

**SAP 10.0**

# **The Government's Standard Assessment Procedure for Energy Rating of Dwellings**

**Version 10.0**

**This version is not currently to be used for any official purpose**

**SAP 2012 should continue to be used for Building Regulations compliance and the production of EPCs until further notice**

This document describes SAP version 10.0 (24-07-2018). Information relating to this version of SAP and any updates will be published on the website below.

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## SUMMARY

This manual describes the Government's Standard Assessment Procedure (SAP) for assessing the energy performance of dwellings. The indicators of energy performance are Fabric Energy Efficiency (FEE), energy consumption per unit floor area, energy cost rating (the SAP rating), Environmental Impact rating based on CO<sub>2</sub> emissions (the EI rating) and Dwelling CO<sub>2</sub> Emission Rate (DER).

The SAP rating is based on the energy costs associated with space heating, water heating, ventilation and lighting, less cost savings from energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The SAP rating is expressed on a scale of 1 to 100, the higher the number the lower the running costs. The rating can exceed 100 if renewable generation technologies are used.

The Environmental Impact rating is based on the annual CO<sub>2</sub> emissions associated with space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The Environmental Impact rating is expressed on a scale of 1 to 100, the higher the number the better the standard. The rating can exceed 100 if renewable generation technologies are used.

The Dwelling CO<sub>2</sub> Emission Rate is a similar indicator to the Environmental Impact rating, which is used for the purposes of compliance with Building Regulations. It is equal to the annual CO<sub>2</sub> emissions per unit floor area for space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies, expressed in kg/m<sup>2</sup>/year.

The method of calculating the energy performance and the ratings is set out in the form of a worksheet, accompanied by a series of tables. The methodology is compliant with the recast Energy Performance of Buildings Directive (2012/31/EU). The calculation should be carried out using a computer program that implements the worksheet and is approved for SAP calculations. BRE approves SAP software used within schemes recognised by government on behalf of the Department for Energy and Climate Change, the Department for Communities and Local Government, the Scottish Government, the Welsh Government, and the Department of Finance and Personnel for Northern Ireland.

## INTRODUCTION

The Standard Assessment Procedure (SAP) is adopted by Government as the UK methodology for calculating the energy performance of dwellings.

The calculation is based on the energy balance taking into account a range of factors that contribute to energy efficiency:

- materials used for construction of the dwelling
- thermal insulation of the building fabric
- air leakage ventilation characteristics of the dwelling, and ventilation equipment
- efficiency and control of the heating system(s)
- solar gains through openings of the dwelling
- the fuel used to provide space and water heating, ventilation and lighting
- energy for space cooling, if applicable
- renewable energy technologies

The calculation is independent of factors related to the individual characteristics of the household occupying the dwelling when the rating is calculated, for example:

- household size and composition;
- ownership and efficiency of particular domestic electrical appliances;
- individual heating patterns and temperatures.

The procedure used for the calculation is based on the BRE Domestic Energy Model (BREDEM<sup>[1,2,3,4,5]</sup>), which provides a framework for the calculation of energy use in dwellings. The procedure is consistent with the standard BS EN ISO 13790.

The Standard Assessment Procedure was first published by the then DOE and BRE in 1993 and in amended form in 1994, and conventions to be used with it were published in 1996 and amended in 1997. Revised versions were published in 1998, 2001, 2005, 2009 and 2012.

The present edition is SAP 10.0; significant changes since the previous version include:

- fuel prices, CO<sub>2</sub> emissions and primary energy factors have been updated
- the calculation of hot water consumption has been adjusted to take account of shower type
- the calculation of lighting energy has been updated to allow for new lighting technologies
- the treatment of distribution loss factors associated with communal heating networks has been revised
- the air flow rates associated with chimneys and flues have been updated
- the assessment of summer internal temperatures has been refined
- the treatment of mechanical ventilation system heat recovery and aerodynamic performance has been revised
- additional flow temperature options have been provided for heat pumps and condensing boilers
- the self-use factor for electricity generated by Photovoltaic (PV) systems has been revised and now allows for the effects of battery storage
- the ability to include solar thermal space heating has been added
- the assumed standard heating pattern has been adjusted

The effect of feed-in tariffs for electricity generated by renewables is not included in SAP calculations.

## **SCOPE OF THE SAP PROCEDURE**

The procedure is applicable to self-contained dwellings (of any size and any age).

For flats, it applies to the individual flat and does not include common areas such as access corridors.

*Note: Common areas of blocks of flats such as heated access corridors, and other buildings (even though used for residential purposes, e.g. nursing homes) are assessed using procedures for non-domestic buildings.*

Where part of an accommodation unit is used for commercial purposes (e.g. as an office or shop), this part should be included as part of the dwelling if the commercial part could revert to domestic use on a change of occupancy. That would be applicable where:

- there is direct access between the commercial part and the remainder of the accommodation, and
- all is contained within the same thermal envelope, and
- the living accommodation occupies a substantial proportion of the whole accommodation unit.

Where a self-contained dwelling is part of a substantially larger building, and the remainder of the building would not be expected to revert to domestic use, the dwelling is assessed by SAP and the remainder by procedures for non-domestic buildings.

SAP is a methodology for calculating energy use and the associated running costs and CO<sub>2</sub> emissions. It does not set any standards or limitations on data.

For SAP calculations dwellings have a standard occupancy and usage pattern, which are typical values of quantities that in practice vary substantially between dwellings of similar size and type. The occupancy assumed for SAP calculations is not suitable for design purposes, for example of hot water systems.

## **GENERAL PRINCIPLES**

### **Input precision and rounding**

Data should be entered into calculation software as accurately as possible, although it is unnecessary to go beyond 3 significant figures (and some product data may only be available to lesser precision).

### **Input data**

Various tables of performance data are provided as part of this document. The tables are used when specific performance information on the product or system is not available. However, when specific performance information is available for the following items, it should be used in preference to data from the tables, particularly in the new build context.

A set of conventions is published separately at: <https://bregroup.com/sap/sap10> which should be used in conjunction with this document in connection with data acquisition and assembly for input to a SAP calculation. The conventions are updated from time to time so it is important to ensure the latest version is used.

#### U-values – walls, floors, roofs

For new build, U-values should be calculated based on the actual construction. U-values for assessing existing homes are discussed below.

#### Thermal mass

The Thermal Mass Parameter (TMP) is required for heating and cooling calculations. It is defined as the sum of (area times heat capacity) over all construction elements divided by total floor area. It can be obtained from the actual construction elements of walls, floors and roofs (including party and internal walls, floors and ceilings). For further details see Table 1e.

#### Linear thermal transmittance ( $\Psi$ -values)

$\Psi$ -values are used for thermal bridging. There are three possibilities.

- a) The use of a global factor, which is multiplied by the total exposed surface area, as described in Appendix K.
- b) On the basis of the length of each junction and the default  $\Psi$ -values in Table K1.
- c) On the basis of the length of each junction and user-supplied  $\Psi$ -values. It is not necessary to supply  $\Psi$ -value for each junction type – default values from Table K1 can be mixed with user-supplied values.

#### Window data

Window U-values and g-values (total solar energy transmittance) can be from a certified window energy rating or manufacturers' declaration. Both values are needed (for the calculation of respectively heat loss and solar gain). Default values from Table 6e may be used where this data is unavailable.

Values of light transmittance ( $g_L$ ) are given in Table 6b for calculation of lighting energy requirements as set out in Appendix L.

For new dwellings and other cases where solar gain provides a significant part of heating requirements the frame factor (representing the glazed fraction of the window) is important in determining solar gain, so actual values should be used wherever possible. Frame factors should be assigned per window (or per group of similar windows) particularly where window areas differ on different facades on the dwelling. Default values are given in Table 6c.

#### Boiler efficiency – gas, oil and solid fuel

Efficiency values should be taken from the Product Characteristics Database<sup>1</sup> (PCDB) wherever possible, and in preference to the default figures provided in Tables 4a and 4b.

#### Warm air heating systems (not heat pumps)

Efficiency values should be taken from the PCDB wherever possible, and in preference to the default figures provided in Table 4a.

#### Heat pumps

Efficiency values should be taken from the PCDB wherever possible, and in preference to the default figures provided in Table 4a.

#### Heat networks

Data for heat networks can be obtained from the PCDB and applied via the procedures in Appendix C. Default figures from Table 4a and Appendix C should be used if PCDB data is unavailable.

#### Efficiency of gas/oil/solid fuel fires and room heaters

Efficiency can be from a manufacturer's declaration as described in Appendix E, section E2. Otherwise, a default figure from Table 4a should be used.

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<sup>1</sup> <http://www.ncm-pcdb.org.uk>

Standing loss – cylinders, thermal stores and CPSUs (includes both gas and electric CPSUs)

The manufacturer's declared loss, obtained in terms of the applicable British Standard and expressed in kWh/day, should be used in preference to default data from Table 2. (Tables 2a and 2b are applied to declared loss as well as to loss from Table 2). Note: The presence of heat pump buffer vessels is ignored, even if installed outside the heated envelope. SAP assumes that the specification of these will require an improvement in heat pump performance at least equal to the standing loss from the buffer vessel.

Pressure test result

The result of a pressure test, where available, is used instead of the default calculations of air infiltration. In the case of a dwelling not yet built, a design value of air permeability can be used subject to the requirements of Building Regulations that apply in the administration where the dwelling will be constructed.

Solar collector performance

The zero-loss collector efficiency and the collector's heat loss coefficients can be used if obtained from test results. If unavailable, default values are provided in Table H1.

