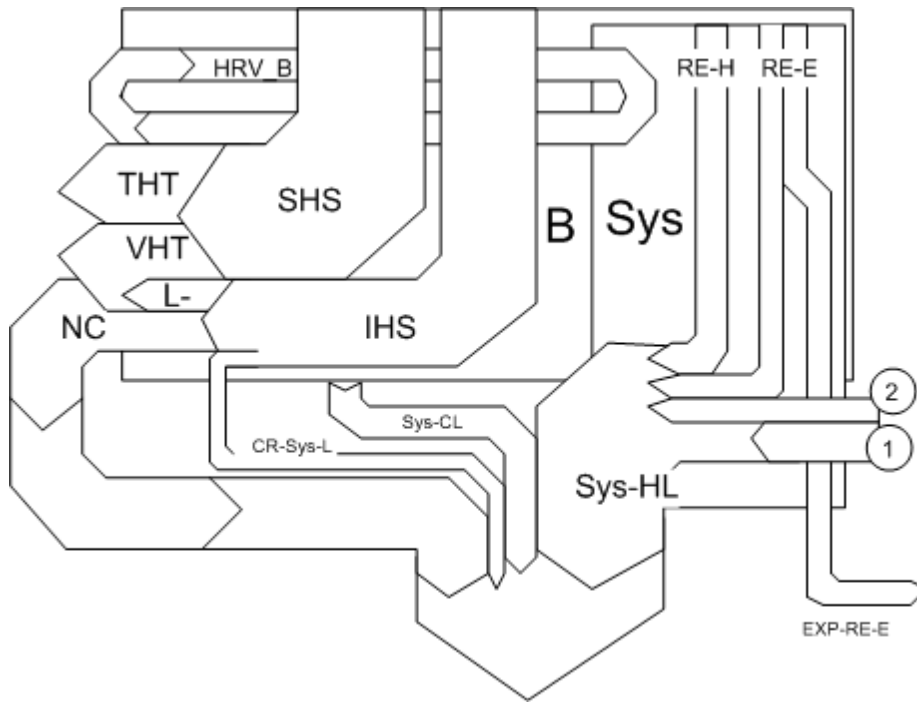


Key

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	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 (extracted from prEN ISO 13790:2005)



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	CR-B->Sys	Additional heat removed from building (into the system e.g. from building mass into vent.system, ..
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	EXP-E	Exported electricity, non-renewable
L-	Heat extracted by cooling system: shown as separate flow: see HR-Sys-L	EXP-RE-E	Exported electricity, from renewable source
L-	Mismatch between transmission and ventilation heat transfer and solar and internal heat sources, leading to average internal temperature lower than required	1	Delivered energy, electricity
NC	Energy need for space cooling	2	Delivered energy, (gas, coal, oil, etc)
HRV-B	Heat recovered in ventilation system (into the building, if not by-passed during cooling period)		
CR-Sys-L	Cold recovered from system loss in building (distribution, storage, emission, etc.)		

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

Figure 5: Energy balance of a building for space cooling (extracted from prEN ISO 13790:2005)

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 unconditioned spaces. Heat transfer between conditioned spaces is ignored in SBEMie.

The floor area within the boundary of the building is the useful floor area, A_{fl} , of the building. The dimension system used to calculate, A_{fl} , uses the internal dimensions of each zone's structural elements (i.e., the internal horizontal dimensions between the internal

surfaces of the external zone walls and half-way through the thickness of the internal zone walls) so that the area presented to the heat flux from inside the building coincides with the overall internal dimensions.

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 and diffuse 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 each building zone and for each calculation period (month),

- 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:

$$Q_{NH} = Q_{L,H} - (\eta_{G,H} \times Q_{G,H})$$

subject to $Q_{NH} \geq 0$, $\gamma_H \leq 2.5$, and $\theta_i > \theta_e$ (otherwise, $Q_{NH} = 0.0$)

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

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

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

$Q_{G,H}$ is the total heat sources (gains) 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 zone;

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

θ_i is the internal (indoor) temperature (the heating set-point taken from the NEAP Activity Database for the activity zone), in °C;

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

If applicable, corrections are applied to account for holidays, according to the occupancy schedules in the NEAP 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:

$$Q_{NC} = Q_{G,C} - (\eta_{L,C} \times Q_{L,C})$$

subject to $Q_{NC} \geq 0$ and $\lambda_C \leq 2.5$ (otherwise, $Q_{NC} = 0.0$)

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

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

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

$Q_{G,C}$ is the total heat sources (gains) 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 zone;

λ_C is the dimensionless loss/gain ratio for the cooling mode.

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

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

The total heat transfer 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 are given by:

$$Q_G = Q_I + Q_S$$

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

Q_G is 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 , by:

$$Q_T = H_T \times (\theta_i - \theta_e) \times t \times f$$

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

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

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

θ_i is the internal temperature of the building zone, in °C, taken from the NEAP Activity Database (heating set-point);

θ_e is the external (outdoor) temperature (the monthly average temperature obtained from the hourly weather data for the location) of the building zone, in °C; 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.

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 , of a zone in the building are calculated according to EN ISO 13789:2007, 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), 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 its surroundings is calculated by:

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

where

H_T is the heat transfer coefficient by transmission of a zone, in W/K;

a_i is a weighting factor dependent on the adjacency of the envelope i in the zone and is currently set in SBEMie following Table 9;

A_i is the area of element i of the envelope in the zone, in m², (the dimensions of windows and doors are taken as the dimensions of the aperture in the wall);

U_i is the thermal transmittance (U-value¹¹) of element i of the envelope in the zone, in W/(m²·K);

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

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

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

Envelope adjacency	a_i
Exterior	1.0
Strongly ventilated spaces	1.0
Unconditioned adjoining space	1.0
Conditioned adjoining space	0.0
Underground	1.0
Same space	0.0
UAS - partially conditioned by surrounding spaces ¹²	0.728
UAS = Unconditioned adjoining space	

Table 9: Weighting factor, a_i , for calculating transmission heat transfer through envelopes

Thermal transmittance of solid ground floors in contact with the earth

If the solid ground floor U-value input to SBEMie had not already been adjusted to account for insulation to counter the heat loss through contact with the ground, then SBEMie adjusts the U-value (as a function of the ratio of exposed perimeter to floor area and the thermal resistance of the floor construction) following the guidance specified in section 3.5.2 of "CIBSE Guide - Vol. A - 2007" (and ISO 13370:2007 – *Thermal Performance of Buildings – Heat Transfer via the Ground – Calculation Methods*), as per the extract described below.

The U-value of a solid floor in contact with the ground depends on the 'characteristic dimension' of the floor and the 'total equivalent thickness' of the factors that, in combination, restrict the heat flow (i.e., wall thickness, surface resistances, and thermal insulation).

The characteristic dimension, B' , in m, is defined as:

$$B' = \frac{A_{fg}}{0.5 \times p_f}$$

¹¹ The U-value for solid ground floors should be adjusted to account for insulation to counter the heat loss through contact with the ground (as a function of the ratio of exposed perimeter to floor area and the thermal resistance of the floor construction) following the guidance specified in section 3.5.2 of "CIBSE Guide - Vol. A - 2007" (and ISO 13370:2007 – *Thermal Performance of Buildings – Heat Transfer via the Ground – Calculation Methods*).

¹² The weighting factor for this adjacency is calculated as the ratio $\frac{18-12}{18-9.76}$, where 18°C is assumed to be the heat set-point temperature of the zone where the envelope belongs, 12°C is assumed to be the temperature of the unconditioned adjoining space, and 9.76°C is taken as the average outside temperature for Dublin from the monthly weather data.

where

A_{fg} is the area of the floor in contact with the ground, in m²;

p_f is the exposed perimeter of the floor, in m, taken as the total length of the external wall separating the heated space from the external environment or from an unheated space outside the insulated fabric.

For an infinitely long floor, B' is the width of the floor (lesser dimension), and at the other limiting case of a square floor, B' is half the length of one side.

The total equivalent thickness, d_{ef} , in m, is calculated as:

$$d_{ef} = d_w + \lambda_g \times (R_{si} + R_f + R_{se})$$

where

d_w is the thickness of the wall surrounding the ground floor, assumed to be 0.3 m;

λ_g is the thermal conductivity of the ground, taken as 1.5 in W/mK, corresponding to a clay or silt soil which is considered most prevalent in the Republic of Ireland;

R_{si} is the inside surface resistance, taken as 0.17 m²K/W;

R_{se} is the external surface resistance, taken as 0.04 m²K/W;

R_f is the thermal resistance of the floor, in m²K/W.

SBEMie asks the user to input the un-corrected U-value for the ground floor of the Actual building as the inverse of the thermal resistance of the floor construction *only* before allowing for any ground effect (perimeter to area) or edge insulation (i.e., the user inputs $1/R_f$). For the Reference building (for compliance purposes), SBEMie assumes $R_f = 0.457$ m²K/W, which is approximately the resistance of the chipboard/air gap/screed/concrete in the Reference building's ground floor construction details from the NEAP Modelling Guide, and for the Notional building, SBEMie assumes $R_f = 0$ m²K/W corresponding to an uninsulated floor.

The thermal transmittance of the floor, U_f , in W/m²K, is then calculated by:

If $d_{ef} < B'$, as is usually the case, then:

$$U_f = \frac{2 \lambda_g}{\pi B' + d_{ef}} \log_e \left[\left(\frac{\pi B'}{d_{ef}} \right) + 1 \right]$$

If $d_{ef} \geq B'$, as may occur for a small, well-insulated floor, then:

$$U_f = \frac{\lambda_g}{(0.457 B' + d_{ef})}$$

4.1.10.2. Thermal bridges:

The default values used in SBEMie 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* and then degraded by the greater of 0.04 W/mK or 50%, as defined in the NEAP Modelling Guide. 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 $Q_{sun,t}$ 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 NEAP 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 NEAP 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:

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

where

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

W_{light} is the energy consumption by lighting, in kWh/m², as determined in Section 4.4;

A is the area of the zone, in m²;

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 the transparent construction parts of the external envelope is determined as:

$$Q_{sun,t} = \sum_j [q_{sun,j} \times f_{sh,j} \times f_{sun,j} \times g_j \times (1.0 - f_f) \times A_j]$$

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/m², for the weather location and orientation of the 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 , as calculated in Section 4.1.12.2.1;

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

A_j is the area of window j , in m², including the frame;

f_f is the computational value for the frame factor (proportion of the window area that is occupied by the frame), i.e., $(1.0 - f_f)$ = proportion of window area that is occupied by the glazing.

The external shading correction 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.

This shading correction factor can be calculated from:

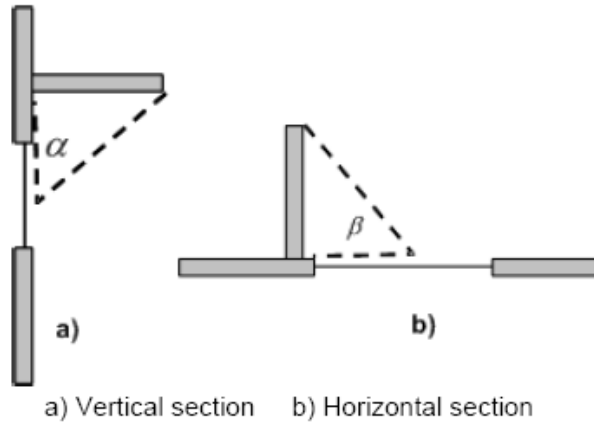
$$f_{sh,j} = F_o \times F_f$$

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 the overhang or fin angle, latitude, orientation, and local climate. Seasonal shading correction factors for typical climates are given in Table 10 and Table 11.



Key

α overhang angle
 β fin angle

Figure 6: Overhang and fin: a) Vertical section b) Horizontal section¹³

NB: For the purposes of this calculation, the angles α and β , indicated by the dashed lines in Figure 6, are taken between the plane of the window and the overhang or fin shadow line at mid-window.

Overhang angle	45°N latitude			55°N latitude			65°N latitude		
	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 overhangs, F_o ¹³

Fin angle	45°N latitude			55°N latitude			65°N latitude		
	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, F_f ¹³

If the overhang accounted for by the shading correction factor above is in fact a brise-soleil, then the factor is applied to the calculation only during the summer months (May to September). **NB:** For the purposes of the calculation, a brise-soleil has strips, louvres, holes, etc., as opposed to a solid overhang.

¹³ Extracted from EN ISO 13790:2008 - Energy performance of buildings — Calculation of energy use for space heating and cooling

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 provides 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:

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

The factor F_W is taken from Table 12 as the value corresponding to the orientation of the glazing and its tilt from the horizontal.

Tilt	Orientation								
	S	SE	E	NE	N	NW	W	SW	H
0°	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
10°	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
15°	1.28	1.27	1.35	1.52	1.68	1.52	1.36	1.29	0.87
20°	1.28	1.27	1.35	1.52	1.68	1.52	1.36	1.29	0.87
25°	1.28	1.27	1.34	1.50	1.64	1.49	1.35	1.29	0.87
30°	1.28	1.27	1.32	1.45	1.55	1.44	1.33	1.28	0.87
35°	1.29	1.26	1.31	1.40	1.46	1.39	1.31	1.28	0.87
40°	1.29	1.26	1.29	1.35	1.38	1.34	1.29	1.27	0.87
45°	1.29	1.26	1.27	1.30	1.29	1.29	1.27	1.27	0.87
50°	1.26	1.23	1.24	1.25	1.24	1.25	1.23	1.24	0.87
55°	1.23	1.20	1.20	1.21	1.19	1.20	1.20	1.21	0.87
60°	1.20	1.17	1.17	1.16	1.14	1.16	1.16	1.18	0.87
65°	1.17	1.14	1.14	1.11	1.09	1.11	1.13	1.15	0.87
70°	1.12	1.11	1.10	1.07	1.04	1.07	1.09	1.10	0.87
90°	0.89	0.91	0.91	0.89	0.88	0.88	0.90	0.90	0.87

Table 12: Correction factor F_W for g-value of non-scattering glazing

4.1.12.2.1. Calculation of the reduction factor for moveable solar protection

Using the methodologies described in EN 13363-1:2003+A1:2007 and EN ISO 13790:2008, the shading reduction factor for moveable shading provisions, $f_{sun,j}$ for window j is derived using the following equation:

$$f_{sun,j} = \frac{[(1 - f_{sh,with}) \times g_{gl} + (f_{sh,with} \times g_{gl+sh})]}{g_{gl}}$$

where

g_{gl} is the total solar energy transmittance of the window when the solar shading is not in use (i.e., glazing only);

g_{gl+sh} is the total solar energy transmittance of the window when the solar shading is in use (i.e., glazing plus shading device);

$f_{sh,with}$ is the weighted fraction of the time with the solar shading in use, e.g., as a function of the intensity of incident solar radiation.

Calculation of the weighted fraction of the time with the solar shading in use

The weighted fraction of the time during which the solar shading device is in use or not in use depends on the climate and the season or month. For the purposes of the SBEMie

calculations, for each climate, a table has been produced with values for $f_{sh,with}$ for a variety of orientations of the window. The values have been derived as the sum of the hourly values of the intensity of incident solar radiation for all hours in the month with intensity higher than 300 W/m^2 , $I_{sol>300}$, divided by the sum of the hourly values of the intensity of incident solar radiation for all hours in the month, I_{sol} , i.e.,

$$f_{sh,with} = \frac{I_{sol>300}}{I_{sol}}$$

Calculation of the total solar energy transmittance of the window when the solar shading is in use

This method applies to all types of movable solar protection devices parallel to the glazing, such as, louvre, Venetian, or roller blinds. The position of the solar protection device can be interior or exterior. It is assumed that for external solar protection devices, the space between the solar protection devices and the glazing is unventilated and for internal solar protection devices, this space is ventilated. Venetian or louvre blinds are assumed to be adjusted so that there is no direct solar penetration.

This method is based on the normal incidence of radiation. It is applicable when the total solar energy transmittance of the glazing is between 0.15 and 0.85, the solar transmittance of the solar protection devices is between 0 and 0.5, and the solar reflectance of the solar protection devices is between 0.1 and 0.8.

The resulting total solar energy transmittance is solely used for calculating the shading reduction factor for moveable shading provisions, f_{sun} . It is not intended to be used for calculating beneficial solar gains or thermal comfort criteria.