Specific fan power and ventilation heat exchanger efficiency

Measured values of specific fan power for these mechanical ventilation systems:

- positive input ventilation from outside (not loft)
- mechanical extract
- balanced supply and extract

and of heat exchanger efficiency for MVHR systems, should be used in place of the default values in Table 4g for those systems that are listed in the PCDB.

**Existing dwellings**

The SAP calculation procedure for existing dwellings follows that for new dwellings. However, some of the data items are usually defaulted or inferred. For further details see Appendix S of SAP 2012 (version 9.93, November 2017). An updated version of Appendix S will be added to this document in a future update.

The calculation is concerned with the assessment of the dwelling itself, as used by standard or typical occupants, and not affected by the way current occupants might use it. Thus, for example, the living area is based on the original design concept and not on the rooms the current occupants heat.

## CALCULATION PROCEDURE AND CONVENTIONS

The method of calculating the energy performance is set out in the form of a worksheet, accompanied by a series of tables. A calculation should follow the numbered entries in the worksheet sequentially. Some entries are obtained by carrying forward earlier entries, other entries are obtained by reference to Tables 1 to 14 or from user-supplied data. The following notes on calculations and conventions should be read in conjunction with the worksheet.

The worksheet is intended as a form of describing the calculation, to be used for implementing the calculation into computer software, rather than for manual calculations.

### 1 DWELLING DIMENSIONS

The boundary of the heated space consists of all the building elements separating it from external environment or from adjacent dwellings or unheated spaces. Any internal elements (internal partition walls or intermediate floors within the dwelling) are disregarded for the purposes of establishing areas.

**Dimensions** refer to the inner surfaces of the elements bounding the dwelling. Thus floor dimensions are obtained by measuring between the inner surfaces of the external or party walls, disregarding the presence of any internal walls.

**Storey height** is the total height between the ceiling surface of a given storey and the ceiling surface of the storey below. For a single storey dwelling (including a single storey flat), or the lowest floor of a dwelling with more than one storey, the measurement should be from floor surface to ceiling surface. However any suspended ceiling should be disregarded. Where the room height varies, such as in a room-in-roof, the



storey height should be an average based on the volume of the space and the internal floor area (plus the thickness of the floor if it is the upper storey of a house).

**Floor area** should be measured as the actual floor area, i.e. if the height of a room extends to two storeys or more only the actual accessible floor area should be used for the calculations. However, as an exception to this rule in the case of stairs, the floor area should be measured as if there were no stairs but a floor in their place at each level.

In general, rooms and other spaces, such as built-in cupboards, should be included in the calculation of the floor area where these are directly accessible from the occupied area of the dwelling. However unheated spaces clearly divided from the dwelling should not be included. The following provides specific guidance:

**Porches:**

- *should be included* if heated by fixed heating devices;
- *should not be included* if unheated and external. In this context 'external' means an addition protruding from the line of the external wall of the dwelling;
- *should not be included* if unheated and thermally separated from the dwelling.

**Conservatories:**

- *should not be included* if they are separated from the dwelling according to the definition in 3.3.3
- *should be included* as part of the dwelling if they are not separated.

**Store rooms and utility rooms:**

- *should be included* if they are directly accessible from the occupied area of the dwelling, whether heated or not;
- *should not be included* if they are unheated and accessible only via a separate external door.

**Basements:**

- *should be included* if accessed via a permanent fixed staircase and either:-
  - basement is heated via fixed heat emitters, or
  - basement is open to the rest of the dwelling..

**Garages:**

- *should be included* if heating is provided within the garage from the main central heating system;
- *should not be included* where the garage is thermally separated from the dwelling and is not heated by the central heating system

**Attics:**

- *should be included* if accessed by a fixed staircase.

When porches or integral garages are not included in floor area, the door and part of the wall between the dwelling and these structures are adjacent to an unheated space and their U-values should be adjusted where appropriate (see section 3.3).

In flats, if corridors and stairwells are heated, treat walls between the flat and heated corridors/stairwells as party walls (see section 3.3).

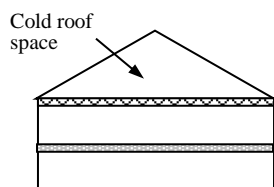
No special treatment of a dwelling's dimensions should be given in cases where a central heating boiler is located in an unheated garage or attic (i.e. the floor area used for the assessment should be the same as if the boiler were in the kitchen or a utility room).

For existing dwellings see additional guidance in Appendix S.

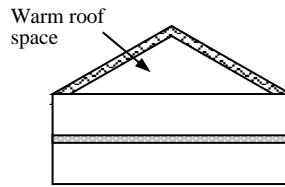
**Pitched roofs**

There are three main types of pitched roof construction:

1. pitched roof with insulation at ceiling level, insulated between (and perhaps also above) joists, diagram a);
2. pitched roof insulated at rafter level (no insulation at ceiling level), insulated between and/or above rafters (“warm roof”), with a non-ventilated loft space but with a ventilated space between the insulation and the roof covering, diagram b);
3. pitched roof insulated either at ceiling level or at rafter level, with roof space converted into habitable space, diagrams c) and d).

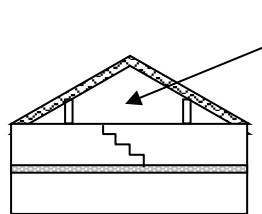


a) Insulation at ceiling level

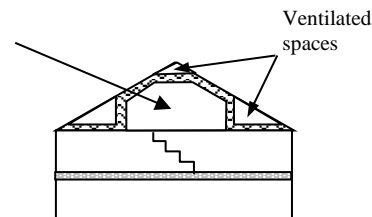


b) Insulation at rafter level

In the cases of a) and b) the roof space should **not** be treated as a separate storey.



c) Room in roof built into a pitched roof insulated at rafter level



d) Room in roof built into a pitched roof insulated at ceiling level

In the cases of c) and d) the floor area of the roof space that is converted into habitable space should be treated as a separate storey.

## 2 VENTILATION RATE

The ventilation air change rate is the rate at which outside air enters/leaves a building.

SAP requires a reasonable estimate of the air change rate in order to calculate the overall heating requirement. The actual ventilation rate depends on a large number of factors, many of which may not be known precisely (e.g. permeability of materials and inadvertent gaps and openings in the structure) and in most cases cannot be assessed from a site survey or from plans.

The infiltration rate can be assessed either from a pressurisation test or, in the absence of pressure test, using the SAP algorithm as defined by (9) to (16) of the worksheet.

Whether or not a pressurisation test has been carried out, the ventilation calculation requires information on chimneys, fans, open flues and passive vents. Chimneys, fans, open flues and passive vents (blocked off during a pressurisation test but open in practice) should be counted in (6a) to (7c) of the worksheet.

Ventilation rates for chimneys, flues, fans and passive vents, flueless gas fires and passive stack ventilators are given in Table 2.1 below.

**Table 2.1 Ventilation rates**

Item	Ventilation rate m <sup>3</sup> /hour
Chimney or open flue attached to closed fire (stove)	10
Chimney or open flue attached to solid fuel boiler	20
Chimney or flue attached to other heater	35
Open chimney	80
Chimney, permanently blocked <sup>1</sup>	20
Open flue/vertical duct with diameter < 200mm	20
Intermittent extract fan	10
Passive vent	10
Flueless gas fire	40

<sup>1</sup> if ventilator area does not exceed 30 000 mm<sup>2</sup>, otherwise treat as open chimney.

[Work to refine the values in Table 2.1 is ongoing, so values may be updated in future.]

## 2.1 Chimneys and flues

For the purposes of SAP a chimney is defined as a vertical duct for combustion gases of diameter 200 mm or more (or a rectangular duct of equivalent size). Vertical ducts with diameter less than 200 mm should be counted as flues.

Ventilation rates should be included only for open flues which take air from the room; they should not be included for room-sealed boilers which take air directly from the outside.

## 2.2 Fans and passive vents

**Intermittent-running extract fans** which exhaust air (typically from the kitchen and bathroom), including cooker hoods and other independent extractor fans, should be included in the 'number of fans' category. For continuously running fans see section 2.6.

**Passive stack ventilators** (passive vents) are an alternative to extract fans. Such systems comprise extract grilles connected to ridge terminals by ducts. Such systems should be supplied with air bricks or trickle vents for air ingress. It is the number of extract grilles that should be used in the calculation.

**Trickle vents or air bricks** alone do not count as passive vents and should not be included in the calculation.

## 2.3 Pressurisation test

A pressurisation test of a dwelling is carried out by installing a fan in the doorway of the principal entrance to the dwelling, sealing all flues and chimneys, and determining the air flow rate required to maintain an excess pressure of 50 pascals (Pa). The pressurisation test should be carried out in accordance with BS EN 13829. The air permeability measured in this way,  $q_{50}$ , expressed in cubic metres per hour per square metre of envelope area is divided by 20 for use in the worksheet (to give an estimate of the air change rate at typical pressure differences). In this case (9) to (16) of the worksheet are not used.

## 2.4 Draught lobby

A draught lobby is an arrangement of two doors that forms an airlock on the main entrance to the dwelling. To be included, the enclosed space should be at least 2 m<sup>2</sup> (floor area), it should open into a circulation area, and the door arrangement should be such that a person with a push-chair or similar is able to close the outer door before opening the inner door. It may be heated or unheated and may provide access to a cloakroom (but it should not be counted as a draught lobby if it provides access to other parts of the dwelling).

A draught lobby should only be specified if there is a draught lobby to the main entrance of the dwelling. If the main entrance has no draught lobby but, for example, a back door does, then no draught lobby should be specified.

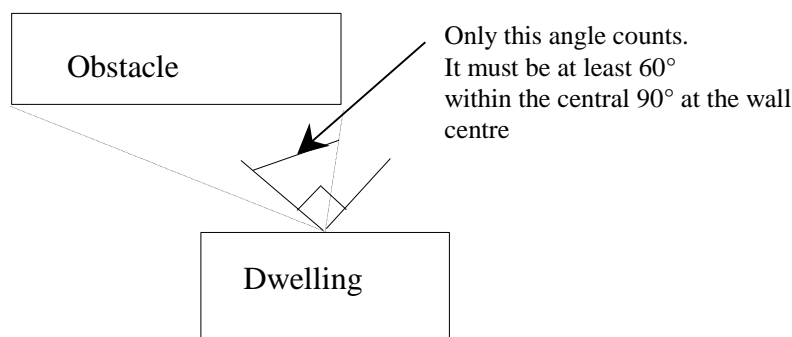
An unheated draught lobby in the form of an external porch should not be counted as part of the area of the dwelling. However, the door between the dwelling and the porch is a 'semi-exposed' element and its U-value should be calculated accordingly (see section 3.3).

Flats with access via an unheated stairwell or corridor should be classified as having a draught lobby.

## 2.5 Sheltered Sides

A side of a building is sheltered if there are adjacent buildings or tree-height hedges which effectively obstruct the wind on that side of the building. A side should be considered sheltered if all the following apply:

- the obstacle providing the shelter is at least as high as the ceiling of the uppermost storey of the dwelling;
- the distance between the obstacle and the dwelling is less than five times the height of the obstacle;
- the width of the obstacle (or the combined width of several obstacles) is such that it subtends an angle of at least  $60^\circ$  within the central  $90^\circ$  when viewed from the middle of the wall of the dwelling that faces the obstacle - see Figure 1



**Figure 1 Shelter angle**

Two partially sheltered sides should be counted as one sheltered side. Architectural planting does not count as shelter unless it actually exists (even though shown as mature trees on drawings).

A party wall extending the whole width of the dwelling should be counted as a sheltered side. For staggered arrangements use the  $60^\circ$  rule above.

## 2.6 Mechanical ventilation

Mechanical ventilation systems use continually running fans. They can be input-only, extract-only or balanced (input and extract).

### 2.6.1 Mechanical ventilation systems

#### (a) Positive input ventilation (PIV)

Positive input ventilation is a fan driven ventilation system, which may provide ventilation to the dwelling directly from the outside or from the loft space. In either case, the SAP calculation requires a minimum of two intermittent extract fans to be entered by the SAP assessor ( $20\text{m}^3/\text{h}$  ventilation rate).

Where positive input ventilation sources input air from the loft, the SAP calculation procedure is the same as for natural ventilation, except that the energy used by the PIV fan is taken as zero and counterbalanced by the effect of slightly warmer air from the loft space compared with outside air.

For positive input ventilation systems supplying air directly from the outside, the procedure for these systems is the same as for mechanical extract ventilation.

#### (b) Mechanical extract ventilation (MEV)

MEV is a fan driven ventilation system, which only extracts air from the dwelling. The SAP calculation is based on a throughput of 0.5 air changes per hour through the mechanical system.

MEV can be either:

- centralised: air is extracted from wet rooms via ducting and expelled by means of a central fan, or
- decentralised: air is extracted by continuously-running fans in each wet room.

### **(c) Balanced whole house mechanical ventilation**

Balanced ventilation provides fresh air to habitable rooms in the dwelling and extracts exhaust air from wet rooms.

A balanced system without heat recovery extracts air from wet rooms via ducting and expels it via a central fan. Air is also supplied to habitable rooms, either via ducting and a central fan or by individual supply air fans in each habitable room. The SAP calculation is based on a throughput of 0.5 air changes per hour through the mechanical system, plus infiltration.

In a balanced system with heat recovery (MVHR) both the extract and supply air are provided via ducting, with a heat exchanger between the outgoing and incoming air.

#### **2.6.2 Data required**

Centralised MEV: The system's Specific Fan Power (SFP) and whether the ducting is rigid or flexible.

Decentralised MEV: SFP of each fan together with the fan's ducting arrangements (the fan can be in the ceiling of the room with a duct to the outside, or in a duct, or in a through-wall arrangement with no duct).

Balanced mechanical ventilation without heat recovery. SFP taking account of all fans and whether the ducting is rigid or flexible.

MVHR. SFP is a single value for the system (depending on the number of wet rooms); the thermal efficiency of the system is affected by the ducting being either rigid or flexible and the thickness of duct insulation, if present.

For systems that have been tested according to the SAP test procedures for mechanical ventilation systems (details at [www.ncm-pcdb.org.uk](http://www.ncm-pcdb.org.uk)) the tested data from the Product Characteristics Database should be used for the calculations provided that in the case of as-built assessments of new dwellings the SAP assessor has been provided with a completed "Inspection checklist and air flow measurement test sheet" from the Building Regulation Domestic Ventilation Compliance Guide. Otherwise the default data in Table 4g is used. In the special case of SFP for MVHR systems, the SFP measured in-situ can be entered by the SAP assessor, subject to suitable documentary evidence<sup>2</sup> being supplied by a suitably qualified installer/commissioner.

#### **2.6.3 In-use factors**

In-use factors are applied in all cases to the SFP and, for MVHR systems, heat exchanger efficiency to allow for differences in practical installations compared to the laboratory test conditions that are defined for the SAP test procedure. For SFP, the in-use factor allows for additional lengths and bends compared to the optimal test configuration and for the practicalities of setting the fan speed at the optimal value for the required flow rate. For MVHR efficiency the tested result is the efficiency of the heat exchanger and the in-use factor allows for losses from ductwork.

In-use factors are taken from the PCDB, but categories are supplied in Table 4h. Specific fan power and heat exchange efficiency are multiplied by the appropriate in-use factor for the purposes of SAP calculations. The factors will be updated in future as relevant to take account of research results on the practical performance of mechanical ventilation systems, and additional values applicable when the system has been installed under an approved installation scheme for mechanical ventilation if such a scheme is implemented.

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<sup>2</sup> The following measurements for the installed system must be included in the documentary evidence, which forms an additional requirement to that specified in the Building Regulation Domestic Ventilation Compliance Guide:

- 1) MVHR fan speed settings at continuous background setting
- 2) Total air flow rate at continuous background setting, supply and extract
- 3) Electrical power drawn when the system is at continuous background setting
- 4) Pressure difference across the MVHR on the supply and extract sides of the unit at continuous background setting

#### 2.6.4 Specific fan power – measured data

The specific fan power for centralised MEV systems and MVHR systems is a single value representing the SFP of the whole system. It is multiplied by the appropriate in-use factor for the purposes of SAP calculations.

In the case of decentralised MEV the specific fan power is provided for each fan and an average value is calculated for the purposes of the SAP calculations. There are two types of fan, one for kitchens and one for other wet rooms, and three types of fan location (in room with ducting, in duct, or through wall with no duct). This gives six possible permutations although all would not normally be present in a given installation. The average SFP, including adjustments for the in-use factors, is given by:

$$SFP_{av} = \frac{\sum SFP_j \times FR_j \times IUF_j}{\sum FR_j} \quad (1)$$

where the summation is over all the fans,  $j$  represents each individual fan,  $FR$  is the flow rate which is 13 l/s for kitchens and 8 l/s for all other wet rooms, and  $IUF$  is the applicable in-use factor.

The specific fan power, inclusive of the in-use factor(s), is used to calculate the annual energy use of the fans (Table 4f) and, where applicable, the gains to the dwelling from the fans (Table 5a). Note that electricity consumption of MVHR systems is not added into the gains because their effect is included in the test results for MVHR efficiency.

#### 2.6.5 MEV systems – air throughput and effective air change rate

The throughput is taken as 0.5 air changes per hour.

#### 2.6.6 Balanced mechanical systems – air throughput and effective air change rate

The throughput of balanced mechanical systems,  $n_{mech}$ , is taken as having been set to an air change rate of 0.5 ach.

The MVHR efficiency is multiplied by the appropriate in-use factor (Table 4h). The heat recovered is allowed for via an effective air change rate  $n_{eff}$  which is

$$n_{eff} = n_{adj} + n_{mech} \times (1 - \eta/100) \quad (2)$$

where  $n_{adj}$  is the effective air change rate obtained at worksheet (22b) and  $\eta$  is the MVHR efficiency in % including the in-use factor.  $\eta$  is zero for balanced systems without heat recovery.

#### 2.6.7 Rigid and flexible ducting

Ventilation systems may be tested with rigid ducting, flexible ducting, or both, and the in-use factors for SFP depend on the ducting type. SAP calculations are undertaken using test data held in the PCDB and in-use factors corresponding to the actual duct type. If data for the actual duct type is not available, the default values from Table 4g are used.

The data and in-use factors for rigid ductwork may be used only if all the ductwork is rigid, specifically:

- for centralised systems, all ducting is rigid (small sections of flexible ducting for vibration isolation, maximum length 200mm per section, is permitted);
- for decentralised systems, all fans with ducting have rigid ducts.

If the above conditions do not apply, the calculation is undertaken using flexible ductwork data, which may be test data held in the PCDB or default data held in Table 4g.