External solar protection device (Figure 7)

The total solar energy transmittance for glazing and an external solar protection device, g_{gl+sh} , is given by:

$$g_{gl+sh} = (\tau_{e,B} \times g_{gl}) + \left(\alpha_{e,B} \times \frac{G}{G_2} \right) + \left[\tau_{e,B} \times (1 - g_{gl}) \times \frac{G}{G_1} \right]$$

where

$\tau_{e,B}$ is the solar transmittance of the solar protection device, which is obtained from Table 13 for typical solar protection devices;

g_{gl} is the total solar energy transmittance of the window when the solar shading is not in use (i.e., glazing only);

$\alpha_{e,B}$ is the absorptance of the solar protection device, which is calculated as:

$$\alpha_{e,B} = 1 - \tau_{e,B} - \rho_{e,B}$$

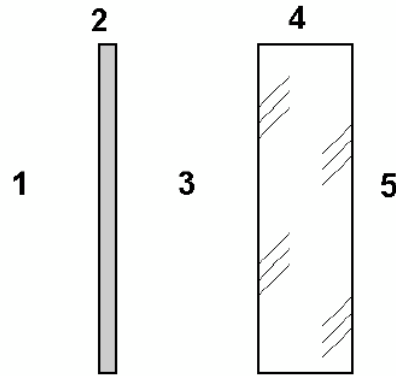
where $\rho_{e,B}$ is the solar reflectance of the solar protection device, which is obtained from Table 13 for typical solar protection devices;

$G_1 = 5 \text{ W/m}^2\text{K}$;

$G_2 = 10 \text{ W/m}^2\text{K}$;

$$G = \frac{1}{\left(\frac{1}{U_g} + \frac{1}{G_1} + \frac{1}{G_2} \right)}$$

where U_g is the thermal transmittance of the window, in $\text{W/m}^2\text{K}$.



- Key**
- 1 Exterior
 - 2 Solar protection device
 - 3 Unventilated air space
 - 4 Glazing
 - 5 Interior

Figure 7: Characteristic position of external solar protection device¹⁴

Transmittance $\tau_{e,B}$		Reflectance $\rho_{e,B}$			
		white	pastel	dark	black
Opaque	0.0	0.7	0.5	0.3	0.1
Medium translucent	0.2	0.6	0.4	0.2	0.1
High translucent	0.4	0.4	0.3	0.2	0.1

Table 13: Data for typical solar protection devices¹⁴

Internal solar protection device (Figure 8)

The total solar energy transmittance for glazing and an internal solar protection device, g_{gl+sh} , is given by:

$$g_{gl+sh} = g_{gl} \times \left[1 - (g_{gl} \times \rho_{e,B}) - \left(\alpha_{e,B} \times \frac{G}{G_3} \right) \right]$$

where

g_{gl} is the total solar energy transmittance of the window when the solar shading is not in use (i.e., glazing only);

$\rho_{e,B}$ is the solar reflectance of the solar protection device, which is obtained from Table 13 for typical solar protection devices;

$\alpha_{e,B}$ is the absorptance of the solar protection device, which is calculated as:

$$\alpha_{e,B} = 1 - \tau_{e,B} - \rho_{e,B}$$

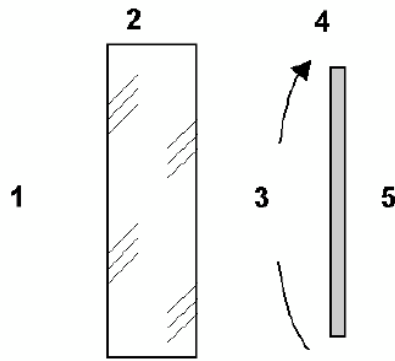
where $\tau_{e,B}$ is the solar transmittance of the solar protection device, which is obtained from Table 13 for typical solar protection devices;

$$G_3 = 30 \text{ W/m}^2\text{K};$$

$$G = \frac{1}{\left(\frac{1}{U_g} + \frac{1}{G_3} \right)}$$

where U_g is the thermal transmittance of the window, in $\text{W/m}^2\text{K}$.

¹⁴ Extracted from EN 13363-1:2003+A1:2007 - Solar protection devices combined with glazing - Calculation of solar and light transmittance - Part 1: Simplified method.



Key

- 1 Exterior
- 2 Glazing
- 3 Air space, ventilated to the interior
- 4 Solar protection device
- 5 Interior

Figure 8: Characteristic position of internal solar protection device¹⁴

4.1.12.3. Solar heat gain through opaque constructions

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

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

where

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

f_{ab} is a factor 0.045 which consists of an assumed value of 0.9 for the dimensionless absorption coefficient for solar radiation of the opaque construction multiplied by the external surface heat resistance which is taken as 0.05 m²K/W.

$q_{sun,j}$ is the quantity of solar radiation per month on the plane in MJ/m², for the weather location and orientation of construction part j ;

$U_{c,j}$ is the thermal transmittance of construction part j , in W/m²K;

$A_{c,j}$ is the area of construction part j , in m².

4.1.13. Gain utilisation factor for heating

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

$$\text{if } \gamma_H > 0 \text{ and } \gamma_H \neq 1: \quad \eta_{G,H} = \frac{1 - \gamma_H^{a_H}}{1 - \gamma_H^{a_H+1}}$$

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

$$\text{if } \gamma_H < 0: \quad \eta_{G,H} = \frac{1}{\gamma_H}$$

with

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

where (for each month and for each building zone)

$\eta_{G,H}$ is the dimensionless gain utilisation factor for heating;

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

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

$Q_{L,H}$ is the total heat losses 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 14;

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 14, in hours.

$a_{0,H}$	$\tau_{0,H}$
1.0	15

Table 14: Values of the numerical parameter $a_{0,H}$ and reference time constant $\tau_{0,H}$ for heating for a monthly calculation method

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, $\eta_{L,C}$, is a function of the loss/gain ratio, λ_C , and a numerical parameter, a_C , that depends on the building zone's thermal inertia, according to the following equation:

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

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

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

with

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

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;

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

$Q_{G,C}$ is 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 15;

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 15, in hours.

$a_{0,C}$	$\tau_{0,C}$
1.0	15

Table 15: Values of the numerical parameter $a_{0,C}$ and reference time constant $\tau_{0,C}$ for cooling for a monthly calculation method

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

The 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:

$$\tau_C = \frac{C_m/3.6}{H_{L,C}}$$

where

τ_C is the time constant of the 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;

$H_{L,C}$ 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. Effective thermal capacity of the building zone

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

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

where

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

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

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

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

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

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

The sum is done for all layers of each element, starting from the internal surface and stopping at the first insulating layer, the maximum thickness given in Table 16, or the middle of the building element; whichever comes first.

Application	Maximum thickness, in m
Determination of the gain or loss utilisation factor	0.10

Table 16: Maximum thickness to be considered for internal heat capacity¹³

4.1.16. Continuous and quasi-continuous heating or cooling mode, monthly method

4.1.16.1. Continuous heating and/or cooling

For continuous heating during the whole heating period, $\theta_{set,H}$, the heating set-point temperature (°C) from the NEAP Activity Database is used as the internal temperature of the building zone.

For continuous cooling during the whole cooling period, $\theta_{set,C}$, the cooling set-point temperature (°C) from the NEAP Activity Database is used as the internal temperature of the building zone.

NOTE: For the monthly method, the actual mean internal 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 actual mean internal temperature may be lower due to instantaneous high heat losses.

4.1.16.2. Quasi-continuous heating

Intermittent heating is considered as continuous heating with adjusted set-point temperatures if mode A or mode B applies:

Mode A:

- If the set-point temperature variations between normal heating and reduced heating periods are less than 3°K and/or
- If the time constant of the building zone is less than 0.2 times the duration of the shortest reduced heating period (for heating),

then the set-point temperature for the heating calculation is the time average of the set-point temperatures. See illustration in a) and b) of Figure 9.

Mode B:

- If the time constant of the building zone is greater than 3 times the duration of the longest reduced heating period, then the set-point temperature for the heating calculation is the set-point temperature for the normal heating mode. See illustration in c) of Figure 9.

4.1.17. Corrections for intermittency, monthly method

4.1.17.1. Heating

In the case of intermittent heating which does not fulfil the conditions in Section 4.1.16.2, the energy demand for heating, $Q_{H,interm}$, in MJ, is calculated by using the following equation; **NB:** this is the condition currently assumed by SBEMie:

$$Q_{H,interm} = a_{H,red} \times Q_{H,cont}$$

where

$Q_{H,cont}$ is the energy demand for continuous heating, in MJ, calculated in accordance with Section 4.1.7.

$a_{H,red}$ is the dimensionless reduction factor for intermittent heating, determined according to the following equation:

$$a_{H,red} = 1 - \left[b_{H,red} \times \left(\frac{\tau_{0,H}}{\tau_H} \right) \times \gamma_H \times (1 - f_{H,hr}) \right]$$

with minimum value: $a_{H,red} = f_{H,hr}$ and maximum value: $a_{H,red} = 1$

and where

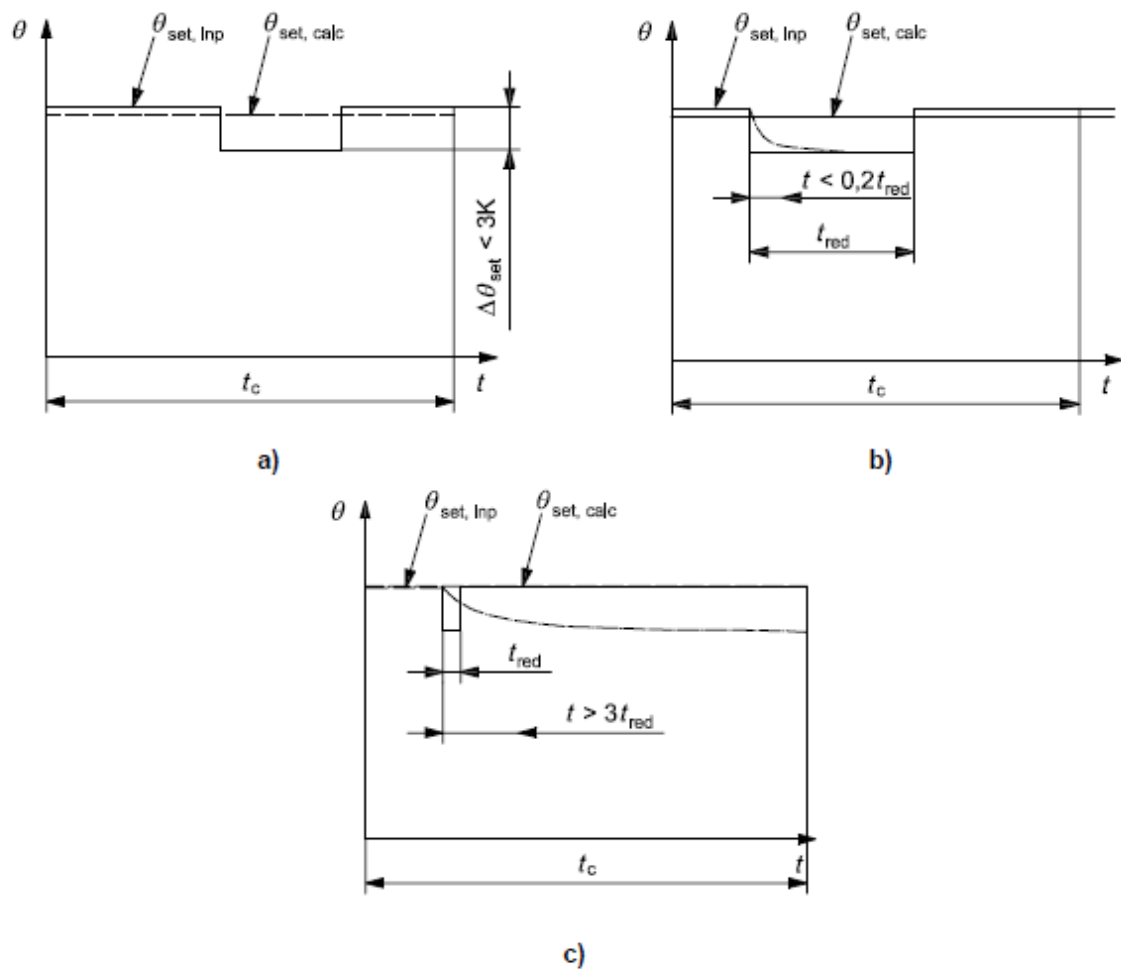
$f_{H,hr}$ is the fraction of the number of hours in the month with a normal heating set-point (no reduced set-point or switch-off);

$b_{H,red}$ is an empirical correlation factor of value = 3;

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

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

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



Key

The cases a, b and c represent different situations as described in the text.

$\theta_{set,inp}$ set-point temperature provided as input

$\theta_{set,calc}$ set-point temperature for the calculation

t time

t_c representative part of the calculation period

Figure 9: Example of quasi-continuous heating¹³

4.1.17.2. Cooling

Due to the diurnal pattern of the weather, and the effect of the building thermal inertia, an evening/night thermostat set-back or switch-off has, in general, a much smaller effect on the energy demand for cooling than a thermostat set-back or switch-off has on the heating energy demand. This implies that a thermostat set-back or switch-off during the evening/night will result in only a small or no decrease in the energy demand for cooling, except during warm months or in the case of high internal gains, in combination with small heat losses. Therefore, the time fraction for intermittency in the cooling mode, $f_{C,day}$ (see next), is based on the number of days in the month with cooling, instead of number of hours in the month as for the heating mode, $f_{H,hr}$ (in Section 4.1.17.1).

In the case of intermittent cooling, the energy demand for cooling, $Q_{C,interm}$, in MJ, is calculated by using the following equation:

$$Q_{C,interm} = a_{C,red} \times Q_{C,cont}$$

where

$Q_{C,cont}$ is the energy demand for continuous cooling, in MJ, calculated in accordance with Section 4.1.8.

$a_{C,red}$ is the dimensionless reduction factor for intermittent cooling, determined according to the following equation:

$$a_{C,red} = 1 - \left[b_{C,red} \times \left(\frac{\tau_{0,C}}{\tau_C} \right) \times \frac{1}{\lambda_C} \times (1 - f_{C,day}) \right]$$

with minimum value: $a_{C,red} = f_{C,day}$ and maximum value: $a_{C,red} = 1$

and where

$f_{C,day}$ is the fraction of the number of days in the month with, at least during daytime, a normal cooling set-point (no reduced set-point or switch-off);

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

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

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

λ_C is the dimensionless loss/gain ratio for the cooling mode.

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

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

$$Q_{NH,yr} = \sum_i Q_{NH,i}$$

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 i , in MJ (adjusted for intermittence following section 4.1.17 if applicable);

$Q_{NC,yr}$ 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 j , in MJ (adjusted for intermittence following section 4.1.17 if applicable).

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:

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

and

$$Q_{NC,yr,zs} = \sum_{jz} Q_{NC,yr,z}$$

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 consumption (use) for heating and the annual energy consumption (use) for cooling, including system losses, are determined as a function of the energy demands for heating and cooling in the ways described in sections 4.5 and 4.6, respectively, expressed in MJ. The auxiliary energy consumption (use) is calculated separately as described in section 4.7.

4.1.21. Reporting results

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

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 each HVAC system, the monthly and annual heating and cooling energy demand is reported.

For the whole building, the monthly and 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 is calculated as:

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

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 NEAP Activity Database for the activity zone), in °C;

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

n is the number of days within a month;

0.0864 is a conversion factor from W.days to MJ.

4.2.1.1. Ventilation heat loss coefficient

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

where

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

$\rho_a \times c_a$ is the air heat capacity per volume ~ 1.2 kJ/m³K (product of the air density, in kg/m³, and the air specific heat capacity, in kJ/kgK);

u_{v-heat} is the air flow rate through the conditioned space, in l/sm² floor area;

A is the zone floor area, in m².

4.2.1.2. Ventilation air flow rate

$$u_{v-heat} = \left(\frac{u_{v-inf}}{3.6} \right) + [(1 - \eta_{HR}) \times u_{v,m,heat}] + u_{v,n,heat}$$

where

u_{v-heat} is the air flow rate through the conditioned space, in l/sm² floor area;

u_{v-inf} is the air flow rate through the conditioned space due to infiltration, converted by dividing by 3.6 from m³/hm² to l/sm² floor area;

η_{HR} is the efficiency of the heat recovery system. The default values are shown in Table 17, which can be over-ridden by the user;

$u_{v,m,heat}$ is the air flow rate through the conditioned space resulting from mechanical ventilation during operation time, in l/sm² floor area. This value is obtained using the ventilation requirements as established in the NEAP Activity Database for each type of activity;

$u_{v,n,heat}$ is the air flow rate through the conditioned space resulting from natural ventilation, in l/sm² floor area. This value is obtained using the ventilation requirements as established in the NEAP Activity Database for each type of activity.