#### 2.6.8 Semi-rigid ducts

Semi-rigid duct systems included in the PCDB have demonstrated that their aerodynamic performance, when installed in a variety of system configurations, is at least as good as that for rigid ducts. Where these duct systems are used with balanced mechanical ventilation, SAP calculations use the performance data for rigid ducts.

### 2.6.9 Two mechanical ventilation systems

Where two systems are used in the same dwelling:

- a) If the two systems are identical, use the data for the system concerned corresponding to half the actual number of wet rooms. If there is an odd number of actual wet rooms, round upwards (e.g. for Kitchen+6 wet rooms, use data for Kitchen+3 wet rooms).
- b) If the systems are different, use an average of the data for the two systems, weighted according to the number of wet rooms served by each system. Round SFP to 2 decimal places and efficiency to nearest whole number for entry into SAP software.
- c) If either of the systems are not included in the Product Characteristics Database the default data (Table 4g) applies.

## 3 HEAT TRANSMISSION

The areas of building elements are based on the internal dimensions of surfaces bounding the dwelling.

Window and door area refers to the total area of the openings, including frames. Wall area is the net area of walls after subtracting the area of windows and doors. Roof area is also net of any rooflights or windows set in the roof. Apart from party walls (see section 3.7) losses or gains to spaces in other dwellings or buildings that are normally expected to be heated to the same extent and duration as the dwelling concerned are assumed to be zero (and these elements are therefore omitted from the calculation of heat losses).

The calculation should allow for different types of element where their U-values differ (e.g. some windows single glazed and some double glazed, masonry main wall and timber framed wall in an extension, main roof pitched and extension roof flat).

### 3.1 U-values of opaque elements

When the details of the construction are known, the U-values should be calculated for the floor, walls and roof. This should always be the case for new dwellings being assessed from building plans. For existing dwellings see Appendix S.

**U-values for walls and roofs** containing repeating thermal bridges, such as timber joists between insulation, etc, should be calculated using methods based on the upper and lower resistance of elements, given in BS EN ISO 6946.

BS EN ISO 6946 gives the calculation that applies to components and elements consisting of thermally homogenous layers (which can include air layer) and is based in the appropriate design thermal conductivity or design thermal resistances of materials and products involved. The standard also gives an approximate method that can be used for inhomogeneous layers, except cases where an insulating layer is bridged by metal.

Thermal conductivity values for common building materials can be obtained from BS EN ISO 10456 or the CIBSE Guide Section A3<sup>[9]</sup>. For specific insulation products, data should be obtained from manufacturers.

**U-values for ground floors and basements** should be calculated using the procedure described in BS EN ISO 13370, in section A3 of the CIBSE Guide A.

The thickness of loft insulation should be determined by inspection if the loft is accessible. The thickness should be measured at least as accurately as in the following list: 0, 12, 25, 50, 100, 150, 200, 250, 300 mm.

### 3.2 Window U-values

The U-value for a window should be that for the whole window opening, including the window frame.

Measurements of thermal transmittance in the case of doors and windows should be made according to BS EN ISO 12567-1. Alternatively, U-values of windows and doors may be calculated using BS EN ISO 10077-1 or BS EN ISO 10077-2. In the case of roof windows, unless the measurement or calculation has been done for the actual inclination of the roof window, adjustments as given in Notes 1 and 2 to Table 6e should be applied.

Table 6e gives values that can be used in the absence of test data or calculated values. Use a value from Table 6e which corresponds most closely to the description of the actual window; interpolation should not be used in this table. The table provides default values for windows corresponding to the generic descriptions given in the table. Measured or specifically calculated values can be better than those in the table because of better frame performance, improved spacer bars and other factors.

The effective window or roof window U-value to be used in worksheet (27) and (27a) takes account of the assumed use of curtains; it is calculated using the formula:

$$U_{w,\text{effective}} = \frac{1}{\frac{1}{U_w} + 0.04} \quad (2)$$

where  $U_w$  is the window U-value calculated or measured without curtains.

### 3.3 U-values of elements adjacent to an unheated space

The procedure for treatment of U-values of elements adjacent to unheated space is described in BS EN ISO 6946 and BS EN ISO 13789.

The following procedure may be used for typical structures (no measurements are needed of the construction providing an unheated space, just select the appropriate  $R_u$  from Tables 3.1 to 3.3 below).

$$U = \frac{1}{\frac{1}{U_0} + R_u} \quad (3)$$

where:  $U$  = resultant U-value of element adjacent to unheated space,  $W/m^2K$ ;  
 $U_0$  = U-value of the element between heated and unheated spaces calculated as if the element was fully exposed to external conditions,  $W/m^2K$ ;  
 $R_u$  = effective thermal resistance of unheated space from the appropriate table below.

$R_u$  for typical unheated structures (including garages, access corridors to flats and rooms in roof) with typical U-values of their elements are given below. These can be used when the precise details on the structure providing an unheated space are not available, or not crucial.

The effect of unheated spaces, however, need not be included if the area of the element covered by the unheated space is small (i.e. less than 10% of the total exposed area of all external walls if the unheated space abuts a wall, or 10% of the total area of all heat-loss floors if the unheated space is below a floor). Consequently a door in an element abutting an unheated space would not need to have its U-value changed (unless it is part of a very small flat where the U-value of the door might make a significant contribution to the result).

#### 3.3.1 Garages

The U-value of elements between the dwelling and an integral garage should be adjusted using  $R_u$  from Table 3.1 or Table 3.2. Attached garages (not integral) should be disregarded.

Apply the following  $R_u$  values for typical configurations of single garages (approximately  $3m \times 6m$ ), double garages (approximately  $6m \times 6m$ ) or similar unheated spaces. If the garage is substantially different from the typical garages assumed then the  $R_u$  value should be calculated using formula (4) given in section 3.3.6.



**Table 3.1  $R_u$  for integral single garages** (single garage is a garage for one car, assuming  $n = 3$ ach)

Garage type	Elements between garage and dwelling	$R_u$ for a single garage	
		Inside <sup>1</sup>	Outside <sup>2</sup>
Single fully integral	Side wall, end wall and floor	0.70	0.35
Single fully integral	One wall and floor	0.55	0.25
Single, partially integral displaced forward	Side wall, end wall and floor	0.60	0.30

**Table 3.2  $R_u$  for integral double garages** (double garage is a garage for two cars, assuming  $n = 3$ ach)

Garage type	Element between garage and dwelling	$R_u$ for a double garage	
		Inside <sup>1</sup>	Outside <sup>2</sup>
Double garage fully integral	Side wall, end wall and floor	0.60	0.35
Double, half integral	Side wall, halves of the garage end wall and floor	0.35	0.25
Double, partially integral displaced forward	Part of the garage side wall, end wall and some floor	0.30	0.25

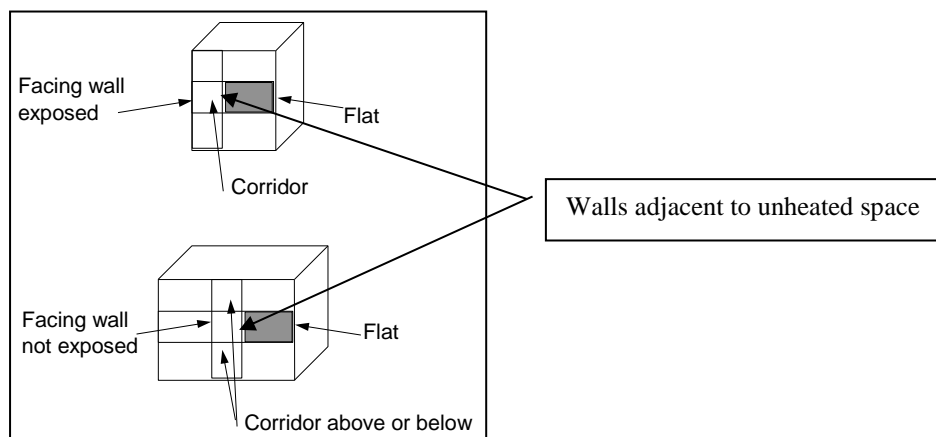
<sup>1</sup>inside garage – when the insulated envelope of the dwelling goes round the outside of the garage

<sup>2</sup>outside garage – when the walls separating the garage from the dwelling are the external walls

### 3.3.2 Stairwells and access corridors in flats

Stairwells and access corridors are not regarded as parts of the dwelling. If they are heated the wall between stairwell or corridor and the dwelling is treated as party wall, see section 3.7. If unheated, the U-value of walls between the dwelling and the unheated space should be modified using the following data for  $R_u$ .

Figure 3.1 shows examples of access corridors in flats.



**Figure 3.1 Access corridors**

The following table gives recommended values of  $R_u$  for common configurations of access corridors and stairwells.

**Table 3.3  $R_u$  for common configurations of stairwells and access corridors.**

Elements between stairwell/corridor and dwelling	Heat loss from corridor through:	$R_u$
Stairwells:		
Facing wall exposed		2.1
Facing wall not exposed		2.5
Access corridors:		
Facing wall exposed, corridors above and below	facing wall, floor and ceiling	0.6
Facing wall exposed, corridor above or below	facing wall, floor or ceiling	0.5
Facing wall not exposed, corridor above and below	floor and ceiling	0.9
Facing wall not exposed, corridor above or below	floor or ceiling	0.7

### 3.3.3 Conservatories

Since the definition of a conservatory can vary, use the definition and any additional requirements that are appropriate to the Building Regulations of the administration where the dwelling is situated.

Thermal separation between a dwelling and a conservatory means that they are divided by walls, floors, windows and doors for which

- i) the U-values are similar to, or in the case of a newly-constructed conservatory not greater than, the U-values of the corresponding exposed elements elsewhere in the dwelling;
- ii) in the case of a newly constructed conservatory, windows and doors have similar draught-proofing provisions as the exposed windows and doors elsewhere in the dwelling.

For a conservatory which is thermally separated, the calculation should be undertaken as if it were not present.

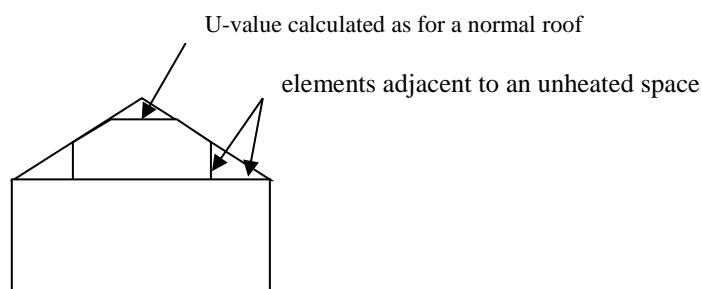
### 3.3.4 Other large glazed areas

Any structure attached to a dwelling that is not a thermally separated conservatory according to the definitions in 3.3.3 should be treated as an integral part of the dwelling. This means that the glazed parts of the structure should be input as if they were any other glazed component (both in the heat loss section, and in the solar gain section according to orientation). See also section 3.2.

### 3.3.5 Room in roof

An approximate procedure applies in the case of a room-in-roof in an existing dwelling (see Appendix S). The following applies to new dwellings and conversions to create a room-in-roof.

In the case of room-in-roof construction where the insulation follows the shape of the room, the U-value of roof of the room-in-roof construction is calculated using the procedure described in paragraph 3.3 using thermal resistance  $R_u$  from Table 3.4. The same applies to the ceiling of the room below.



**Figure 3.2 Room in roof****Table 3.4  $R_u$  for room in roof adjacent to unheated loft space**

Area (figure 3.2)	Element between dwelling and unheated loft space	$R_u$
Room in roof built into a pitched roof insulated at ceiling level	insulated wall of room in roof	0.5
	or insulated ceiling of room below	0.5

If the insulation follows the slope of the roof, the U-value should be calculated in the plane of the slope. For existing dwellings see Appendix S.

**3.3.6 Other cases of  $R_u$** 

In most other cases the effect of an unheated space will be small and should be disregarded. Where it needs to be accounted for a general formula for  $R_u$  is:

$$R_u = \frac{A_i}{\sum (A_e \times U_e) + 0.33nV} \quad (4)$$

- $A_i, A_e$  = areas of internal and external elements ( $m^2$ ), excluding any ground floor  
 $U_e$  = U-values of external elements ( $W/m^2K$ )  
 $V$  = volume of unheated space ( $m^3$ )  
 $n$  = air change rate of unheated space (ach)

Typical values of the air change rate in unheated spaces are given in Table 3.5. A default value of  $n = 3$  ach should be used if the airtightness of the unheated space is not known.

**Table 3.5 Typical air change rates for unheated spaces**

Air tightness type	$n$ (air changes per hour)
No doors or windows, all joints between components well-sealed, no ventilation openings provided	0.1
All joints between components well-sealed, no ventilation openings provided	0.5
All joints well-sealed, small openings provided for ventilation	1.0
Not airtight due to some localised open joints or permanent ventilation openings	3.0
Not airtight due to numerous open joints, or large or numerous permanent ventilation openings	10.0

**3.4 Thermal bridging**

The SAP calculation takes account of thermal bridging, at junctions between elements and around openings. If linear thermal transmittance values are available for these junctions, they can be multiplied by the length of the junction concerned, and the total added to the transmission heat transfer coefficient.

If specific values for thermal bridges are not known, heat loss should be calculated using the total exposed surface area. Further details are in Appendix K.

### 3.5 Dwellings that are part of larger buildings

In the case of a dwelling that is part of a larger building, for example a block of flats or where the remainder of the building is used for non-domestic purposes, the elements between the dwelling and the remainder of the building are considered:

- as party walls (see 3.7) in the case of walls if the spaces adjacent to the dwelling are normally heated to similar levels as the dwelling, or
- to have zero heat loss in the case of floors and ceilings if the spaces adjacent to the dwelling are normally heated to similar levels as the dwelling, or
- as heat loss elements (see 3.3) to an unheated space if the adjacent spaces are unheated, heated only intermittently or heated to a low level.

### 3.6 Curtain walling

Curtain walling is sometimes used for flats but may need a special procedure to get the heat loss and the solar gains correct simultaneously.

Where the U-value of curtain walling is a U-value for the whole façade, i.e. an average value including mullions, transoms, glazing and spandrel panels, these should be assessed by:

- entering the façade U-value as the wall U-value, applied to the opaque area;
- entering the façade U-value as the window U-value, applied to the glazed area;
- assigning a frame factor of 1.0 to the windows.

The façade U-value includes all effects of thermal bridging within the façade<sup>3</sup>, and may also include the thermal bridging for other junctions such as corners. Therefore, calculate the thermal bridging heat loss with:

- the lengths of window and door surrounds set to zero;
- for other junctions that were included in the façade U-value, enter their actual lengths but with psi-values set to zero;
- for all other junctions that were not included in the façade U-value, enter their actual lengths and psi-values.

### 3.7 Party walls

In this context ‘party wall’ (also known as ‘separating wall’) comprises any wall between the dwelling and another heated space which can be:

- another dwelling
- commercial building
- a heated corridor or stairwell in a block of flats
- a heated common area

Where of cavity construction a party wall can provide a mechanism for heat loss via air movement within the cavity between lower floors and the loft space and between the cavity and outside. To allow for this party walls should be assigned a U-value as follows (Table 3.10):

**Table 3.10: U-values for party walls**

Party wall construction	U-value (W/m <sup>2</sup> K)
Solid (including structurally insulated panel)	0.0
Unfilled cavity with no effective edge sealing	0.5
Unfilled cavity with effective sealing around all exposed edges and in line with insulation layers in abutting elements	0.2
Fully filled cavity with effective sealing at all exposed edges and in line with insulation layers in abutting elements	0.0

Where edge sealing is adopted, either on its own or in conjunction with a fully filled cavity, it must be effective in restricting air flow and be aligned with the thermal envelope. Sealing is required at top and bottom and vertically.

<sup>3</sup> See BS EN ISO 12631.

## 4 DOMESTIC HOT WATER

The demand for hot water is derived from the floor area of the dwelling and the characteristics of the bathing facilities (showers and baths) provided. The calculation is specified in Appendix J. The energy required to produce that amount of hot water is then calculated, taking account of losses in heating and storage. Heat to the dwelling from storage cylinders and distribution pipework is also estimated [‘heat gains from water heating’, (65)] so that it can be taken into account in the calculation of space heating requirements.

Water can be heated by any of the systems in the water heating section of Table 4a which includes systems that provide both space and water heating and systems that provide water heating only. Provision is made separately for the use of instantaneous electric showers in Appendix J.

For systems that recover heat from waste water or use surplus electrical energy from Photovoltaic (PV) systems to heat water (PV diverters), rather than exporting to the electricity grid, see Appendix G.

### 4.1 Distribution loss

A distinction is made between instantaneous water heating, which heats water when it is required, and water heating that relies on storage of hot water in a hot water vessel, such as a cylinder or thermal store. Hot water cylinders contain secondary potable water; thermal stores contain primary water. ‘Primary’ and ‘cylinder’ losses are not used in the calculation for instantaneous heaters.

‘Single-point’ heaters, which are located at the point of use and serve only one outlet, do not have distribution losses either. Gas multipoint water heaters and instantaneous combi boilers are also instantaneous types but, as they normally serve several outlets, they are assumed to have distribution losses.

### 4.2 Storage loss

Stored hot water systems can either be served by an electric immersion heater or obtain heat from a boiler or a heat pump via pipework circulating primary water. In both cases, water storage heat losses are incurred to an extent that depends on how well the water storage is insulated. These losses apply for:

- hot water cylinders
- the store volume of storage combination boilers (where the boiler efficiency is derived from test data);
- thermal stores;
- combined primary storage units (CPSUs);
- heat networks

Water storage losses are set to zero for non-storage combi boilers and instantaneous water heaters.

For cylinders the preferred way of establishing cylinder heat losses is from measured data on the cylinder concerned, in kWh/day, according to BS 1566 or BS EN 15332.

For thermal stores and CPSUs (including electric CPSUs) the preferred way of establishing heat losses is from measured data for the thermal store or CPSU concerned, in kWh/day, according to the HWA Performance Specification for thermal stores<sup>9</sup>. Note: Heat pump buffer vessels are ignored.

If measured data is not available, losses from the storage vessel should be estimated by multiplying the loss factor from Table 2 by the volume of the vessel and the volume factor from Table 2a.

In all cases, the loss rate is to be multiplied by a temperature factor from Table 2b. This factor accounts for the average temperature of the cylinder or thermal store under typical operating conditions, compared to its temperature under test.

For combi boilers the storage loss factor is zero if the efficiency is taken from Table 4b. The loss is to be included for a storage combination boiler if its efficiency is the manufacturer’s declared value or is obtained from the Product Characteristics Database, using the data in Tables 2, 2a and 2b (its insulation thickness and volume are also to be provided by the manufacturer or obtained from the database).