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

Table 17: Default efficiencies of the heat recovery systems

4.2.2. Heat transfer by ventilation, cooling mode

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

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

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 cooling set-point taken from the NEAP Activity Database for the activity zone);

θ'_e is the modified external air temperature as appearing in Table 18;

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

0.0864 is a conversion factor from W.days to MJ.

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 18: Values¹⁵ 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

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

where

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

$\rho_a \times c_a$ is the air heat capacity per volume ~ 1.2 kJ/m³K (product of the air density, in kg/m³, and the air specific heat capacity, in kJ/kgK, respectively);

u_{v-cool} is the air flow rate through the conditioned space, in l/sm² floor area;

A is the zone floor area, in m²

4.2.2.2. Ventilation air flow rate

$$u_{v-cool} = \left(\frac{u_{v-inf}}{3.6} \right) + [(1 - \eta_{HR}) \times u_{v,m,cool}] + u_{v,n,cool}$$

where

u_{v-cool} is the air flow rate through the conditioned space, in l/sm² floor area;

u_{v-inf} is the air flow rate through the conditioned space due to infiltration, converted by dividing by 3.6 from m³/hm² to l/sm² floor area;

η_{HR} is the efficiency of the heat recovery system. The default values are shown in Table 17, which can be over-riden by the user. This parameter is set to 0 if heat recovery can be bypassed or switched off in summer (referred to as variable heat recovery efficiency in SBEMie);

$u_{v,m,cool}$ is the air flow rate through the conditioned space resulting from mechanical ventilation during operation time, in l/sm² floor area. This value is given by the ventilation requirements as established in the NEAP Activity Database for each type of activity;

$u_{v,n,cool}$ is the air flow rate through the conditioned space resulting from natural ventilation, in l/sm² floor area. This value is obtained using the ventilation requirements as established in the NEAP Activity Database for each type of activity.

¹⁵ Taken from NEN 2916:1998: *Energy performance of non-residential buildings - Determination method*.

4.2.3. Demand-controlled ventilation

The Actual building includes the ability to model demand-controlled ventilation for zones with mechanical ventilation while, for naturally ventilated zones, there is the option of enhanced ventilation control, which refers to natural ventilation with BMS control (i.e., modifying the ventilation flow rate provided by natural means in the space based on some form of control). The details for implementing demand-controlled ventilation are outlined below (taken from NEAP Modelling Guide).

For zones whose ventilation is defined as mechanical, the following options are available in iSBEMie:

1. No demand-controlled ventilation (*default option*)
2. Demand control dependent on number of occupants
3. Demand control dependent on gas sensors

If the option selected is either 2 or 3 from above, then the parameter “air flow regulation type” will become active with the following available options:

1. Damper control (*default option*)
2. Speed control

For zones whose ventilation is defined as natural, the options available in iSBEMie are:

1. No demand-controlled ventilation (*default option*)
2. Enhanced ventilation

Depending on the user inputs, a modified demand control fresh air rate (FAR_{dc}) is determined from the NEAP fresh air rate (FAR_{max}) as follows:

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

where

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

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

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

C_{dc} is a demand control coefficient and is determined based on the data in Table 19.

Type of demand control	Demand control coefficient (C_{dc})
None	0
Control based on occupancy number of occupants	0.85
Control based on gas sensor	0.95
Enhanced natural ventilation	0.5

Table 19: Values for demand control coefficient

4.2.4. Infiltration air flow rate (heating and cooling)

This methodology has been extracted from the CEN standards EN 15242. When it can be assumed that there is no interaction between the ventilation system (e.g., mechanical

system) and the leakages impact, a simplified approach can be used to calculate the infiltrated and exfiltrated values as follows.

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

Calculate infiltration due to the stack effect ($u_{v-inf-stack}$) for heating mode

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

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

where

Q_{4pa} is the air leakage characteristics for a pressure difference of 4 Pa, in m³/hm² of outer envelope, i.e., the average volume of air (in m³/h) that passes through a unit area of the building envelope (in m²) 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 20, 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), in °C;

θ_i is the internal (indoor) temperature (the heating set-point taken from the NEAP Activity Database for the activity zone where the envelope belongs), in °C.

leakages level		m ³ /h per m ² of outer envelope (exp n = 0.667)		
		Q_{4pa}	Q_{10pa}	Q_{50pa}
single family	low	0.5	1.0	2.5
	average	1.0	2.0	5.0
	high	2.0	3.5	10.0
multi family; non-residential except industrial	low	0.5	1.0	2.5
	average	1.0	2.0	5.0
	high	2.0	3.5	10.0
industrial	low	1.0	2.0	5.0
	average	2.0	3.5	10.0
	high	4.0	7.0	20.0

leakages level		n (vol.h) (exp n=0.667)			outer area/vol 1/m
		n _{4Pa}	n _{10Pa}	n _{50Pa}	
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	0.4
	average	0.4	0.8	2	0.4
	high	0.8	1.4	4	0.4

industrial	low	0.3	0.6	1.5	0.3
	average	0.6	1.1	3	0.3
	high	1.2	2.1	6	0.3

leakages level		m ³ /h per m ² of floor area (exp n = 0.667)			outer area/floor area
		Q _{4pa}	Q _{10pa}	Q _{50pa}	
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 20: Examples of leakages characteristics¹⁶

Calculate infiltration due to the wind impact ($u_{v-inf-wind}$) for heating and cooling modes

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

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

where

Q_{4pa} is the same as defined above;

ΔC_p is the wind pressure coefficient defined as:

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

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

- for vertical walls: average wind speed for a wind sector of $\pm 60^\circ$ to the external wall axis (orientation);
- for roofs: wind speed considering all wind sectors.

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

Calculate the resulting air flow from stack and wind, u_{v-sw}

For each zone, the air flow due to the stack and wind effects is calculated as:

¹⁶ Extracted from EN 15242:2007 - Ventilation for buildings — Calculation methods for the determination of air flow rates in buildings including infiltration

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

where

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

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

Q_{4pa} is the same as defined above;

\max is the maximum value, i.e., greater of.

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

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

where

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

\max is the maximum value, i.e., greater of.

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:

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

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

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

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 .

4.2.5. Outputs produced

Q_{V-heat} : heat transfer by ventilation for the heating requirements calculations.

Q_{V-cool} : heat transfer by ventilation for the cooling requirements calculations.

4.3. Hot water demand

Energy demand for each zone (MJ/month) is calculated as:

$$Q_{HWz} = \text{database demand} \times \frac{4.18}{1000} \times A_z \times \Delta T$$

where

Q_{HWz} is the hot water energy demand for zone z , in MJ/month;

database demand is the hot water demand from the NEAP Activity Database (see APPENDIX A:), in l/m^2 per month;

ΔT is the temperature difference °C that water is heated up), taken as 50°C (the energy is required to raise the water temperature from 10°C to 60°C);

$\frac{4.18}{1000}$ is the specific heat capacity of water in MJ/kgK;

A_z is the area of zone z , in m^2 .

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

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

$$Loss_{HWz} = 0.17 \times Q_{HWz}$$

where

$Loss_{HWz}$ is the hot water distribution heat loss for zone z , in MJ/month;

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

For each Hot Water System (HWS):

- Carry out calculations for each solar energy system (SES) serving the HWS, if applicable, to calculate the SES contribution to HWS, used to reduce hot water demand;
- Evaluate hot water demand, area served, and distribution losses for HWS using:
 - Sum monthly demand for all zones served by HWS;
 - Sum monthly distribution losses for all zones served by HWS;
 - Sum area of all zones served by HWS;
- Evaluate earliest start time and latest end time for any zone served by HWS;
- Account for contribution from solar energy system, Section 4.9, if applicable;
- Account for contribution from CHP, if applicable.

4.3.1. Hot Water storage

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

$$V_{store} = Q_{day} \times 18$$

where

V_{store} is the storage volume, in litres,

Q_{day} , is the daily HW energy demand, in MJ/day, is calculated by:

$$Q_{day} = \frac{Q_{month_max}}{N_{days}}$$

where

Q_{month_max} is the maximum monthly demand, in MJ;

N_{days} is the number of days in the month;

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

If the storage losses (MJ/month) have not been input by the user, then storage losses are calculated as:

$$Loss_{store} = Loss_{day} \times (V_{store_5})^{1/3} \times \frac{365}{12} \times (V_{store})^{2/3} \times 3.6$$

where

$Loss_{store}$ is the HW storage losses, in MJ/month;

$Loss_{day}$ is the HW storage losses per day in kWh per litre of storage and is calculated as follows:

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

V_{store_5} is the storage volume, in litres, if the annual hot water demand were 5 MJ/m², i.e., it is calculated as $= \frac{5}{365} \times 18 \times A_{HWS}$

where

18 is the same computational value described above;

A_{HWS} is the total area served by the HWS, in m²;

$\frac{365}{12}$ is multiplication by the number of days in the year and division by the number of months in order to obtain the monthly storage losses;

V_{store} is the hot water storage volume, in litres, as calculated above or as input by the user;

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

4.3.2. Secondary circulation

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

$$loop_{SC} = \sqrt{A_{HWS}} \times 4.0$$

where

$loop_{SC}$ is the secondary circulation loop length, in m;

A_{HWS} is the total area served by the HWS, in m²;

4.0 is a computational value.

The secondary circulation losses (MJ/month) are calculated as:

$$Loss_{SC_m} = l_m \times loop_{SC} \times h_{SC} \times N_m \times \frac{3.6}{1000}$$

where

$Loss_{SC_m}$ is the secondary circulation losses, in MJ, for month m ;

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

$loop_{SC}$ is the secondary circulation loop length in m;

h_{SC} is the number of daily hours of operation of the secondary circulation (or 24 hours if there is no time switch on the secondary circulation);

N_m is the number of days in month m ;

$\frac{3.6}{1000}$ is a factor to convert W to kWh and then kWh to MJ.

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

$$P_{SC} = \frac{(0.25 \times loop_{SC}) + 42}{500}$$

where

P_{SC} is the secondary circulation pump power, in kW;

$loop_{SC}$ 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 as above. This is then included in the auxiliary energy calculated for the building.

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.

Energy for lighting, W_{light} , in kWh/m².year, is calculated as:

$$W_{light} = \sum_{j=1}^{12} \left\{ N_j \times \left[\sum_{i=1}^{24} (P_j \times F_{Dji} \times F_{Oji}) + \sum_{i=1}^{24} (P_{dj} \times F_{Od}) + (24 \times P_p) \right] \right\} \div 1000$$

where:

N_j is number of days in month j ;

P_j is lighting power density in W/m² for each hour of month j ;

P_{dj} is display lighting power density in W/m² for each hour of month j ;

P_p is parasitic power density in W/m²;

- F_{Dji} is daylight correction factor (utilisation factor) for hour i of month j ;
- F_{Oji} is occupancy correction factor for hour i of month j ;
- F_{Oad} is occupancy correction factor for display lighting throughout the year;
- 1000 is conversion from W to kW.

4.4.1. Calculate lighting power density in the Actual and Reference buildings, P_j

The lighting power density for the Actual and Reference buildings are calculated as specified in the NEAP Modelling Guide for the relevant building regulations.

Where the user selects a lamp type for each zone in the Actual building, the default luminous efficacy values in Table 21 will be used in the calculation by SBEMie.

If the Actual building includes constant illuminance control, then the general lighting power density is reduced by 10%, following the NEAP Modelling Guide.

Lamp Type	Luminaire lumens per circuit Watt	
	Side-lit and not daylit activities	Top-lit activities
LED	50.0	50.0
Tungsten and Halogen	7.5	9.0
Fluorescent - compact	22.5	27.0
T12 Fluorescent - halophosphate - low frequency ballast	25.0	30.0
T8 Fluorescent - halophosphate - low frequency ballast	27.5	33.0
T8 Fluorescent - halophosphate - high frequency ballast	32.5	39.0
T8 Fluorescent - triphosphor - high frequency ballast	36.3	43.5
Metal Halide	25.0	39.0
High Pressure Mercury	22.5	27.0
High Pressure Sodium	35.0	42.0
T5 Fluorescent - triphosphor-coated - high frequency ballast	37.5	45.0
Fluorescent (no details)	22.5	27.0

Table 21: Luminous efficacies used by SBEMie in correspondence to the lamp types selected (from 2017 NEAP Modelling Guide)

4.4.2. Calculate display lighting power density in the Actual and Reference buildings, P_{dj}

For the Actual building

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

For the Reference building

The display lighting in the Reference building is based on the display lighting power density from the NEAP Activity Database multiplied by 0.682 (i.e., adjustment between lamp efficacy of 22 and 15 lamp lumens per circuit-watt).

Daylight harvesting and local manual switching do not apply to display lighting in the Actual or Reference building (i.e., they only affect general lighting).

4.4.3. Calculate parasitic power, P_p

The parasitic power density, P_p , is assumed to be:

- For manual switching: 0 W/m²
- For photoelectric control (dimming or switching) or constant illuminance control: default for digitally-addressable systems = 0.57 W/m², default for stand-alone sensors = 0.3 W/m², or the user can specify the value for the system used.
- For occupancy sensing: default = 0.3 W/m², or the user can specify the value for the system used.

4.4.4. Calculate daylight correction factor, F_{Dji}

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

4.4.4.1. Daylight penetration

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

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

where W_{win} is the total window area including the frame (adjusted for the frame factor of each window), W_{roof} is the total rooflight area including the frame (adjusted for the frame factor of each rooflight), and A is the area of all room surfaces (ceiling/roof, floor, walls, windows, and rooflights).

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

Calculate the daylight factor for front, middle, and back of zone:

DF_F is the average daylight factor (%) in the front part of zone within the first 3 m from the facade:

$$DF_F = (1.75 \times DF_1) + DF_2$$

DF_M is average daylight factor (%) in the middle part of zone within the second 3 m from the facade:

$$DF_M = (0.25 \times DF_1) + DF_2$$

DF_B is average daylight factor (%) in the back part of zone beyond the first 6 m from the facade:

$$DF_B = DF_2$$

4.4.4.2. Photoelectric control

Calculate the utilisation factor:

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

If the photo sensor is in the front of the zone only, then:

$$F_D = \left[\text{area daylit by windows} \times \frac{(F_{D,F} + 1)}{2} \right] + [(1 - \text{area daylit by windows}) \times 1.0]$$

If the photo sensor is in the front and back, then:

$$F_D = \left[\text{area daylit by windows} \times \frac{(F_{D,F} + F_{D,M})}{2} \right] + [(1 - \text{area daylit by windows}) \times F_{D,B}]$$

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

$$F_D = \left[\text{area daylit by windows} \times \frac{(F_{D,F} + F_{D,M})}{2} \right] + [(1 - \text{area daylit by windows}) \times F_{D,B}]$$

where

$F_{D,F}$ is the utilisation factor for the front part of the room

$F_{D,M}$ is the utilisation factor for the middle part of the room

$F_{D,B}$ is the utilisation factor for the back part of the room

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

Photoelectric switching:

E_{ext} is the external illuminance (in kLux) – from the illuminance data for the particular weather location, as shown for Dublin in Table 22.

E_{design} is the design illuminance (in Lux)

Front part of room:

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

else if $(E_{ext} \times DF_F \times 10) > (0.5 \times E_{design})$ then $F_{D,F} = 0.5$

else $F_{D,F} = 1$

Middle part of room:

$if (E_{ext} \times DF_M \times 10) > E_{design} \quad then F_{D,M} = 0$
 $else if (E_{ext} \times DF_M \times 10) > (0.5 \times E_{design}) \quad then F_{D,M} = 0.5$
 $else F_{D,M} = 1$

Back part of room:

$if (E_{ext} \times DF_B \times 10) > E_{design} \quad then F_{D,B} = 0$
 $else if (E_{ext} \times DF_B \times 10) > (0.5 \times E_{design}) \quad then F_{D,B} = 0.5$
 $else F_{D,B} = 1$

Photoelectric dimming

Front part of room:

$if (E_{ext} \times DF_F \times 10) > E_{design} \quad then F_{D,F} = 0$
 $else F_{D,F} = \frac{E_{design} - (E_{ext} \times DF_F \times 10)}{E_{design}}$

Middle part of room:

$if (E_{ext} \times DF_M \times 10) > E_{design} \quad then F_{D,M} = 0$
 $else F_{D,M} = \frac{E_{design} - (E_{ext} \times DF_M \times 10)}{E_{design}}$

Back part of room:

$if (E_{ext} \times DF_B \times 10) > E_{design} \quad then F_{D,B} = 0$
 $else F_{D,B} = \frac{E_{design} - (E_{ext} \times DF_B \times 10)}{E_{design}}$

NB: In normal operation, the residual light output and power consumption of dimmed lights will occur throughout working hours unless (potential future modifications to SBEMie) the circuit is switched off by the occupants, an occupancy sensor, or a time switch.