For boiler systems with separate hot water storage, primary losses are incurred in transferring heat from the boiler to the storage; values for primary losses are obtained from Table 3. For a combi boiler the additional loss in Table 3a is included to allow for draw-off losses occurring as a consequence of unacceptable water temperatures during warm-up (in the case of combi boiler tested to EN 13203-2 or OPS 26 the additional loss is obtained from the test data using Table 3b or Table 3c).

The efficiency of gas and oil boilers for both space and water heating is reduced by 5% if the boiler is not interlocked for space and water heating (see section 9.4.11).

### 4.3 Heat networks

Where hot water is provided by a heat network:

- a) If the DHW is provided by a heat network, in most cases a Heat Interface Unit (HIU) will be used and a heat loss of 1.46 kWh/day should be assumed. No temperature or volume factor correction is applied (from Table 2b).
- b) If there is a hot water cylinder within the dwelling, measured cylinder heat loss data (kWh/day) according to BS 1566 or BS EN 15332 should be used. If unavailable an appropriate loss factor should be obtained from Tables 2 and 2a, then corrected with Table 2b. It is possible for both a HIU and hot water cylinder to be present, meaning both heat losses should be included.
- c) If neither of the above applies, a measured loss of 2.2 kWh/day should be used, corrected using Table 2b. This is equivalent to a cylinder of 110 litres and a factory insulation thickness of 50mm (loss factor of 0.0152 kWh/litre/day).

Primary circuit loss for insulated pipework and cylinderstat should be included (see Table 3).

The efficiency for water heating is incorporated in the price of heat from a heat network in Table 12.

### 4.4 Solar collector

A solar collector coupled with solar water storage reduces the fuel needed for domestic hot water (see Appendix H). The solar water storage can be either as the lower part of a multi heat source cylinder, or as a separate solar cylinder. For heat networks see H3 in Appendix H.

### 4.5 Alternative DHW heating systems

In most cases the system specified for water heating should be that intended to heat the bulk of the hot water during the course of the year. For example, an immersion heater should be disregarded if provided only for backup where the principal water heating system is from a central heating boiler, as should other devices intended for or capable of heating only limited amounts of hot water. Exceptions are:

- (a) micro-CHP and heat pump packages assessed by Appendix N where the package provides DHW only in the heating season;
- (b) solid fuel room heaters with a back boiler where an immersion heater is provided to heat water in the summer (see section 12.4.4);
- (c) combined heat pump and boiler packages, where hot water is heated by both heat generators throughout the year. See section (c) of N3.7.

In these cases (only), software will create duplicate worksheet entries and allow different values for each heat generator. These will occur at lines (64), (216), (217), (219), (247), (264). For (a) and (b), these duplicate entries (for summer immersion) will be zero during non-summer months.

## 5 INTERNAL GAINS

Internal gains from lights, appliances, cooking and from the occupants of the dwelling (metabolic gains) are estimated from floor area (Table 5).

Gains from central heating pumps located within the heated space and other items should be added and then included in worksheet (70)<sub>m</sub>, using the values given in Table 5a.

Gains from the fans in a whole-dwelling mechanical ventilation system should be included, but no useful gains are assumed from individual extractor fans.

## 6 SOLAR GAINS AND UTILISATION FACTOR

### 6.1 Solar gains for openings

The heat gain through windows and glazed doors is calculated as

$$G_{\text{solar}} = 0.9 \times A_w \times S \times g_{\perp} \times \text{FF} \times Z \quad (5)$$

where:

$G_{\text{solar}}$  is the average solar gain in watts

0.9 is a factor representing the ratio of typical average transmittance to that at normal incidence

$A_w$  is the area of an opening (a window or a glazed door), m<sup>2</sup>

$S$  is the solar flux on the applicable surface from U3 in Appendix U, W/m<sup>2</sup>

$g_{\perp}$  is the total solar energy transmittance factor of the glazing at normal incidence (see Table 6b)

FF is the frame factor for windows and doors (fraction of opening that is glazed)

$Z$  is the solar access factor from Table 6d

Frame factors (FF) should be assigned per window (or per group of similar windows) particularly where the areas of the windows differ on different facades on the dwelling. Default values are given in Table 6c.

In the case of a window certified by a reputable rating scheme<sup>4</sup> the quoted solar factor is  $g_{\text{window}}$  which is equal to  $0.9 \times g_{\perp} \times \text{FF}$ . The solar gain for such windows is calculated as

$$G_{\text{solar}} = A_w \times S \times g_{\text{window}} \times Z \quad (6)$$

In the case of ‘arrow slit’ windows where the width of opening at the external side of the wall is substantially less than the width of the window, this should be taken into account by multiplying FF (or in the case of a scheme-rated window,  $g_{\text{window}}$ ) by the ratio of the opening width at the external surface of the wall to the width of the window.

Solar gains should be calculated separately for each orientation, and then totalled for use in the calculation. E/W orientation of windows may be assumed if the actual orientation is not known\*. The solar access factor describes the extent to which radiation is prevented from entering the building by nearby obstacles. The over-shading categories are dependent on how much the view of the sky through the windows is blocked. The categories are defined in Table 6d in terms of the percentage of sky obscured by obstacles (the ‘average’ category applies in many cases, and can be used for SAP calculations if the over-shading is not known\*).

### 6.2 Openings for which solar gain is included

Openings should be classified as windows, glazed doors or solid doors according to the percentage of glazed area (the percentage of total area of opening that is glass, i.e. excluding framing, mullions, transoms, solid panels etc.). For SAP calculations definitions in Table 6.1 apply:

**Table 6.1 : Classification of openings**

Category	Description	Glazing area	Solar gain included
1	Solid door	< 30 %	No
2	Semi-glazed door	30% - 60%	No
3	Window or glazed door	> 60 %	Yes
4	Roof windows	All cases	Yes

<sup>4</sup> Such as the British Fenestration Rating Council, BSI Kitemark or CERTASS.

\* Subject, in the case of a new dwelling, to any requirements of Building Regulations that apply in the administration where the dwelling will be constructed.

Patio doors which have large glazing areas, generally 70% or more, should be treated as windows and so should take account of solar gain. No allowance should be made for solar gain via doors in categories 1 and 2 even though they have some glazing. French windows often have high frame factors (around 50%) and are thus classified as semi-glazed doors for which no solar gain is included.

### 6.3 More than one glazing type

Sometimes a dwelling has more than one type of glazing (e.g. some double glazing and some single glazing). In these cases the gains should be calculated separately for each glazing type, and added in the same manner as (74) to (82), to obtain the entry for (83)<sub>m</sub> for each month.

### 6.4 Utilisation factor

The solar gains are added to the internal gains to give total heat gains. A utilisation factor is then applied to the gains, which has the effect of reducing the contribution of gains where they are large in relation to the heat load. This factor is calculated from the ratio of the total heat gains to the heat loss coefficient of the dwelling and is obtained as described in Table 9a.

### 6.5 Solar gain in summer

Solar gains in summer (see Appendix P) take account of blinds or curtains that can be drawn to reduce solar gain, and overhangs. These factors are not included in the calculation of solar gains in the winter period.

## 7 MEAN INTERNAL TEMPERATURE

The calculated mean internal temperature for each month is based on the heating requirement of a typical household, taking account of the extent to which the dwelling is insulated and how well the heating can be controlled. The average temperature is obtained separately for the living area and for the rest of the dwelling and then combined to obtain the mean internal temperature for the dwelling, using the data and equations in Tables 9, 9a and 9b.

The temperature difference between the living area and the rest of the dwelling is obtained from Table 9, using the Heat Loss Parameter (HLP) from worksheet (40) and the 'Control' column of Table 4e.

### 7.1 Living area

The living area is the room marked on a plan as the lounge or living room, or the largest public room (irrespective of usage by particular occupants), together with any rooms not separated from the lounge or living room by doors, and including any cupboards directly accessed from the lounge or living room. Living area does not, however, extend over more than one storey, even when stairs enter the living area directly.

The living area fraction is the floor area of the living area divided by the total floor area.

## 8 CLIMATIC DATA

Calculations are based on the climatic data (solar radiation, wind speed and external temperature) provided in Appendix U.

## 9 SPACE HEATING REQUIREMENT

The 'useful' energy required from the heating system each month is calculated from internal and external temperatures and the heat transfer coefficient allowing for internal and solar gains. Totalled over one year this quantity is known as the dwelling's Space Heating Requirement and is calculated at worksheet (98).

The quantity of fuel or electrical energy required to provide that useful energy is then calculated for each month, taking account of the efficiency of the space heating system (obtained from Product Characteristics Database (PCDB) or Table 4a or 4b).



## 9.1 Heating systems

It is assumed that the dwelling has heating systems capable of heating the entire dwelling. Calculations are on the basis of a main heating system and secondary heaters as described in Appendix A. The proportion of heat from the main and secondary systems is as given in Table 11.

For a new dwelling that has no heating system specified, it should be assumed that the dwelling will be heated by direct acting electric heaters.

Heat networks are characterised as systems where heat is generated and supplied by a network and heat generator(s) that is located outside of the dwellings it serves, see Appendix C.

For an electric Combined Primary Storage Unit (CPSU), see Appendix F.

## 9.2 Heating system efficiency (space and DHW)

### 9.2.1 Heating systems based on a gas or oil boiler

Boiler efficiency may be obtained from:

- a) The Product Characteristics Database (PCDB);
- b) Table 4b of this document.

The preferred source of boiler efficiency is the PCDB, which contains boiler efficiency figures intended for use in SAP, for further details refer to Appendix D. If there is no entry in the database an indicative seasonal efficiency should be taken from Table 4b. Where a boiler has been listed in the PCDB for operation with a particular fuel (e.g. mains gas), this data record cannot be applied for use with a different fuel (e.g. LPG), a separate PCDB data record is required using applicable test data. Otherwise a default value from table 4b should be used.