4.4.4.3. Manual switching

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

- maximum distance from a switch to the luminaire it controls is 6 m or twice the luminaire mounting height if this is greater
- or if the area of the room is less than 30 m²
- 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&E, industrial process areas, warehouse storage, and performance areas (stages), for all of which, $F_D = 1$.

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

- the building is occupied for the first time in the day

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

Following such an event, F_D is calculated as follows:

$$\text{if } (E_{ext} \times DF_F \times 10) > E_{design} \quad \text{then } F_D = 0.5$$

and if there are side windows in one orientation only, then:

$$F_D = [\text{area daylight by windows} \times 0.5] + [(1 - \text{area daylight by windows}) \times 0.5]$$

$$\text{else } F_D = 1$$

4.4.4.4. Manual plus photoelectric control

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

Time	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
630	0.00	0.00	0.86	1.18	4.35	5.88	4.24	1.92	0.01	0.00	0.00	0.00
730	0.00	0.33	3.73	4.96	10.11	11.54	9.53	6.53	2.60	0.13	0.13	0.00
830	0.50	3.14	9.17	11.01	16.13	17.45	14.97	12.40	7.78	2.73	2.44	0.33
930	3.24	7.74	15.15	18.22	23.30	23.94	21.64	19.31	13.98	7.84	6.00	3.00
1030	6.81	11.88	20.56	23.99	29.99	30.90	28.33	24.92	20.10	12.20	9.17	6.17
1130	9.19	14.64	24.24	29.27	34.52	35.31	34.00	30.28	25.39	16.10	11.47	8.23
1230	10.32	16.41	25.44	32.43	36.89	37.86	36.51	33.69	28.09	19.34	11.80	7.85
1330	9.80	15.51	24.86	34.76	38.14	37.29	38.16	35.38	28.50	19.64	10.46	7.01
1430	7.60	12.82	21.93	33.04	37.48	36.62	37.36	34.61	27.14	18.55	7.49	4.69
1530	3.97	9.22	17.07	29.35	34.19	34.26	33.90	31.32	23.36	14.83	3.62	2.00
1630	0.84	4.60	10.78	23.19	28.76	30.14	29.42	27.52	18.71	9.81	0.58	0.00
1730	0.00	0.87	4.70	16.94	22.10	23.88	24.12	20.27	11.86	4.40	0.00	0.00
1830	0.00	0.00	0.82	10.28	15.82	17.92	17.42	12.83	5.70	0.85	0.00	0.00
1930	0.00	0.00	0.00	4.22	8.82	11.08	10.42	6.26	1.17	0.00	0.00	0.00

Table 22: External illuminances in Dublin in kilolux (derived from the IPCC Emission Scenario: High (RCP8.5), Mid sensitivity TRY Met Éireann¹⁰ irradiance data). Outside these times the external illuminance is assumed to be zero

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, $F_O = 1$ if the lighting is switched on 'centrally' (this is assumed in SBEMie if there is no manual switching or photoelectric control).

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&E, industrial process areas,

warehouse storage, and performance areas (stages), $F_o = 1$ even if occupancy sensing or manual control is provided, unless an automatic time switch dims or switches off the lighting (i.e., the options “Auto On / Dimmed” or “Auto On / Auto Off” in Table 23).

4.4.5.1. Local occupancy sensing

$$F_{oi} = F_{oc} \quad (\text{for each hour } i \text{ in the calculation})$$

In these expressions, F_{oc} is given in Table 23. System types are defined in the CEN standard EN 15193: *Energy performance of buildings — Energy requirements for lighting*.

Occupancy Sensing	F_{oc}
<i>Systems without automatic presence or absence detection</i>	
Manual On/Off Switch	1.00
Manual On/Off Switch + additional automatic sweeping extinction signal	0.95
<i>Systems with automatic presence and/or absence detection</i>	
Auto On / Dimmed	0.95
Auto On / Auto Off	0.90
Manual On / Dimmed	0.90
Manual On / Auto Off	0.82

Table 23: F_{oc} values

4.4.6. Time switching – used for display lighting only – calculate F_{od}

Automatic time switch:

If there is an automatic time-switch for display lighting, then

$$F_{od} = 1 - f$$

where $f = 0.2$ to represent a reduction of 20% in the power density of display lighting.

If there is no time-switch for display lighting, then $f = 0$.

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 and 4.1.17.1, the heating energy demand (H_d) for the HVAC system h_i will be the addition of the demand of all the zones attached to that HVAC system. The heating energy use (H_e) for the HVAC system is then calculated by:

$$H_e = \frac{H_d}{SSEff}$$

where $SSEff$ is the seasonal efficiency of the heating system as discussed in section 3.3.3.

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

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 and 4.1.17.2, the cooling energy demand (C_d) for the HVAC system h_i will be the addition of the demand of all the zones attached to that HVAC system. The cooling energy use (C_e) for the HVAC system is then calculated by:

$$C_e = \frac{C_d}{SSEER}$$

where $SSEER$ is the seasonal energy efficiency ratio of the cooling system as discussed in section 3.3.3.

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

4.6.1. Correction for Metering

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

4.7. Auxiliary energy use

Auxiliary energy use is calculated on a monthly basis for each zone, depending on its servicing strategy, defined in the building.

4.7.1. Data requirements

Ventilation rate:

- For mechanical ventilation, SBEMie uses outside fresh air rates from the NEAP Activity Database (for the chosen activity in zone).

- For mechanical exhaust, users need to enter air flow rate.

Specific fan power (SFP):

- Users need to enter the SFP where there is mechanical ventilation, either at zone level or HVAC level.
- Users must also enter the SFP at zone level where there is zonal mechanical exhaust.

4.7.2. Definition of algorithms

The auxiliary energy for each zone is calculated monthly as shown below (in kWh/m²) and then multiplied by the area of the zone (in m²), and, if applicable, also corrected for metering.

The auxiliary energy is the product of the auxiliary power density and annual hours of operation of the HVAC system from the NEAP Activity Database (e.g., the hours when the heating set-point is above the set-back temperature based on the daily/weekly/annual schedules from the NEAP Activity Database).

The zone’s auxiliary power density is the sum of the pump and fan power density.

4.7.2.1. Pump power

The pump power density for the Actual building will depend on the type of HVAC system and whether the pump has variable speed control. Table 24 determines which HVAC system types need to account for pump power and whether the option of specifying variable speed pumping is available to the user. Table 25 gives the pump power densities for constant speed pumping as well as variable speed pumping.

HVAC system type	Pump power	Variable speed pumping allowed
Central heating using water: radiators	LTHW ¹⁷ only	Yes
Central heating using water: convectors	LTHW only	Yes
Central heating using water: floor heating	LTHW only	Yes
Central heating with air distribution	None	No
Other local room heater - fanned	None	No
Other local room heater - unfanned	None	No
Unflued radiant heater	None	No
Flued radiant heater	None	No
Multiburner radiant heaters	None	No
Flued forced-convection air heaters	None	No
Unflued forced-convection air heaters	None	No
Single-duct VAV	Both LTHW and CHW ¹⁸	No
Dual-duct VAV	Both LTHW and CHW	No
Indoor packaged cabinet (VAV)	Both LTHW and CHW	Yes
Fan coil systems	Both LTHW and CHW	Yes
Induction system	Both LTHW and CHW	Yes
Constant volume system (fixed fresh air rate)	Both LTHW and CHW	No
Constant volume system (variable fresh air rate)	Both LTHW and CHW	No

¹⁷ Low temperature hot water

¹⁸ Chilled water

Multizone (hot deck/cold deck)	Both LTHW and CHW	No
Terminal reheat (constant volume)	Both LTHW and CHW	No
Dual duct (constant volume)	Both LTHW and CHW	No
Chilled ceilings or passive chilled beams and displacement ventilation	Both LTHW and CHW	Yes
Active chilled beams	Both LTHW and CHW	Yes
Water loop heat pump	Both LTHW and CHW	No
Split or multi-split system	None	No
Single room cooling system	None	No

Table 24: Assigning pump power to HVAC systems (from 2017 NEAP Modelling Guide)

Pump configuration	Pump power density (W/m ²)	
	LTHW only	Both LTHW and CHW
Constant speed pumping	0.6	1.8
Variable speed pumping with differential sensor across pump	0.5	1.5
Variable speed pumping with differential sensor in the system	0.4	1.1
Variable speed pumping with multiple pressure sensors in the system	0.3	0.9

Table 25: Pump power density for Actual building (from 2017 NEAP Modelling Guide)

4.7.2.2. Fan power

For zones whose servicing strategy is mechanical ventilation as well as heating and/or cooling, the fan power density is determined for each zone using one of the following equations as determined by Table 26:

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

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

$$FPS_3 = \text{greater of } \left(\frac{SCR}{5}, FAR_{max} \right) \times SFP_{central}$$

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

where

FAR_{max} is the peak fresh air supply rate (l/s.m²) that is set by the NEAP activity type;

SCR is the space conditioning supply rate (i.e., the air flow rate needed to condition the space, in l/s.m²), which is calculated as follows:

$$SCR = \frac{\text{greater of } (PSH, PSC)}{\rho \times C_p \times \Delta T}$$

where

$\rho = 1.2 \text{ kg/m}^3$ is the air density;

$C_p = 1.018 \text{ kJ/kgK}$ is the air specific heat capacity;

$\Delta T = 8^\circ\text{K}$, PSH is the peak space heating load;

PSC is the peak space cooling load (i.e., in W/m² of floor area for each zone);

$SFP_{central}$ is the central unit specific fan power, in W/(l/s);

$SFP_{terminal}$ is the terminal unit specific fan power, in W/(l/s), if applicable.

HVAC system type	Fan power density
Central heating using water: radiators	-
Central heating using water: convectors	-
Central heating using water: floor heating	-
Central heating with air distribution	FPS_2
Other local room heater - fanned	-
Other local room heater - unfanned	-
Unflued radiant heater	-
Flued radiant heater	-
Multiburner radiant heaters	-
Flued forced-convection air heaters	-
Unflued forced-convection air heaters	-
Single-duct VAV	FPS_2
Dual-duct VAV	FPS_2
Indoor packaged cabinet (VAV)	FPS_1
Fan coil systems	FPS_1
Induction system	FPS_3
Constant volume system (fixed fresh air rate)	FPS_2
Constant volume system (variable fresh air rate)	FPS_2
Multizone (hot deck/cold deck)	FPS_2
Terminal reheat (constant volume)	FPS_2
Dual duct (constant volume)	FPS_2
Chilled ceilings or passive chilled beams and displacement ventilation	FPS_4
Active chilled beams	FPS_3
Water loop heat pump	FPS_2
Split or multi-split system	-
Single room cooling system	-

Table 26: Assigning fan power equations to HVAC systems (from 2017 NEAP Modelling Guide)

For zones whose servicing strategy is mechanical ventilation (which might include heat recovery) but no heating or cooling, the fan power density is the product of the fresh air supply rate from the NEAP Activity Database and the specific fan power defined by the user at zone level.

For zones with mechanical exhaust, the fan power density is the product of the user defined exhaust rate and the specific fan power defined by the user. The exhaust fan energy will be an addition to the fan energy for supply & extract ventilation, if available.

For zones served by the HVAC systems listed in Table 27, additional fan energy is included to account for integral fans using the ratio (to be input by the user) of associated fan power, in W per kW of heat output (delivered) by the heating system.

HVAC system type
Central heating using water: convectors <i>(but only in case the system utilises fanned convectors)</i>
Other local room heater - fanned

Table 27: Additional fan power for HVAC systems (from 2017 NEAP Modelling Guide)

For zones with de-stratification fans, the following is added to the monthly auxiliary energy calculation:

$$\frac{1}{3.6} \text{ kWh/m}^2 \text{ (i.e., 1 MJ/m}^2\text{)}$$

Energy for other ancillary services in the building, such as secondary hot water circulation (Section 4.3.2), forced circulation for solar water heating systems (Section 4.9), night cooling, etc., will be an addition to the fan and pump energy in order to form the total auxiliary energy for the building.

4.7.2.3. Demand-controlled ventilation

In addition to affecting the fresh air load (i.e., energy to heat and cool the fresh air), demand-controlled ventilation can also affect the auxiliary energy. Where the air flow regulation uses fan speed control (i.e., using variable speed fans), the auxiliary energy calculation, as per the 2017 NEAP Modelling Guide, will use FAR_{dc} instead of FAR_{max} , but if the air flow regulation uses damper control, then the auxiliary energy calculation will not be affected.

4.8. Hot water energy use

As described in section 4.3, for each HWS, calculate:

- hot water demand, in MJ/month;
- distribution losses, in MJ/month;
- storage losses, in MJ/month;
- secondary circulation losses, in MJ/month;
- secondary circulation pump energy (added to auxiliary energy).

Distribution efficiency

The monthly HWS distribution efficiency is calculated as:

$$Eff_{dist} = \frac{Q_{HWS}}{(Q_{HWS} + Loss_{dist} + Loss_{stor} + Loss_{sec})}$$

where

- Eff_{dist} is the monthly hot water distribution efficiency for the HWS;
- Q_{HWS} is the water heating energy demand for the HWS, in MJ/month;
- $Loss_{dist}$ is the hot water distribution losses for the HWS, in MJ/month, if applicable;
- $Loss_{stor}$ is the hot water storage losses for the HWS, in MJ/month, if applicable;
- $Loss_{sec}$ is the hot water secondary circulation losses for the HWS, in MJ/month, if applicable.

Hot Water energy consumption

The hot water energy consumption, in MJ/month, for the HWS is calculated as:

$$E_{HWS} = \frac{\left(\frac{Q_{HWS}}{Eff_{dist}} \right)}{Eff_{gen}}$$

where

E_{HWS} is the water heating energy consumption for the HWS, in MJ/month;

Q_{HWS} is the water heating energy demand for the HWS, in MJ/month;

Eff_{dist} is the monthly hot water distribution efficiency for the HWS;

Eff_{gen} is the hot water generator efficiency for the HWS.

If the hot water system is connected to a solar water heating system and/or a CHP generator, the water heating energy consumption is calculated as:

$$E_{HWS} = \frac{\left[\left(\frac{Q_{HWS}}{Eff_{dist}} \right) - C_{CHP} - C_{SES} \right]}{Eff_{gen}}$$

where

E_{HWS} is the water heating energy consumption, in MJ/month;

Q_{HWS} is the water heating energy demand for the HWS, in MJ/month;

Eff_{dist} is the monthly hot water distribution efficiency for the HWS;

C_{CHP} is the water heating contribution to this HWS from a CHP, in MJ/month, if applicable;

C_{SES} is the water heating contribution to this HWS from a SES, in MJ/month, if applicable;

Eff_{gen} is the hot water generator efficiency for the HWS.

Note: If the hot water is provided by the HVAC system's heat generator, rather than by an independent generator, the efficiency of the heat generator is reduced by 5% for the water heating calculation in order to take account of the reduction in the efficiency at part-load operation (since the generator would have been sized to accommodate both the space and water heating loads).

4.9. Solar thermal energy systems

The energy yield given by the solar thermal energy system is calculated according to the collector orientation and inclination. In order to calculate the radiation at the collector plane, the hourly radiation data is processed to yield values of monthly global solar radiation for the orientations and inclinations shown in Table 28 and Table 29, respectively.

For the purposes of SBEMie calculations, solar hot water is used to displace some (or all) of the hot water demand presented to the hot water system in the building, and hence, reduce the fuel that would otherwise be used by the hot water generator in order to meet the whole demand.

4.9.1. Data requirements

General

- HWS which the solar energy system is serving: specifies the name given by the user for the hot water system (HWS) to which the solar energy system (SES) is connected. This parameter is needed for the software to know the demand of the zones served by the hot water system and that is being displaced by the solar energy system;
- Area: specifies the solar collector maximum projected area through which un-concentrated solar radiation enters the collector, in m²;
- Orientation: specifies the orientation of the solar collector;
- Inclination: specifies the inclination of the solar collector 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 28: Orientations for which the monthly solar radiation has been calculated for SBEMie

Inclinations
0
15
30
45
60
75
90

Table 29: Inclinations for which the monthly solar radiation has been calculated for SBEMie

Collector parameters

If the collector parameters are known, they should be entered by the user into iSBEMie. Otherwise, the default values in Table 30 will be used by the software. The collector parameters are as follows:

- η_0 : (sigma-zero) is the zero-loss collector efficiency factor from the collector test standards EN 12975-2 and related to the aperture area;
- a_1 : is the linear heat loss coefficient from the collector test standards EN 12975-2 and related to the aperture area, in W/m²K;

- a_2 : is the temperature dependence of the heat loss coefficient from the collector test standards EN 12975-2 and related to the aperture area, in W/m^2K^2 ;
- IAM : is the Incidence Angle Modifier of the collector from the collector test standard EN 12975-2 when the test angle of incidence between the collector and the direct solar radiation for the test condition is 50° .

Collector type	η_0	a_1	a_2	IAM
Unglazed collector	0.9	20	0	1
Flat plate collector	0.75	6	0	0.94
Evacuated tube collector	0.65	3	0	0.97

Table 30: Default solar collector parameters

Solar storage

The solar storage parameters are as follows:

- Solar pre-heating type: specifies the arrangements for solar pre-heating as one of the following options:
 - dedicated solar pre-heating storage: when there is one or more dedicated solar storage vessel that are heated with the solar collectors only and that do not contain any other heating sources;
 - combined cylinder: the solar storage is combined in a hot water cylinder with one or more back-up heating sources, i.e., the solar energy system shares the same storage vessel with the hot water system;
- Solar storage volume, V_{sol} : this refers to the dedicated solar storage volume, and it should be calculated according to the arrangements for solar pre-heating as indicated in the schematics in Figure 10:
 - in the case of one or more separate pre-heat tank(s), such as arrangements a) or c) in Figure 10, the solar storage volume is the volume of the pre-heat tank(s);
 - in the case of a combined cylinder, such as arrangement b) in Figure 10, the solar storage volume is the volume between the bottom of the lowest back up element (electric element or heat exchanger) to the lowest element of the solar primary;
 - in the case of a thermal store (hot water only) where (only) the solar coil is within the thermal store, i.e., no back-up heating, the solar storage volume is the volume of the dedicated thermal storage;
 - in the case of a direct system, such as arrangement d) in Figure 10, the solar volume should be calculated as 0.3 times the volume of the cylinder. See also Note 2 below.

Note 1

The schematic examples reflected in the Figure 10 are unlikely to represent all types of commercial solar thermal installations. Where necessary, and for more complex systems, an accredited dynamic simulation tool can be used.

Note 2

The dedicated solar volume of a solar thermal installation varies depending on the control and timing strategy of the back-up system. To optimise the

performance of the solar thermal system, the back-up system should be prevented from operating during and prior to the period of the day where the solar radiation is strong enough to contribute to the hot water requirements.

- Insulation type and thickness: specifies the type and thickness of the insulation of the solar storage tank.

If the hot water storage vessel is shared between the solar energy system and the back-up hot water system, then the storage losses are already accounted for in Section 4.3.1. If the solar system has a dedicated hot water storage vessel, then the storage losses are calculated using the same procedure as in Section 4.3.1.

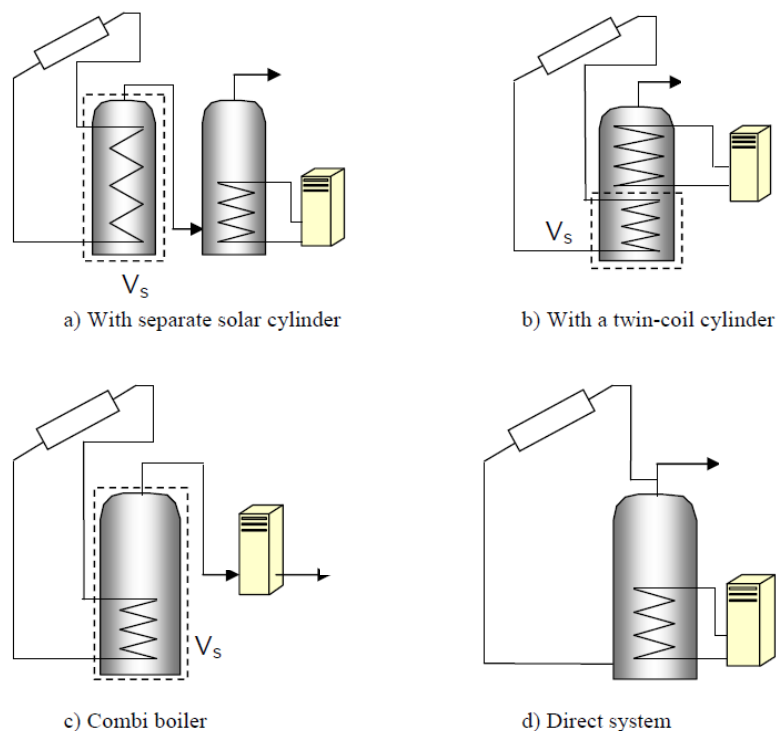


Figure 10: Arrangements for solar pre-heating (these schematics are not intended to show safety measures and devices needed to make the systems safe - Adapted from SAP 2005.

Collector loop

The solar loop refers to all elements located between the solar collector and the point where the back-up heating source supplies the hot water system with energy. The collector loop parameters are as follows:

- Heat transfer rate of the heat exchanger(s) in the solar loop, in W/K, $(U_{st})_{hx}$:
 - For solar thermal direct systems in which the solar primary transmission fluid and the consumed water are the same (arrangement d) in Figure 10), the option *there is no heat exchanger* should be chosen in iSBEMie;
 - For indirect systems where the primary circuit fluid is different to that of the secondary side of the system, there will be one or more heat exchangers in the storage vessel;

In order to calculate the drop in system efficiency induced by the heat exchanger(s) in the solar loop, the heat transfer rate of the heat exchanger(s)

needs to be entered by the user. If this value is not known, the default option should be used.

- For small systems, the heat transfer rate of the heat exchanger in the solar loop value can be obtained from test results according to the standards *EN 12975-3 - Performance characterisation of stores for solar heating systems*;
- For large systems, the value is taken from the heat exchanger performance data sheet provided by the manufacturer;
- For systems with more than one heat exchanger, using an intermediary or tertiary arrangement, such as with a thermal store, an equivalent heat transfer rate should be entered by the user (alternatively, dynamic simulation tools can be used);
- Overall heat loss coefficient of all pipes in the solar loop, $U_{loop,p}$, including pipes between collectors and array pipes and between collector array and the solar storage tank(s), in W/K;
 - If the pipe and insulation for the solar loop are known, the overall heat loss coefficient of all pipes in the solar loop can be calculated accordingly - see for instance, *John A. Duffie and William A. Beckman: Solar Engineering of Thermal Process. Wiley-Interscience ed., 1991*;
 - If the pipe and insulation for the solar loop are not known, default values should be used.

Distribution losses

If there are pipes between the solar thermal system and the back-up heating system, the user needs to specify whether the distribution pipes between the solar energy system and the back-up heating source are insulated. This is used to estimate the thermal losses of the distribution between the thermal solar system and the back-up heater.

Auxiliary energy

The auxiliary energy parameters are as follows:

- Circulation system: specifies the type of circulation system that the solar thermal system uses, i.e., either *thermosiphon systems*, *forced circulation systems assisted with photovoltaics*, or *forced circulation systems using grid electricity* for the circulation pump;
- Nominal power of pump(s): specifies the nominal input power, in W, of the circulation pump(s) in the solar loop, i.e., the power stated on the pump(s) label;

For a multi-stage pump, the power corresponding to the typical operation mode is chosen.

4.9.2. Definition of algorithms

Useful solar thermal output: $Q_{W,sol,us,mi}$

The (monthly) useful contribution of the solar thermal system to the hot water requirements of the building, in kWh, is calculated as:

$$Q_{W,sol,us,mi} = Q_{W,sol,out,mi} - Q_{sol,ls,mi}$$

where

$Q_{W,sol,out,mi}$ is the heat output of the solar thermal system in month i , in kWh;

$Q_{sol,ls,mi}$ is the thermal losses of the solar thermal system in month i , in kWh.

Solar thermal output system: $Q_{W,sol,out,mi}$

The output of the solar thermal system, in kWh, is calculated as:

$$Q_{W,sol,out,mi} = f_{sol,mi} \times Q_{W,sol,us,mi}$$

where

$Q_{W,sol,us,mi}$ is the hot water requirements in month i , in kWh;

$f_{sol,mi}$ is the fraction of the hot water covered by the thermal solar system in month i , calculated as:

$$f_{sol,mi} = (a \times Y_{W,mi}) + (b \times X_{W,mi}) + (c \times Y_{W,mi}^2) + (d \times X_{W,mi}^2) + (e \times Y_{W,mi}^3) + (f \times X_{W,mi}^3)$$

where

$X_{W,mi}$ is a value that depends on the collector loop heat loss coefficient and the temperature difference, but also on the storage tank volume by taking into account the storage tank capacity correction factor. It is calculated as:

$$X_{W,mi} = \frac{A \times U_{loop} \times \eta_{loop} \times \Delta T_{mi} \times f_{st} \times t_{mi}}{Q_{W,sol,us,mi} \times 1000}$$

where

A is the collector area, in m^2 ;

U_{loop} is the heat loss coefficient of the collector loop and is determined by the collector characteristics and the insulation of the pipes, in W/m^2K . It is calculated as:

$$U_{loop} = a_1 + (a_2 \times 40) + \left(\frac{U_{loop,p}}{A} \right)$$

where

$U_{loop,p}$ is the overall heat loss coefficient of all pipes in the solar loop, including pipes between collectors and array, and pipes between collector array and solar storage tank(s), in W/K ;

- If pipe and insulation for the collector are known, formulas for insulated pipes can be used, or
- If collector characteristics are not known, a default calculation is undertaken using $U_{loop,p} = 5 + (0.5 \times A)$

η_{loop} is the efficiency factor of the collector taking into account the influence of the heat exchanger calculated as:

- if the heat exchanger characteristics in the collector loop are known, then:

$$\eta_{loop} = 1 - \Delta\eta$$

where

$$\Delta\eta = \frac{(\eta_0 \times A \times a_1)}{(U_{st})_{hx}}$$

and $(U_{st})_{hx}$ is the heat transfer rate of the heat exchanger(s) in the solar loop, in W/K;

For direct systems, $\Delta\eta = 0$

- if the heat exchanger characteristics in the collector loop are not known, then:

$$\eta_{loop} = 0.85;$$

ΔT_{mi} is the reference temperature difference in month i calculated as:

$$\Delta T_{mi} = T_{ref,mi} - T_{e,avg,mi}$$

where

$T_{ref,mi}$ is the reference temperature in month i , in °C, calculated as:

$$T_{ref,mi} = 11.6 + (1.18 \times T_w) + (3.86 \times T_{cw}) - (1.32 \times T_{e,avg,mi})$$

where

T_w is the desired hot water temperature, taken as 40°C;

T_{cw} is the mains water supply temperature, taken as 10°C;

$T_{e,avg,mi}$ is the monthly average outside temperature for each location;

f_{st} is the storage tank capacity correction factor, calculated as:

$$f_{st} = \left(\frac{V_{ref}}{V_{sol}} \right)^{0.25}$$

where

V_{ref} is the reference volume equal to 75 litres per m² of collector;

V_{sol} is the solar storage tank volume, in litres;

t_{mi} is the length of month i , in hours;

$Y_{W,mi}$ is a value that depends on the collector data (zero-loss collector efficiency) and the solar irradiance on the collector plane. It is calculated as:

$$Y_{W,mi} = \frac{A \times IAM \times \eta_0 \times \eta_{loop} \times I_{mi} \times t_{mi}}{Q_{W,sol,us,mi} \times 1000}$$

where

I_{mi} is the average solar irradiance on the collector plane during the month i , in W/m²;

a, b, c, d, e, f are the correlation factors depending on the storage tank type as shown in Table 31. The values used are those calculated in the f-chart method (*John A. Duffie and William A. Beckman: Solar Engineering of Thermal Process. Wiley-Interscience ed., 1991*).

Correlation factors for collector arrays connected to hot water storage tanks	
a	1.029
b	-0.065
c	-0.245

<i>d</i>	0.0018
<i>e</i>	0.0215
<i>f</i>	0

Table 31: Correlation factors - Adapted from EN 15316-4-4:2007

Calculation of auxiliary energy consumption: $W_{sol,aux,mi}$

The auxiliary energy consumption (electricity required by the circulation pumps) of the solar thermal system, in kWh, is calculated according to:

- For thermosiphon systems or forced circulation systems assisted with photovoltaics, $W_{sol,aux,mi} = 0$
- For forced circulation systems using grid electricity,

$$W_{sol,aux,mi} = \frac{P_{aux,nom} \times t_{aux,mi}}{1000}$$

where

$P_{aux,nom}$ is the nominal power of the circulation pumps, input by the user, in W. If it is not known, then it is calculated as:

$$P_{aux,nom} = 25 + (2 \times A)$$

$t_{aux,mi}$ is the operation time of the pump in month *i*, in hours.

The annual operation time of the circulation pump is assumed to be 2000 hours. The monthly operation time of the pump is determined by the distribution of the annual operation time corresponding to the monthly distribution of the solar irradiance (e.g., if January irradiation is 5% of annual irradiation, then January operation time of the pump is assumed to be 5% of the annual operation time of the pump).

Thermal losses of the solar system: $Q_{sol,ls,mi}$

The thermal losses of the solar thermal system, in kWh, calculated as:

$$Q_{sol,ls,mi} = Q_{W,sol,st,ls,mi} + Q_{bu,dis,ls,mi}$$

where

$Q_{W,sol,st,ls,mi}$ is the solar storage tank heat losses, in kWh;

- For combined cylinders, the solar storage tank heat losses are calculated as part of the hot water module calculations (Section 4.3.1);
- For separate solar cylinder installations, the losses are calculated depending on the type and thickness of the insulation following the same calculation methodology as described for hot water cylinders of the back-up systems (Section 4.3.1);

$Q_{bu,dis,ls,mi}$ is the heat distribution losses between the thermal solar system and the back-up heater, in kWh. If there are pipes between the SES and the back-up system, the losses are determined based on whether the distribution pipes between the solar energy system and back-up heating source are insulated as follows:

- If the pipes are insulated:

$$Q_{bu,dis,ls,mi} = 0.02 \times \frac{Q_{W,sol,out,mi}}{Q_{W,sol,us,mi}}$$

- If the pipes are not insulated:

$$Q_{bu,dis,ls,mi} = 0.05 \times \frac{Q_{W,sol,out,mi}}{Q_{W,sol,us,mi}}$$

4.9.3. Outputs produced

SBEMie deducts the useful hot water produced by the solar thermal energy system from the requirements intended to be met by the HWS to which the solar energy system is connected.

4.10. Photovoltaics

The energy yield given by the photovoltaic system (PV) is calculated according to the collector orientation and inclination. In order to calculate the radiation at the PV module, the hourly radiation data is processed to yield values of monthly global solar radiation for the orientations and inclinations shown in Table 28 and Table 29, respectively. The algorithms used in SBEMie follow the standards EN 15316-4-6:2007.

4.10.1. Definition of algorithms

Photovoltaic electricity generation

The monthly electricity produced by the photovoltaic modules, $E_{el,PV,out}$ in kWh, is calculated as:

$$E_{el,PV,out} = \frac{P_{pk} \times E_{sol} \times f_{shading} \times f_{per}}{I_{ref}}$$

where

P_{pk} is the PV array installed peak power, in kW_p, obtained under standard test conditions¹⁹. If it is not included in the input, it is calculated as:

$$P_{pk} = K_{pk} \times A$$

where

K_{pk} is the default peak power coefficient, in kW_p/m², depending on the type of the photovoltaic modules as given in Table 32;

A is the area of the photovoltaic panels, excluding the supporting construction (without the frame), in m²;

E_{sol} is the monthly solar radiation on the PV system, in kWh/m²;

$f_{shading}$ is the over-shading factor taken from the Table 33 according to the level of over-shading of the PV array. The over-shading level refers to the percentage of the sky that is blocked by obstacles. It should be assessed taking into account the inclination of the panels;

¹⁹ Reference testing values of cell temperature $\theta=25^{\circ}\text{C}$, in plane irradiance $I_{ref}=1 \text{ kW/m}^2$, air mass solar reference spectrum AM=1.5 for a PV module or a PV cell testing – EN 6182.9

f_{per} is a system performance value taken from Table 34 according to the ventilation strategy of the PV array (definitions in Table 35);

I_{ref} is the reference solar irradiance equal to 1 kW/m².