Separate efficiencies are used for space heating ( $\eta_{\text{winter}}$ ) and for water heating ( $\eta_{\text{water}}$ ).

### 9.2.2 Gas or oil boiler with flue gas heat recovery system

A condensing gas or oil boiler may be fitted with a flue gas heat recovery system. The requisite parameters are obtained from the Product Characteristics Database. The amendments to the calculation procedure are described in Appendix G.

### 9.2.3 Heating systems based on a gas or oil range cooker boiler

For definitions see paragraph B4 (Appendix B). Boiler efficiency may be obtained from:

- a) The Product Characteristics Database;
- b) Table 4b of this document.

For twin burner models the preferred source of efficiency is from the database, which contains the boiler seasonal efficiency values and case heat emission data intended for use in SAP. If there is no entry in the database or it is not of the twin burner type, indicative seasonal efficiency values should be taken from Table 4b.

Separate efficiencies are used for space heating and for water heating, as described in 9.2.1 above.

### 9.2.4 Heating systems based on a solid fuel boiler

This applies to independent solid fuel boilers, open fires with a back boiler and room heaters with a boiler.

Boiler efficiency may be obtained from:

- a) The Product Characteristics Database;
- b) Table 4a of this document.

The preferred source of boiler efficiency is the Product Characteristics Database. The heating type and responsiveness is that for the applicable type of appliance given in Table 4a. If there is no entry in the database an indicative seasonal efficiency should be taken from Table 4a.

Table 4a gives two sets of efficiency values for solid fuel appliances:

- (A) the minimum efficiency for HETAS approved appliances;
- (B) default values

Values from column (A) can be used for consideration of a design where it is anticipated that a HETAS-approved appliance will be used: data for the actual appliance should be used to provide certificated energy ratings. Values from column (B) should be used for appliances, particularly those already installed in dwellings, for which efficiency data are not available.

Solid fuel boiler efficiencies for open fires and closed room heaters with boilers are the sum of the heat to water and heat directly to room. It is the designer's responsibility to ensure that the ratio of these figures is appropriate to the dwelling being assessed. These systems are assigned a lower responsiveness to allow for limitations on the controllability of heat output to the room.

### 9.2.5 Direct-acting electric boiler

A direct-acting electric boiler (also known as an electric flow boiler) heats water for space heating radiators as it circulates. Possible tariffs are standard tariff, off-peak 7-hour and off-peak 10-hour. Heating control options are the same as for other radiator systems.

Water heating is usually by an electric immersion. The cylinder can be within the same casing as the boiler or it can be a separate cylinder; the treatment in SAP is the same for both of these cases.

### 9.2.6 Micro-cogeneration (micro-CHP)

Data is obtained from the Product Characteristics Database and used as described in Appendix N. The data provides the secondary heating fraction based on the micro-cogeneration package output power and the design heat loss of the dwelling.

### 9.2.7 Heat pumps

Heat pump data may be obtained from:

- a) The Product Characteristics Database;
- b) Table 4a of this document.

Heating control options for heat pumps are given in Group 2 (wet systems) or Group 5 (warm air systems) of Table 4e. A bypass arrangement is usually necessary with TRVs to ensure sufficient water is circulating while the heat pump is operating. Zoning arrangements or TRVs may not be appropriate for small domestic installations for this reason.

The preferred source of annual efficiency data for heat pumps is the Product Characteristics Database, which is used as described in Appendix N. This data includes any secondary heating required, based on the heat pump output power and the design heat loss of the dwelling. It also takes account of any proportion of domestic water heating provided by an electric immersion.

If a heat pump is not included in the database the appropriate default annual efficiency (given in Table 4a under "Efficiency"), is used in worksheet (206) or (207) for space heating and (217) for water heating.

#### MCS approved heat pump installations

Where a heat pump has been installed under the Microgeneration Certification Scheme (MCS), or equivalent, and the SAP calculation uses an efficiency from Table 4a (i.e. its performance is not available via the Products Characteristics Database), an installation factor from the table below is applied to the efficiency.

Installation factors for electric heat pumps installed in accordance with MIS 3005 <sup>5</sup>	Code (Table 4a)	Multiply efficiency by:	
		Space	DHW
Ground source heat pump with flow temperature <= 35°C (see 9.3)	211, 213	1.39	1.32
Air source heat pump with flow temperature <= 35°C (see 9.3)	214	1.47	1.03
Heat pump for water heating only	941	-	1.03

<sup>5</sup> Microgeneration Installation Standard MIS 3005 (Heat Pump Standard), issue 3.0 or any later issue.

Ground source heat pump in other cases	221, 223	1.53	1.35
Air source heat pump in other cases	224	1.29	1.12

These installation factors apply only where an MCS certificate, or equivalent, has been produced by the installer, and made available to the assessor, that attests the heat pump has been installed and commissioned to the current version of Microgeneration Installation Standard MIS 3005 (see [www.microgenerationcertification.org/mcs-standards/installer-standards](http://www.microgenerationcertification.org/mcs-standards/installer-standards)), or an equivalent standard.

### 9.2.8 Electric storage systems

A ‘high heat retention storage heater’ is one with heat retention not less than 45% measured according to BS EN 60531. It incorporates a timer, electronic room thermostat and fan to control the heat output. It is also able to estimate the next day’s heating demand based on external temperature, room temperature settings and heat demand periods. Qualifying storage heaters are included in the Product Characteristics Database.

### 9.2.9 Room heaters

Where available, manufacturer’s declared values should be used for the efficiency of gas, oil and solid fuel room heaters, certified as explained in Appendix E.

Otherwise, and for other types of room heaters, the efficiency should be taken from Table 4a.

#### Gas fires

The following notes provide guidance for identifying the appropriate entry from the room heater section of Table 4a, for gas fires already installed in a dwelling. (They are not intended to classify gas fires for testing purposes.)

Gas fires can be “open” or “closed” fronted. Open fronted means the fuel bed and combustion gases are not “sealed” from the room in which the gas fire is fitted. Such a fire may or may not have a glass panel in front of the fuel bed, but the glass panel will not be sealed to the front of the fire. Closed fronted means the fuel bed and combustion gases are “sealed” (generally with a glass panel sealed to the front of the fire) from the room in which the gas fire is fitted.

Fuel effect gas fires can be “live fuel effect” (LFE), “inset live fuel effect” (ILFE) or “decorative fuel effect” (DFE). The products of combustion from a DFE pass unrestricted from the fire-bed to the chimney or flue; for the LFE/ILFE the products of combustion are restricted before passing into the chimney or flue. For further clarification of LFE/ILFE/DFE see clauses 3.1.2, 3.1.3 and 3.1.4 and Figure D.1 of BS 7977-1:2009+A1:2013.

#### Room heaters with boilers

Gas, oil and solid fuel room heaters can have a boiler, which may provide either domestic hot water only or both space heating and domestic hot water.

For gas back boilers, separate efficiencies apply to the boiler and to the associated room heater. This means that:

- if the back boiler provides space heating, it should be defined as the main heating system, and the gas fire should be indicated as the secondary heater;
  - if the back boiler provides domestic hot water only, the boiler efficiency is used for water heating and the gas fire efficiency for space heating (gas fire as main or as secondary heater).
- Gas back boilers are found only behind open-flued gas fires without fan assistance. Note that the fire and the boiler share the same flue.

For oil and solid fuel room heaters with boilers, the efficiency is an overall value (i.e. sum of heat to water and heat to room). This means that:

- if the boiler provides space heating, the combination of boiler and room heater should be defined as the main heating system;
- if the boiler provides domestic hot water only, the overall efficiency should be used as the efficiency both for water heating and for the room heater (room heater as main or as secondary heater).

### 9.2.10 Other heating systems

For other systems the seasonal efficiency should be taken from Table 4a. For systems not covered by the table, guidance should be sought from BRE.

## 9.3 Temperature of heat emitters for condensing boilers and heat pumps

The efficiency of condensing boilers and heat pumps is higher when they supply heat at lower temperature. SAP calculations allow for this in the case of a low-temperature heating system.

A low-temperature heating system is defined as one in which the hot (flow) water leaving the heat generator never exceeds a temperature limit, even on the 'design day' (a day with cold weather conditions chosen for calculating the maximum heat losses from the building). This compares to standard design practice for condensing boilers, where this water may reach 80°C or 70°C, depending upon design, with a design return (boiler inlet) water temperature of 60°C in either case. For heat pumps, standard practice for design flow temperature is assumed at 58°C<sup>6</sup>, irrespective of heat emitter type. Alternate space heating efficiencies are made available for condensing boilers and heat pumps at design flow temperatures of 55°C, 45°C and 35°C.

The low-temperature heating system definition does not include heating systems in which the water temperature is lower only some of the time, such as those with weather compensation or load compensation controls, nor does it include underfloor systems in which a thermostatic mixing valve is used to blend water at a high temperature with cooler water before entering the underfloor heating system<sup>7</sup>.

Low-temperature heating requires a different system design, mainly to ensure that the heat emitters (radiators, fan-assisted radiators or convectors, or underfloor heating pipes) can deliver the same amount of heat at the lower temperature as a traditional radiator system would have done at a typical higher temperature. The emitters in each room must be sized correctly to ensure they are capable of achieving the necessary heat output. Suitable controls must also be installed to ensure the design temperature of water leaving the heat generator is not exceeded while the system is providing space heating, and the system commissioned for low temperature operation. Provided that space heating and water heating are not carried out simultaneously, separate control arrangements can apply to the water heating.