Module type	Peak power coefficient in kW _p /m ²
Mono crystalline silicon	0.088
Multi crystalline silicon	0.080
Multi layer thin film amorphous silicon	0.035
Other thin film layers	0.018
Thin film copper-indium-gallium-diselenide	0.056
Thin film cadmium-telluride	0.049

Table 32: Default peak power coefficient, K_{pk} , (values obtained from the lower performance values for each technology as published by the Database of Photovoltaic Modules Performance Parameters produced by Sandia National Laboratories)

Level of over-shading	Mono crystalline silicon	Multi crystalline silicon	Multi layer thin film amorphous silicon	Other thin film layers	Thin film copper-indium-gallium-diselenide	Thin film cadmium-telluride
None or very little <20%	1	1	1	1	1	1
Modest [20-60%]	0.7	0.7	0.8	0.8	0.8	0.8
Significant [60-80%]	0.5	0.5	0.6	0.6	0.6	0.6
Heavy >80%	0.3	0.3	0.4	0.4	0.4	0.4

Table 33: Shading factor, $f_{shading}$, (adapted from SAP 2005 but modified to reflect different performance sensitivity to shading of different PV technologies)

Ventilation Strategy	Mono crystalline silicon	Multi crystalline silicon	Multi layer thin film amorphous silicon	Other thin film layers	Thin film copper-indium-gallium-diselenide	Thin film cadmium-telluride
Strongly ventilated or forced ventilated modules	0.80	0.80	0.80	0.80	0.80	0.80
Moderately ventilated modules	0.75	0.75	0.78	0.78	0.78	0.78
Unventilated modules	0.70	0.70	0.73	0.73	0.73	0.73

Table 34: System performance factor, f_{per} , (adapted from SAP 2005 but modified to reflect different performance sensitivity to ventilation levels of different PV technologies)

Ventilation Strategy	Definition
Strongly ventilated or forced ventilated modules	It refers to those situations where there is no thermal interaction between the PV module and the surface where it is mounted. This could apply for instance to stand-alone system mounted on a flat roof.
Moderately ventilated modules	There is an air gap between the PV module and the surface where they are mounted. This would apply to roof slope systems where a suitable air gap between the PV module and the roof has been allowed for.
Unventilated modules	There is no air gap between the PV modules and the surface where it is mounted

Table 35: PV array ventilation strategy definitions

4.10.2. Self-use & exported energy

The methodology for calculating the self-use and exported energy from PV systems follows the method outlined in the SEAI NEAP Modelling Guide (Appendix E). Self-use $E_{b,PV}$ and exported energy $E_{e,PV}$ due to PV systems are calculated according to a PV solar factor $\beta_{bt,PV,i,m}$, also known as the “beta-factor”, which is looked up from the NEAP Activity Database for a given building type bt , end use i and month m .

First, for each end use i , the proportion of solar energy available for self-use at end use i at month m is determined through multiplying the solar factor $\beta_{bt,PV,i,m}$ for building type bt by the energy demand $E_{d,i,m}$.

$$E_{d,PV,i,m} = \beta_{bt,PV,i,m} \cdot E_{d,i,m}$$

$$E_{d,PV,m} = \sum_{i=1}^6 E_{d,PV,i,m}$$

where

$E_{d,PV,m}$ is the energy demand available to be covered by generation from the PV system in month m .

The self-use factor $f_{0,m}$ is defined as the proportion of electricity generated by the PV system which is used directly in the building. This value will have an upper limit of 1.

$$f_{0,m} = \min\left(\frac{E_{d,PV,m}}{E_{el,PV,m}}, 1\right)$$

where

$f_{0,m}$ is the self-use factor, i.e. the proportion of PV systems energy generation used in the building for a system without a battery.

$E_{el,PV,m}$ is the total electricity generated by the PV system in month m .

Once the monthly self-use factors have been calculated, the monthly PV self-use $E_{b,PV,m}$ and export $E_{e,PV,m}$ are adjusted accordingly.

$$E_{b,PV,m} = f_{0,m} \cdot E_{el,PV,m}$$

$$E_{e,PV,m} = (1 - f_{0,m}) \cdot E_{el,PV,m}$$

If the building has a battery, the self-use factor is adjusted through accounting for features of the battery and the PV array. This value will also have an upper limit of 1.

$$B = \frac{Q_{battery}}{P_{pk}}$$

$$f_{B,m} = \min(f_{0,m} + (f_{max} - f_{0,m}) \cdot (1 - \exp(-kB)), 1)$$

where

$Q_{battery}$ is the capacity of the battery in kWh.

P_{pk} is the peak power of the PV array.

f_{max} is 0.95 for all building types bt .

k is 3 for all building types bt .

This leads to an adjustment in the monthly self-use and exported energy values.

$$E_{b,PV,m} = f_{B,m} \cdot E_{el,PV,out}$$

$$E_{e,PV,m} = (1 - f_{B,m}) \cdot E_{el,PV,out}$$

The annual self-used energy by PVs is calculated as:

$$E_{b,PV} = \sum_m E_{b,PV,m}$$

The annual exported energy by PVs is calculated as:

$$E_{e,PV} = \sum_m E_{e,PV,m}$$

4.11. Wind generators

The methodology followed to calculate the electricity generated by wind turbines in SBEMie 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 weather data and by applying a turbine efficiency of conversion. Correction of the wind resource due to turbine height and terrain type is allowed for.

4.11.1. Data requirements

- Terrain type: specifies the type of terrain where the wind generator is installed from smooth flat country (no obstacles) to urban with average building height bigger than 15 m, as shown in Table 36;
- 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 SBEMie purposes, this efficiency is considered to change with the monthly wind speed and turbine rated power according to Table 37.

Terrain type	K_R terrain factor	z_o roughness length (m)
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 36: Terrain categories and related parameters (CIBSE, 2002)

Product of mean monthly wind speed (m/s) and $C_R(z)$ coefficient	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 37: Wind turbine efficiencies of conversion, K_{WT}

4.11.2. Definition of algorithms

Wind turbine electricity generation

The monthly electricity produced by the wind turbine, in kWh, is calculated as:

$$E_{WT} = \frac{0.5 \times \rho \times (C_R(z) \times V_0)^3 \times A \times EPF \times K_{WT} \times 24 \times N}{1000}$$

where

ρ is the air density $\sim 1.225 \text{ kg/m}^3$;

$C_R(z)$ is the roughness coefficient at height z and is calculated as:

$$C_R(z) = K_R \times \ln\left(\frac{z}{z_0}\right)$$

where

K_R is the terrain factor (Table 36);

z_0 is the roughness length (Table 36);

z is the wind turbine hub height, in m;

V_0 is the mean monthly wind speed as derived from the hourly weather data for the location, in m/s

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

$$A = \frac{\pi \times D^2}{4}$$

where

D is the wind turbine diameter, in m;

EPF is the energy pattern factor calculated using the hourly wind speed data from the weather data set as:

$$EPF = \frac{APD}{0.5 \times \rho \times V_0^3}$$

where

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

$$APD = \left[\sum_{i=1}^{8760} (0.5 \times \rho \times V_i^3) \right] \div 8760$$

where

V_i is the wind speed at hour i , as given by the weather data, in m/s;

8760 is the number of hours in a year;

K_{WT} is the wind turbine efficiency of conversion, in %, as given in Table 37;

N is the number of days in the month.

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 such that:

$$A_{V_{AWT}} = \frac{\pi \times D_e^2}{4}$$

where

$A_{V_{AWT}}$ is the swept area of the vertical axis wind turbine, in m²;

D_e is the vertical axis wind turbine equivalent diameter used for the calculations, in m.

4.11.3. Commentary on accuracy

Wind speed used in SBEMie is taken from the IPCC Emission Scenario: High (RCP8.5), Mid sensitivity TRY Met Éireann¹⁰ data set for Dublin. Variations in the local wind resource from the one used by SBEMie 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.

4.11.4. Self-use & exported energy

The methodology for calculating the self-use and exported energy from wind turbines follows the method outlined in the SEAI NEAP Modelling Guide (Appendix E). Self-use $E_{b,WT}$ and exported energy $E_{e,WT}$ due to installed wind generators are calculated using a fixed self-use factor f_{WT} .

The monthly self-use due to the wind generator WT is calculated as:

$$E_{b,WT,m} = E_{WT,m} \cdot f_{WT}$$

where

f_{WT} is set at a constant value of 0.70 for all building types bt across all months m .

$E_{b,WT,m}$ is the energy demand in the building covered by generation from the wind turbines in month m .

$E_{WT,m}$ is the total energy generated by the wind turbines in month m .

The annual self-used energy by wind turbines is calculated as:

$$E_{b,WT} = \sum_{WT,m} E_{b,WT,m}$$

The monthly exported energy due to the wind generator WT is calculated as:

$$E_{e,WT,m} = E_{WT,m} \cdot (1 - f_{WT})$$

The annual exported energy by wind turbines is calculated as:

$$E_{e,WT} = \sum_{WT,m} E_{e,WT,m}$$

4.12. CHP generators

4.12.1. Data requirements

- Fuel type: specifies the fuel type used for the CHP generator;
- Heat seasonal efficiency: is the total useful heat supplied by the CHP plant divided by the total fuel energy input (using the gross calorific value);
- Electrical (power) seasonal efficiency: is the total electrical power generated by the CHP plant divided by the total fuel energy input (using the gross calorific value);
- Building space heating supplied: specifies the percentage of the building's space heating demand supplied by the CHP generator (if the building is served by more than one HVAC system, then the percentage supplied refers to the space heating demand of the HVAC system to which the CHP plant is connected);
- Building hot water supplied: specifies the percentage of the building's hot water demand supplied by the CHP generator (the percentage supplied refers to the hot water demand of the HWS which is served by the HVAC system to which the CHP plant is connected);
- Building space cooling supplied: specifies the percentage of the building's space cooling demand supplied by the tri-generation plant (if the building is served by more than one HVAC system, then the percentage supplied refers to the space cooling demand of the HVAC system to which the tri-generation plant is connected);
- Chiller seasonal energy efficiency ratio: is the seasonal efficiency of the heat-fired chiller (typically an absorption chiller), calculated as the ratio of the useful cooling output to the energy input over the cooling season.

Note: the CHPQA Quality index is input in SBEMie for reporting purposes only in order to inform the compliance checking process by Building Control for new builds. This value is not used in the calculations.

4.12.2. Definition of algorithms

Energy consumption by the CHP plant

Amount of monthly energy, Q , used by the CHP plant, in kWh, is calculated as:

$$Q = \frac{(H_{SH} \times p_{SH}) + \left(\frac{H_{SC} \times p_{SC}}{SEER_{SC}}\right)}{\eta_{THSH}} + \frac{(H_{HW} \times p_{HW})}{\eta_{TH}}$$

where

H_{SH} is the monthly space heating demand of the building, in kWh;

p_{SH} is the proportion (fraction) of the space heating demand supplied by the CHP plant;

H_{HW} is the monthly hot water demand of the building, in kWh;

p_{HW} is the proportion (fraction) of the hot water demand supplied by the CHP plant;

H_{SC} is the monthly space cooling demand of the building, in kWh;

p_{SC} is the proportion (fraction) of the space cooling demand supplied by the heat-fired chillers of the CHP plant;

$SEER_{SC}$ is the heat-fired chiller seasonal energy efficiency ratio of the CHP plant, taking into account any system losses associated with provision of cooling to the served spaces by the HVAC system to which the CHP is connected;

$\eta_{TH_{SH}}$ is the seasonal thermal efficiency of the CHP plant (defined as the total useful heat supplied divided by the total fuel energy input, using the gross calorific value), taking into account any system losses associated with provision of heating to the served spaces by the HVAC system to which the CHP is connected;

η_{TH} is the seasonal thermal efficiency of the CHP plant (defined as the total useful heat supplied divided by the total fuel energy input, using the gross calorific value). If the CHP provides proportions of both space heating and water heating, the thermal efficiency is reduced by 5% for the water heating calculation in order to take account of the reduction in the efficiency at part-load operation.

Electricity generated by the CHP plant

The monthly electricity, E_{CHP} , produced by the CHP plant, in kWh, is calculated as:

$$E_{CHP} = Q \times \eta_E$$

where

η_E is the seasonal electrical (power) efficiency of the CHP plant.

4.12.3. Self-use & exported energy

The methodology for calculating the self-use and exported energy from CHP generators follows the method outlined in the SEAI NEAP Modelling Guide (Appendix E). Self-use $E_{b,CHP}$ and exported energy $E_{e,CHP}$ due to an installed CHP plant are calculated as follows. First, the monthly CHP self-use factor $f_{CHP,m}$ is determined:

$$f_{CHP,m} = \begin{cases} 0.4, & \frac{E_{CHP,m}}{E_{d,m}} < 0.4 \\ \frac{E_{CHP,m}}{E_{d,m}}, & \frac{E_{CHP,m}}{E_{d,m}} \geq 0.4 \end{cases}$$

where

$E_{d,m}$ is the total energy demand from the building in month m .

$E_{CHP,m}$ is the energy produced by CHP in month m .

The monthly self-use by the CHP plant is then calculated as:

$$E_{b,CHP,m} = E_{CHP,m} \cdot f_{CHP,m}$$

The annual self-use by the CHP plant is calculated as:

$$E_{b,CHP} = \sum_m E_{b,CHP,m}$$

The monthly exported energy by the CHP plant is calculated as:

$$E_{e,CHP,m} = E_{CHP,m} \cdot (1 - f_{CHP,m})$$

The annual exported energy by the CHP plant is calculated as:

$$E_{e,CHP} = \sum_m E_{e,CHP,m}$$

4.13. Constraint condition on renewable self-use and exported energy

The methodology for constraining the renewable self-use and exported energy follows the method outlined in the SEAI NEAP Modelling Guide (Appendix E). The total monthly renewable self-use $E_{self-use,m}$ due to installed PV, wind turbines and CHP plant is constrained such that it cannot exceed total monthly demand $E_{d,m}$ in the building. The unconstrained total monthly self-use is given as:

$$E_{self-use,m} = E_{b,PV,m} + E_{b,WT,m} + E_{b,CHP,m}$$

where

$E_{b,PV,m}$ is the monthly PV self-use in month m as calculated in section 4.10.2.

$E_{b,WT,m}$ is the monthly wind self-use in month m as calculated in section 4.11.4.

$E_{b,CHP,m}$ is the monthly CHP self-use in month m as calculated in section 4.12.34.10.2.

And likewise, the total monthly exported renewable energy to the grid is given as:

$$E_{export,m} = E_{e,PV,m} + E_{e,WT,m} + E_{e,CHP,m}$$

where

$E_{e,PV,m}$ is the monthly exported energy due to PV in month m as calculated in section 4.10.2.

$E_{e,WT,m}$ is the monthly exported energy due to wind generators in month m as calculated in section 4.11.4.

$E_{e,CHP,m}$ is the monthly exported energy due to CHP in month m as calculated in section 4.12.34.10.2.

The constrained total monthly self-use $E_{c,self-use,m}$ is then determined as the minimum of $E_{self-use,m}$ and $E_{d,m}$:

$$E_{c,self-use,m} = \begin{cases} E_{self-use,m}, & E_{self-use,m} < E_{d,m} \\ E_{d,m}, & E_{self-use,m} \geq E_{d,m} \end{cases}$$

If there is any excess self-use energy this will be reallocated to the exported energy:

$$E_{c,export,m} = E_{export,m} + (E_{c,self-use,m} - E_{self-use,m})$$

where

$E_{c,export,m}$ is the constrained exported renewable energy in month m .

Additionally, a constraint factor R_c may then be derived as the ratio between constrained and unconstrained exported energy:

$$R_c = \sum_m E_{c,export,m} / E_{export,m}$$

The constraint factor can subsequently be used to obtain the effective constrained self-use and exported energy due to individual renewable sources for the purposes of compliance checking.

5. Options for interfacing to SBEMie

SBEMie requires data to be presented in a standard format through an input interface. iSBEMie (interface to SBEMie) was adapted from the UK's iSBEM interface to fulfil the role of the default interface. However, other approved interfaces to SBEMie may become available. These other interfaces are not discussed in this document.

5.1. iSBEMie

The iSBEMie input module acts as the interface between the user and the SBEMie calculation engine. The user is guided towards appropriate databases as described earlier in this document, and the input is formatted so that data is presented correctly to the calculation engine, compliance checking module, and the BER generating module.

5.1.1. Logic behind iSBEMie structure

iSBEMie is structured as a series of forms in Microsoft Access[®]. This software was chosen at the time of development as the platform for speed and convenience with programming in order to enable delivery within a limited timescale.

During the development of iSBEM and iSBEMie, BRE has had extensive experience with operating the software and explaining it to users. This has enabled them to develop a detailed user guide with terms that most potential users can understand and follow.

5.1.2. How iSBEMie collects the data for SBEMie

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 data. This structure is dealt with in full detail in the *iSBEMie User Guide*²⁰, 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

²⁰ Available from the SEAL's website.

- Construction
- Thermal bridges
- Links between elements
- Building services - setting up the systems used in the building
 - HVAC systems
 - Hot water generators including solar hot water
 - Photovoltaic systems
 - Wind generators
 - Combined heat and power
 - Lighting and its control
 - General issues relating to ventilation, power factor correction, etc.
 - Allocation of systems to each zone
- Ratings - deals with the results in terms of delivered energy consumption, primary energy consumption, CO₂ emissions, and ratings for the building
- Building Navigation – used to review entered data

Information is entered into the first four of these forms by the user, and once the building description is complete, the calculation can be run. Results are then displayed in the Ratings form.

6. References

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APPENDIX A: Guidance on HW demand calculation from data in the NEAP Activity Database

The calculation of the monthly HW demand is produced as follows:

$$HWS_i = \frac{HWS \times HP_m}{HPF}$$

where:

HWS_i is the monthly HW demand (l/m² per month i);

HWS is the nominal HW demand value for the specific activity (l/m² per day); Field 'HWS' in the 'activity' table of the NEAP Activity Database.

HP_m is the sum of the hourly values in the occupancy schedule for the specific activity for the month i ;

HPF is the factor containing the approximation of the sum of the hourly values in the occupancy schedule for the specific activity for an average weekday; Field 'HWS_HP_FACTOR' in the 'activity' table of the NEAP Activity Database.

Therefore, for hourly calculations, the hourly HWS demand could be calculated as:

$$HWS_h = \frac{HWS \times HP_h}{HPF}$$

where:

HWS_h is the hourly HW demand (l/m² per hour h);

HWS is the nominal HW demand value for the specific activity (l/m² per day); Field 'HWS' in the 'activity' table of the NEAP Activity Database.

HP_h is the activity's relevant hourly value from the occupancy schedule; Field 'hxx' from the 'daily_schedules' table for the relevant occupancy schedule of the NEAP Activity Database.

HPF is the factor containing the approximation of the sum of the hourly values in the occupancy schedule for the specific activity for an average weekday; Field 'HWS_HP_FACTOR' in the 'activity' table of the NEAP Activity Database.

APPENDIX B: **Basic Logic for Filtering Recommendations for BERs**

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

Content with a clear background describes the logic that is mandatory for the production of the formal Advisory Report in the Republic of Ireland.

Sections that have grey background are NOT a required element of the Advisory Report in the Republic of Ireland. They are used in iSBEMie 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.

B1.0 Schematic logic of filtering process

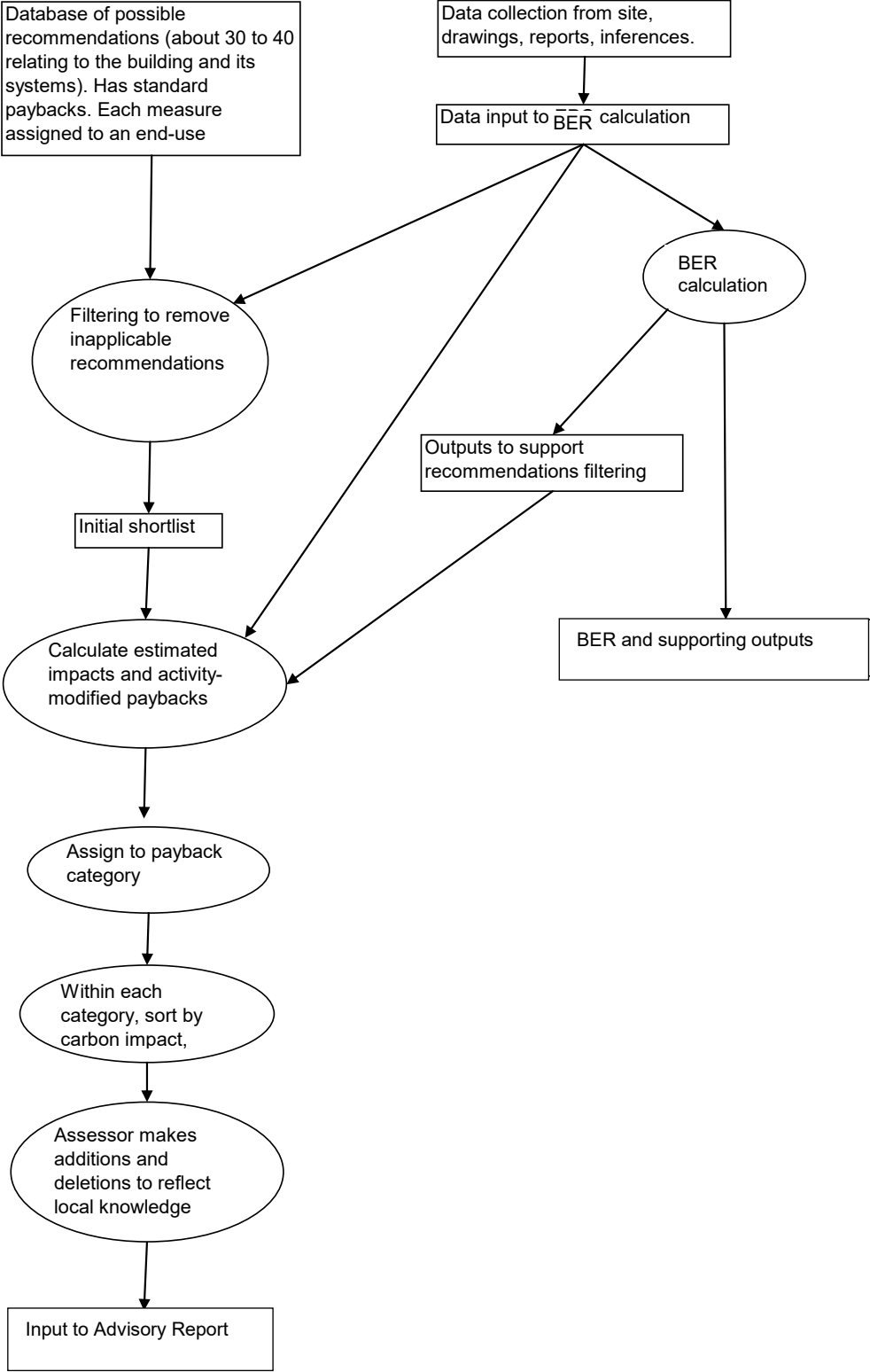


Figure 11: Schematic logic of recommendations filtering process

The initial list of potential recommendations is a subset of those collected by AECOM for use with Display Energy Certificates (DEC) in the UK. Since the BER calculation contains no information on operation or maintenance, potential recommendations relating to these

aspects of energy efficiency have been omitted. On the other hand, the more detailed information available for the calculation has, in some cases, allowed the DEC recommendations to be refined. The basic payback information has also been taken from the DEC source. To retain some consistency over as wide a range of recommendations as possible, the paybacks for office applications have been used (This application contains the largest number of recommendations). However, the paybacks are adjusted within the following logic to reflect the intensity and duration of use of the building being assessed.

The filtered and prioritised recommendations are intended to guide assessors, who have the final responsibility for them. Assessors are able to remove or add recommendations. With some software (for e.g., iSBEMie), they may also comment on recommendations and provide justification for additions and removals.

B2.0 The logic, Step by Step

Note: It is important that all default values are set (or overwritten by the assessor, either directly or via the inference procedures).

B2.1 Basic whole-building information

- From calculations already carried out for BER, record Reference building's
 - Heating kWh/m², Cooling kWh/m², Lighting kWh/m², Hot water kWh/m², Auxiliary kWh/m²
 - Heating kgCO₂/m², Cooling kgCO₂/m², Lighting kgCO₂/m², Hot water kgCO₂/m², Auxiliary kgCO₂/m²
 - Identify which of these services are actually present in the building
 - Calculate % of CO₂ emissions attributable to each end-use
- From calculations already carried out for BER, record Actual building's
 - Heating kWh/m², Cooling kWh/m², Lighting kWh/m², Hot water kWh/m², Auxiliary kWh/m²
 - Heating kgCO₂/m², Cooling kgCO₂/m², Lighting kgCO₂/m², Hot water kgCO₂/m², Auxiliary kgCO₂/m²
 - Calculate % of "energy" (price-weighted) attributable to each end-use
 - Calculate % of CO₂ emissions attributable to each end-use
- From calculations already carried out for BER, record Typical building's
 - Heating kWh/m², Cooling kWh/m², Lighting kWh/m², Hot water kWh/m², Auxiliary kWh/m²
 - Heating kgCO₂/m², Cooling kgCO₂/m², Lighting kgCO₂/m², Hot water kgCO₂/m², Auxiliary kgCO₂/m²

B2.2 Categorise end-uses as good/fair/poor

B2.2.1 Heating

- **For heating**, compare Actual kWh/m² with that for Reference and Typical
 - If **Actual < Reference**, classify heating energy efficiency as "good"
 - If **Reference ≤ Actual < Typical**, classify heating energy efficiency as "fair"
 - Otherwise, classify heating energy efficiency as "poor"

- **For heating**, compare Actual kgCO_2/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify heating CO₂ efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify heating CO₂ efficiency as “fair”
 - Otherwise, classify heating CO₂ efficiency as “poor”

B2.2.2 Cooling

- **For cooling**, compare Actual kWh/m^2 with that for Reference
 - If **Actual < 0.85 x Reference**, classify cooling energy efficiency as “good”
 - If **0.85 x Reference ≤ Actual < 1.5 x Reference**, classify cooling energy efficiency as “fair”
 - Otherwise, classify cooling energy efficiency as “poor”
- **For cooling**, compare Actual kgCO_2/m^2 with that for Reference
 - If **Actual < 0.85 x Reference**, classify cooling CO₂ efficiency as “good”
 - If **0.85 x Reference ≤ Actual < 1.5 x Reference**, classify cooling CO₂ efficiency as “fair”
 - Otherwise, classify cooling CO₂ efficiency as “poor”

B2.2.3 Lighting

- **For lighting**, compare Actual kWh/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify lighting energy efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify lighting energy efficiency as “fair”
 - Otherwise, classify lighting energy efficiency as “poor”
- **For lighting**, compare Actual kgCO_2/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify lighting CO₂ efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify lighting CO₂ efficiency as “fair”
 - Otherwise, classify lighting CO₂ efficiency as “poor”

B2.2.4 Domestic Hot Water

- **For hot water**, compare Actual kWh/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify hot water energy efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify hot water energy efficiency as “fair”
 - Otherwise, classify hot water energy efficiency as “poor”
- **For hot water**, compare Actual kgCO_2/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify hot water CO₂ efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify hot water CO₂ efficiency as “fair”
 - Otherwise, classify hot water CO₂ efficiency as “poor”

B2.2.5 Auxiliary (includes Mechanical Ventilation)

- **For Auxiliary**, compare Actual kWh/m^2 with that for Reference and Typical
 - If **Actual < Reference**, classify Auxiliary energy efficiency as “good”
 - If **Reference ≤ Actual < Typical**, classify Auxiliary energy efficiency as “fair”
 - Otherwise, classify Auxiliary energy efficiency as “poor”
- **For Auxiliary**, compare Actual kgCO_2/m^2 with that for Reference and Typical

- If **Actual < Reference**, classify Auxiliary energy efficiency as “good”
- If **Reference ≤ Actual < Typical**, classify Auxiliary energy efficiency as “fair”
- Otherwise, classify Auxiliary energy efficiency as “poor”

B2.3 Recommendation triggered by system components

Notes:

- Boiler criterion is set to 0.7 rather than 0.65 in order to classify default boilers as poor.
- “Potential impact” criteria have been pre-calculated using boiler efficiencies and rules taken from draft DEC thresholds of 4% and 0.5% of total building value.
- These are generally applied **both** at project and individual component level (there may be exceptions where only one is meaningful).
- Where recommendations are applied at project level, the assessment of impact assumes that for all systems components which trigger the recommendation, the recommendation is applied. The overall building energy (and CO₂) is then compared to the original building energy (and CO₂).

B2.3.1 Heating

B2.3.1.1 Heating efficiency

- **Check if using default heating efficiency – if yes, trigger EPC-H4**

Note: Assessing impact of recommendation **EPC-H4** is done similarly to that for recommendation **EPC-H1** shown overleaf.

- If **heat generator efficiency > 0.88**, classify heat generator efficiency as “good”.
- If **0.88 ≥ heat generator efficiency > 0.70**, classify heat generator efficiency as “fair”.
 - If fuel is gas, oil or LPG, trigger recommendation **EPC-H3** (condensing boiler)

Note: If hot water is provided by the space heating boiler, hot water is included in the energy and CO₂ proportions below.

Fuel	Price Factor (with respect to gas)
gas	1
LPG	2.74
Biogas	1.48
oil	1.72
coal	0.61
Anthracite	1.07
Smokeless fuel (inc coke)	0.61
Dual fuel appliances (mineral + wood)	1.48
biomass	1.48
electricity	3.43
Waste heat	0.2

Table 38: Fuel Price factors

- Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 38). Calculate new heating (and, if appropriate, HWS) energy as ratio between actual efficiency and **0.89**. Determine % change in total building energy.

- If **change in total energy is > 4%**, potential impact is “high”
 - If **4% ≥ change in total energy > 0.5%**, potential impact is “medium”
 - Otherwise, change in total energy potential impact is “low”
- Assess likely scale of CO₂ impact from proportion of total CO₂. Calculate new heating (and, if appropriate HWS) CO₂ emissions as ratio between actual efficiency and **0.89**. Determine % change in total building CO₂ emissions.
 - If **change in total CO₂ is > 4%**, potential impact is “high”
 - If **4% ≥ change in total CO₂ > 0.5%**, potential impact is “medium”
 - Otherwise, change in total CO₂ 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 38). Calculate new heating (and, if appropriate, HWS) energy as ratio between actual efficiency and **0.81**. Determine % change in total building energy.
 - If **change in total energy is > 4%**, potential impact is “high”
 - If **4% ≥ change in total energy > 0.5%**, potential impact is “medium”
 - Otherwise, change in total energy potential impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂. Calculate new heating (and, if appropriate HWS) CO₂ emissions as ratio between actual efficiency and **0.81**. Determine % change in total building CO₂ emissions
 - If **change in total CO₂ is > 4%**, potential impact is “high”
 - If **4% ≥ change in total CO₂ > 0.5%**, potential impact is “medium”
 - Otherwise, change in total CO₂ potential impact is “low”
- If heating fuel is electricity, and if **heat generator efficiency < 2**, trigger recommendation **EPC-R1** (consider GSHP) and **EPC-R5** (consider ASHP)

Note: the air-source’s CoP default in iSBEMie 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 38). Calculate new heating (and, if appropriate, HWS) energy as ratio between actual efficiency and **2.2**. Determine % change in total building energy
 - If **change in total energy is > 4%**, potential impact is “high”
 - If **4% ≥ change in total energy > 0.5%**, potential impact is “medium”
 - Otherwise, change in total energy potential impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂. Calculate new heating (and, if appropriate HWS) CO₂ emissions as ratio between actual efficiency and **2.2**. Determine % change in total building CO₂ emissions
 - If **change in total CO₂ is > 4%**, potential impact is “high”
 - If **4% ≥ change in total CO₂ > 0.5%**, potential impact is “medium”
 - Otherwise, change in total CO₂ 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 38). Calculate new heating (and, if appropriate, HWS) energy as ratio between actual efficiency and **3.1**. Determine % change in total building energy
 - If **change in total energy is > 4%**, potential impact is “high”

- If $4\% \geq$ change in total energy $> 0.5\%$, potential impact is “medium”
- Otherwise, change in total energy potential impact is “low”
- Assess likely scale of CO₂ impact from proportion of total CO₂. Calculate new heating (and, if appropriate, HWS) CO₂ emissions as ratio between actual efficiency and 3.1. Determine % change in total building CO₂ emissions
 - If change in total CO₂ is $> 4\%$, potential impact is “high”
 - If $4\% \geq$ change in total CO₂ $> 0.5\%$, potential impact is “medium”
 - Otherwise, change in total CO₂ potential impact is “low”

B2.3.1.2 Heating controls

- **Does the heating system have centralised time control?** If not, trigger recommendation **EPC-H2**
 - Improve heating efficiency by 1 percentage point and
 - Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 38),
 - If total energy cost for building changes $> 4\%$, impact is “high”
 - If $4\% \geq$ total energy cost for building changes $> 0.5\%$, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂
 - If total CO₂ emissions from the building change $> 4\%$, impact is “high”
 - If $4\% \geq$ total CO₂ emissions from the building change $> 0.5\%$, 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 38),
 - If total energy cost for building changes $> 4\%$, impact is “high”
 - If $4\% \geq$ total energy cost for building changes $> 0.5\%$, impact is “medium”
 - Otherwise impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂
 - If total CO₂ emissions from the building change $> 4\%$, impact is “high”
 - If $4\% \geq$ total CO₂ emissions from the building change $> 0.5\%$, 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 38),
 - If total energy cost for building changes $> 4\%$, impact is “high”
 - If $4\% \geq$ total energy cost for building changes $> 0.5\%$, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂

- If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 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 38),
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂.
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 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 38),
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂.
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”

B2.3.2 Cooling

B2.3.2.1 Cooling Efficiency

- **Check if using default cooling efficiency – if yes, trigger EPC-C1**

Note: Assessing impact of recommendation **EPC-C1** is done similarly to that for recommendation **EPC-C2** shown below.

- 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**
 - Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 38). 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 CO₂ impact from proportion of total CO₂. Calculate new cooling CO₂ emissions as ratio between actual efficiency and **2.5**. Determine % change in total building CO₂ emissions
 - If **change in total CO₂ is > 4%**, potential impact is “high”
 - If **4% ≥ change in total CO₂ > 0.5%**, potential impact is “medium”
 - Otherwise, change in total CO₂ potential impact is “low”
- If **2.0 > cold generator efficiency**, classify cold generator efficiency as “poor”
 - Trigger recommendation **EPC-C2** as above

B2.3.2.2 Duct and AHU leakage

- 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** and calculate impact
 - Reduce cooling energy by **P** where **P** is:
 - For VAV, constant volume, multizone, terminal reheat, dual duct, **P=5%**
 - For fan coil, induction, **P=2%**
 - For 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 38),
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - If **10% ≤ duct and AHU leakage**, classify duct leakage as “poor”
 - Trigger recommendation **EPC-C3** – as above, and calculate impact - this time, reducing cooling energy by **P** where **P** is:
 - For VAV, constant volume, multizone, terminal reheat, dual duct, **P=10%**
 - For fan coil, induction, **P=4%**
 - For chilled ceiling, chilled beam, **P=1%**

B2.3.3 Hot Water

B2.3.3.1 Hot water generator efficiency

- If hot water is NOT provided by the space heating heat generator
 - If **heat generator efficiency > 0.79**, classify heat generator efficiency as “good”
 - If **0.79 ≥ heat generator efficiency > 0.7**, classify heat generator efficiency as “fair”
 - And trigger recommendation **EPC-W1**

B2.3.3.3 Secondary HWS circulation

- If there is secondary HWS 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 38). Calculate reduction in hot water energy as **30% of total hot water energy**. Determine % change in total building energy
 - If **change in total energy is > 4%**, potential impact is “high”
 - If **4% ≥ change in total energy > 0.5%**, potential impact is “medium”
 - Otherwise, change in total energy potential impact is “low”
 - Assess likely scale of CO₂ impact from proportion of total CO₂. Calculate reduction in hot water emissions as **30% of total hot water energy**. Determine % change in total building CO₂ emissions
 - If **change in total CO₂ is > 4%**, potential impact is “high”
 - If **4% ≥ change in total CO₂ > 0.5%**, potential impact is “medium”
 - Otherwise, change in total CO₂ potential impact is “low”

B2.3.4 Fuel Switching

Note: The potential impact calculations are the same process for each of the fuel-switching recommendations – only the fuel CO₂ contents and prices differ.

- If coal, trigger recommendations **EPC-F2**, **EPC-F3**, and **EPC-F6**
If hot water is provided by the space heating boiler, include hot water in energy and CO₂ proportions below

- Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 38), 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 > 4%**, impact is “high”
- If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F2** from proportion of total CO₂
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 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 38), 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 > 4%**, impact is “high”
- If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F3** (from proportion of total CO₂
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”

- If $4\% \geq$ total CO₂ from the building change > 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 38), 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 > 4%, impact is “high”
- If $4\% \geq$ total energy cost for building changes > 0.5%, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F6** from proportion of total CO₂
 - If total CO₂ emissions from the building change > 4%, impact is “high”
 - If $4\% \geq$ total CO₂ emissions from the building change > 0.5%, impact is “medium”
 - Otherwise, impact is “low”

• If heating fuel is oil or LPG, trigger recommendations **EPC-F1** and **EPC-F4**
If hot water is provided by the space heating boiler, include hot water in energy and CO₂ proportions below

- Assess likely scale of energy impact from proportion of total “energy” (assumed to be price-weighted using factor from Table 38), 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 > 4%, impact is “high”
- If $4\% \geq$ total energy cost for building changes > 0.5%, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F1** from proportion of total CO₂
 - If total CO₂ emissions from the building change > 4%, impact is “high”
 - If $4\% \geq$ total CO₂ emissions from the building change > 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 38), 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 > 4%, impact is “high”
- If $4\% \geq$ total energy cost for building changes > 0.5%, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F4** from proportion of total CO₂
 - If total CO₂ emissions from the building change > 4%, impact is “high”
 - If $4\% \geq$ total CO₂ emissions from the building change > 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 38), 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 > 4%**, impact is “high”
- If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
- Otherwise, impact is “low”
- Assess likely scale of CO₂ impact for **EPC-F5** from proportion of total CO₂
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”

B2.3.5 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
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely impact on CO₂
 - Impact is assessed by **changing all T12 lamps to T8 lamps** and assessing the % change in CO₂ for the project
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
- 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
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely impact on CO₂
 - Impact is assessed by **changing all T8 lamps to T5 lamps** and assessing the % change in CO₂ for the project
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”

- If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
- Check whether any spaces have **GLS lamps**
 - If they do, trigger recommendations **EPC-L2**
 - Assess likely impact on energy (assumed price weighted)
 - Impact is assessed by **changing all GLS lamps to CFL** and assessing the % change in energy for the project
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely impact on CO₂
 - Impact is assessed by **changing all GLS lamps to CFL** and assessing the % change in CO₂ for the project
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
- 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
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
 - Assess likely impact on CO₂
 - Impact is assessed by **changing all T8 lamps with mains frequency ballast to T8 lamps with high frequency ballast** and assessing the % change in CO₂ for the project
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”
- 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.*
 - If **total energy cost for building changes > 4%**, impact is “high”
 - If **4% ≥ total energy cost for building changes > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”

- Assess likely impact on CO₂
 - Impact is assessed by **changing all HP mercury to SON replacements (HP sodium)** and assessing the % change in CO₂ for the project. *Note that the paybacks will be different for EPC-L3 and EPC-L6 although the CO₂ impact will be the same.*
 - If **total CO₂ emissions from the building change > 4%**, impact is “high”
 - If **4% ≥ total CO₂ emissions from the building change > 0.5%**, impact is “medium”
 - Otherwise, impact is “low”

B2.3.6 Renewables

- Is a wind turbine installed? If not, trigger recommendation **EPC-R2**
 - Energy impact is (currently always) low
 - CO₂ impact is (currently always) low
- Is solar thermal water heating installed? If not, trigger recommendation **EPC-R3**
 - Energy impact is (currently always) low
 - CO₂ impact is (currently always) low
- Is a photovoltaic system installed? If not, trigger recommendation **EPC-R4**
 - Energy impact is (currently always) low
 - CO₂ impact is (currently always) low

Note: Ideally, we need a proper calculation to estimate impact, but, generally, the absolute impacts are likely to be low. The assessor can over-write this if the building merits special consideration.

B2.3.7 Envelope

Note: For envelope (and lighting) recommendations, guidance on impact is often very general. We can improve this in future - maybe looking at the gain/loss ratio, etc.

Scale of Potential Impact			
Proportion of total energy or CO ₂ accounted for by end-use	Overall consumption for end-use		
	<i>Good efficiency</i>	<i>Fair efficiency</i>	<i>Poor efficiency</i>
<i>20% + energy or CO₂</i>	Medium	Medium	High
<i>5% to 20% energy or CO₂</i>	Low	Medium	High
<i>5% - energy or CO₂</i>	Low	Low	Medium

Table 39: Scale of potential impact

Roofs

For pitched roofs with lofts

- If any have **U-value > 1.0**, trigger recommendation **EPC-E6**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

For flat roofs

- If any have **U-value > 1.0**, trigger recommendation **EPC-E2**

- Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
- Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

Walls

For solid walls

- If any have **U-value > 1.0**, trigger recommendation **EPC-E3**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

For cavity walls

- If any have **U-value > 1.0**, trigger recommendation **EPC-E4**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

Glazing

For all glazing

- If any have **U-value > 3.5** (assumed single glazed), trigger recommendation **EPC-E5**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂
- And trigger recommendation **EPC-E8**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

Floors

- If any have **U-value > 1.0**, trigger recommendation **EPC-E1**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

Airtightness

- If **permeability > 14**, trigger recommendation **EPC-E7**
 - Assess likely impact on energy (assumed price weighted)
 - Use Table 39 applied to heating energy
 - Assess likely impact on CO₂
 - Use Table 39 applied to heating CO₂

Overheating

- **Check whether any space in the building overheats**

This is done by assessing if the solar gain limit defined in the NEAP is exceeded in any zone in the building

 - If yes, trigger recommendation **EPC-V1**
 - Energy impact is (currently always) medium
 - CO₂ impact is (currently always) medium

B2.4 Next step: “Triggered” recommendations now need prioritising

To calculate **PAYBACK** for each recommendation, adjust standard paybacks (from Table 42) 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 x REFERENCE** building cooling consumption (kWh/m².year)
- **For cooling measures relating to mechanical ventilation**
 - Multiply payback by **60** and divide by **REFERENCE** building auxiliary energy consumption (kWh/m².year)
- **For hot water measures**
 - Multiply payback by **10** and divide by **REFERENCE** building hot water energy consumption (kWh/m².year)

Note: Standard paybacks are for offices and are derived by AECOM from an analysis of reported (expected) paybacks by CT surveys (in this case, in offices). (These surveys presumably are mostly in larger buildings). The adjustment scales the payback according to the ratio of typical building consumption to ECG 019⁵ (average of types 1 and 2, except cooling type 3). (Note: need to choose suitable air-con adjustment). Actual values are of secondary importance as the results are primarily used to rank measures.

B2.5 Calculate supporting information

To calculate **EURO 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 40.

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 40: 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 CO₂ content of different fuels by multiplying the financial payback by the relative CO₂ 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 EURO PER CARBON SAVING value calculated above by relevant value from Table 41.

To	From									
	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 41: Fuel switching recommendations adjustment to calculate EURO 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 < 3 years**
 - Sort these by decreasing magnitude of CO₂ saving
 - If there are more than **15**, select the first **15**
 - These are the “recommendations with a **short** payback”
- Select all recommendations with **3 ≤ payback < 7 years**
 - Sort these by decreasing magnitude of CO₂ saving
 - If there are more than **10**, select the first **10**
 - These are the “recommendations with a **medium** payback”
- Select all recommendations with **payback ≥ 7 years**
 - Sort these by decreasing magnitude of CO₂ 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 CO₂ saving
 - If there are more than **10**, select the first **10**
 - These are the “other recommendations”

B3.0 Some caveats

These recommendations have been generated for the building and its energy systems operated according to standard schedules that are appropriate to the general activities in the building. The assessor should use their 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 Building Energy 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 CO₂ savings in these areas, and a full “energy audit” to identify them is strongly recommended.

B5.0 Working list of BER recommendations

CODE	DESCRIPTION	CATEGORY	PAYBACK Currently using an average of FAIR and POOR values
EPC-C1	default chiller efficiency	COOLING	3
EPC-C2	install high efficiency chiller	COOLING	3.5
EPC-C3	Inspect and seal ductwork	COOLING	7.5
EPC-W1	High efficiency water heater	HOT-WATER	4.15
EPC-W3	DHW storage insulation	HOT-WATER	3.8
EPC-W4	DHW secondary circulation time control	HOT-WATER	4.5
EPC-W2	DHW point of use system	HOT-WATER	8
EPC-E1	insulate floor	ENVELOPE	15
EPC-E2	insulate roof	ENVELOPE	25
EPC-E3	insulate solid walls	ENVELOPE	6.5
EPC-E4	cavity wall insulation	ENVELOPE	3.7
EPC-E5	secondary glazing	ENVELOPE	4.6
EPC-E6	insulate loft	ENVELOPE	5.6
EPC-E7	pressure test	ENVELOPE	7
EPC-E8	improve glazing	ENVELOPE	9.3
EPC-F1	Oil or LPG to natural gas (heating)	FUEL-SWITCHING	1.08
EPC-F2	Coal to natural gas (heating)	FUEL-SWITCHING	3.75
EPC-F3	Coal to biomass (heating)	FUEL-SWITCHING	3.81
EPC-F4	Oil or LPG to biomass (heating)	FUEL-SWITCHING	6.7
EPC-F5	gas to biomass (heating)	FUEL-SWITCHING	6.72
EPC-F6	Coal to oil (heating)	FUEL-SWITCHING	8.4
EPC-H2	heating central time control	HEATING	1.8
EPC-H5	local time control	HEATING	5.8
EPC-H6	Room temperature control	HEATING	4.8
EPC-H7	Heating optimum start and stop control	HEATING	2.5
EPC-H8	heating weather compensation controls	HEATING	5
EPC-H1	install high efficiency boiler	HEATING	2.3
EPC-H3	install condensing boiler	HEATING	6.6
EPC-H4	default heat generator efficiency	HEATING	3
EPC-L1	T12 to T8	LIGHTING	0.6
EPC-L2	GLS to CFL	LIGHTING	0.85
EPC-L3	HP mercury to SON replacements	LIGHTING	1.8
EPC-L5	T8 to T5	LIGHTING	2.8
EPC-L6	HP mercury to SON	LIGHTING	3.5
EPC-L7	Mains to HF ballast	LIGHTING	5.7
EPC-V1	overheating	OVERHEATING	1.7
EPC-R1	consider GSHP	RENEWABLES	11.7
EPC-R2	install wind turbine	RENEWABLES	15.9
EPC-R3	install solar thermal water heating	RENEWABLES	20.2
EPC-R4	install PV system	RENEWABLES	44.7
EPC-R5	consider ASHP	RENEWABLES	9.8

Table 42: Working list of BER recommendations

CODE	TEXT
EPC-C1	The default chiller 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.
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.
EPC-F1	Consider switching from oil or LPG to natural gas
EPC-F2	Consider converting the existing boiler from coal to natural gas
EPC-F3	Consider switching from coal to biomass
EPC-F4	Consider switching from oil or LPG to biomass
EPC-F5	Consider switching from gas to biomass
EPC-F6	Consider switching from coal to oil
EPC-H2	Add time control to heating system
EPC-H5	Add local time control to heating system
EPC-H6	Add local temperature control to the heating system
EPC-H7	Add optimum start/stop to the heating system
EPC-H8	Add weather compensation controls to heating system
EPC-H1	Consider replacing heating boiler plant with high efficiency type
EPC-H3	Consider replacing heating boiler plant with a condensing type
EPC-H4	The default heat generator efficiency is chosen. It is recommended that the heat generator system be investigated to gain an understanding of its efficiency and possible improvements.
EPC-L1	Replace 38mm diameter (T12) fluorescent tubes on failure with 26mm (T8) tubes
EPC-L2	Replace tungsten GLS lamps with CFLs: Payback period dependent on hours of use
EPC-L3	Replace high-pressure mercury discharge lamps with plug-in SON replacements
EPC-L5	Consider replacing T8 lamps with retrofit T5 conversion kit.
EPC-L6	Replace high-pressure mercury discharge lamps with complete new lamp/gear SON (DL)
EPC-L7	Introduce HF (high frequency) ballasts for fluorescent tubes: Reduced number of fittings required
EPC-V1	In some spaces, the solar gain limit defined in the NEAP is exceeded, which might cause overheating. Consider solar control measures such as the application of reflective coating or shading devices to windows.
EPC-R1	Consider installing a ground source heat pump
EPC-R2	Consider installing building mounted wind turbine(s)
EPC-R3	Consider installing solar water heating
EPC-R4	Consider installing PV
EPC-R5	Consider installing an air source heat pump

Table 43: Text for BER recommendations