Low temperature emitters apply to SAP calculations when a suitable commissioning certificate that confirms compliance with all aspects of the design, installation and commissioning requirements for low temperature operation has been signed by a suitably qualified individual and supplied to the SAP assessor.

At present the only design guidance recognised by SAP is *BRE Trust Report FB 59, Design of low-temperature domestic heating systems*<sup>8</sup>. It includes an example design, installation and commissioning certificate. Other guidance that may become available in future may also be recognised if the same conditions and restrictions are observed.

### 9.3.1 Condensing boilers

Condensing boilers operate at higher efficiency with lower return temperatures. The space heating efficiency data in Table 4b and database records for boilers is based on the design flow temperature of the water in the heat distribution system being 70°C or 80°C (regardless, a design return temperature of 60°C).

Where the heating system has been designed to operate at a lower temperature the space heating efficiency of a condensing boiler is increased by the applicable efficiency adjustment given in Table 4c. These adjustments apply to all heat emitter types when the design flow temperature, as stated on the commissioning certificate (rounded to the nearest whole number), is less than the default case. The assessor should enter this value in software, whereby linear interpolation is used to derive an efficiency adjustment.

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<sup>6</sup> High temperature heat pumps are capable of supplying a design flow temperature of 65°C; this is taken as the default design flow temperature for SAP calculations. Provision for recording annual efficiency data for high temperature heat pumps is provided by the PCDB.

<sup>7</sup> Underfloor systems may still have a mixing valve but only as a protection device

<sup>8</sup> Available from [www.brebookshop.com](http://www.brebookshop.com). A supporting calculation tool and guide can be found at [www.ncm-pcdb.org.uk/sap/lowtemperatureheating](http://www.ncm-pcdb.org.uk/sap/lowtemperatureheating)

### 9.3.2 Heat pumps

Heat pumps operate at higher efficiency with lower flow temperatures. The default space heating efficiency data in 9.2.7 and Table 4a provide values for design flow temperatures of  $\leq 35^{\circ}\text{C}$  and  $>35^{\circ}\text{C}$ . PCDB records provide space heating efficiency values for design flow temperatures of  $35^{\circ}\text{C}$ ,  $45^{\circ}\text{C}$ ,  $55^{\circ}\text{C}$  and  $58^{\circ}\text{C}$  (and  $65^{\circ}\text{C}$  for high temperature heat pumps).

The default is a flow temperature of  $58^{\circ}\text{C}$ . If the heating system has been designed to operate at a lower temperature, and this is evidenced by a commissioning certificate (when temperature rounded to the nearest whole number), then heat pump efficiency data for the flow temperature is applied. The assessor should enter the design flow temperature in software, whereby linear interpolation is used as necessary to derive an efficiency from PCDB data records bounding the entered flow temperature (extrapolation cannot be used). For design flow temperatures below  $35^{\circ}\text{C}$ , the efficiency at  $35^{\circ}\text{C}$  is used. Design flow temperatures above  $58^{\circ}\text{C}$  cannot be entered, unless a high temperature heat pump, in which case a maximum temperature of  $65^{\circ}\text{C}$  can be entered.

## 9.4 Heating controls

The type of controls incorporated into the heating system influences the calculated energy use. This section gives specifications of the types of controls mentioned in Table 4e. 'Heat generator' means a device that provides heat such as a boiler or heat pump.

### 9.4.1 Room thermostat

A sensing device to measure the air temperature within the building and switch on and off the space heating. A single target temperature may be set by the user.

### 9.4.2 Time switch

A switch operated by a clock to control either space heating or hot water, but not both. The user chooses one or more "on" periods, usually in a daily or weekly cycle.

### 9.4.3 Programmer

Two switches operated by a clock to control both space heating and hot water. The user chooses one or more "on" periods, usually in a daily or weekly cycle. A mini-programmer allows space heating and hot water to be on together, or hot water alone, but not heating alone. A standard programmer uses the same time settings for space heating and hot water. A full programmer allows the time settings for space heating and hot water to be fully independent.

### 9.4.4 Programmable room thermostat

A combined time switch and room thermostat which allows the user to set different periods with different target temperatures for space heating, usually in a daily or weekly cycle. For SAP calculations this is treated the same as a separate programmer and room thermostat.

### 9.4.5 Delayed start thermostat

A device or feature within a device, to delay the chosen starting time for space heating according to the temperature measured inside or outside the building.

### 9.4.6 Thermostatic radiator valve (TRV)

A radiator valve with an air temperature sensor, used to control the heat output from the radiator by adjusting water flow.

### 9.4.7 Programmable TRV

A TRV that allows the heating times for the room in which it is situated to be set separately from those of other rooms.

Note: A system of programmable TRVs do not themselves provide a boiler interlock (see 9.4.11). Systems of programmable TRVs recognised in SAP are included in the Products Characteristics Database.

### 9.4.8 Communicating TRV

A TRV that has the capability to respond to commands (relating to both timing and temperature level) from a central controller.

Note. Systems of communicating TRVs recognised in SAP are included in the Products Characteristics Database and incorporate provision for boiler interlock for space heating (see 9.4.11).

#### **9.4.9 Cylinder thermostat**

A sensing device to measure the temperature of the hot water cylinder and switch on and off the water heating. A single target temperature may be set by the user.

Note: A cylinder thermostat should be assumed to be present when the domestic hot water is obtained from a heat network, an immersion heater, a thermal store, a combi boiler or a CPSU.

#### **9.4.10 Flow switch**

A flow switch is a device which detects when there is no water flow through the system because the TRVs on all radiators are closed.

#### **9.4.11 Boiler interlock (gas and oil boilers)**

This is not a physical device but an arrangement of the system controls so as to ensure that the boiler does not fire when there is no demand for heat. In a system with a combi boiler it can be achieved by fitting a room thermostat. In a system with a regular boiler it can be achieved by correct wiring interconnections between the room thermostat, cylinder thermostat, and motorised valve(s). It may also be achieved by a suitable boiler energy manager.

In systems without an interlock the boiler is kept cycling even though no water is being circulated through the main radiators or to the hot water cylinder. This results in a reduction in operating efficiency and for this reason Table 4c specifies that a seasonal efficiency reduction of 5% should be made for such systems. For the purposes of the SAP, an interlocked system is one in which both the space and stored water heating are interlocked. If either is not, the 5% seasonal efficiency reduction is applied to both space and water heating; if both are interlocked no reductions are made.

It is also necessary to specify whether a hot water cylinder has a thermostat or not. A cylinder thermostat normally shuts down the primary circuit pump once the demand temperature in the cylinder is met. The cylinder thermostat itself might not switch off the boiler; this is only done if the pump and boiler are interlocked and so the presence of a cylinder thermostat does not in itself signify the presence of an interlock for water heating. If there is no cylinder thermostat, however, there can be no interlock since the system does not know when the demand temperature is reached. A boiler system with no cylinder thermostat or assumed cylinderstat (see 9.4.9) must therefore be considered as having no interlock.

A boiler system with no room thermostat (or a device equivalent in this context, such as a flow switch or boiler energy manager), even if there is a cylinder thermostat, must be considered as having no interlock.

For solid fuel boilers and electric boilers the boiler interlock question is not relevant and the efficiency values in Table 4a allow for normal operation of these appliances. For such systems there is no efficiency reduction for the absence of interlock.

Note: TRVs alone (other than some communicating TRVs) do not perform the boiler interlock function and require the addition of a separate room thermostat in one room.

#### **9.4.12 Bypass**

A fixed bypass is an arrangement of pipes that ensures a minimum flow rate is maintained through the heat generator. It is commonly used to ensure a minimum flow rate through a boiler or heat pump and to limit circulation pressure when alternative water paths are closed (particularly in systems with thermostatic radiator valves).

A fixed bypass is achieved either by ensuring that one radiator stays open or by adding a short pipe with a fixed-position valve between the flow and return pipe. A radiator without a TRV or hand valve is a common form of fixed bypass.

An automatic bypass valve controls the water flow through it according to the water pressure difference across it, typically by spring loading, so that the bypass operates only to the extent needed to maintain a minimum flow rate through the system.

The control type 'TRVs + programmer + bypass' is a non-interlocked system in the absence of other arrangements to provide the interlock function.

#### **9.4.13 Boiler energy manager**

Typically a device intended to improve boiler control using a selection of features such as weather compensation, load compensation, start control, night setback, frost protection, anti-cycling control and hot water over-ride. For the purposes of the SAP it is an equivalent to a hard-wired interlock; any other features (e.g. those in 9.4.15 or 9.4.18) are considered separately.

#### **9.4.14 Time and temperature zone control**

A system of control that allows the heating times of at least two zones to be programmed independently, as well as having independent temperature control.

In the case of wet systems this can be achieved by:

- separate plumbing circuits, either with their own programmer, or separate channels in the same programmer; or
- programmable TRVs (9.4.7) or communicating TRVs (9.4.8) that are able to provide time and temperature zone control (conventional TRVs without a timing function provide only independent temperature control).

In the case of direct-acting electric systems, including underfloor heating, it can be achieved by providing separate temperature and time controls for different rooms.

Time and temperature zone control is applicable when the following conditions are met:

- a. there are at least two zones in which heating times and temperatures are controlled independently of each other;
- b. each zone is either a single room or number of adjacent rooms, and these zones are separated from each other by doors or a change of storey;
- c. one of the zones includes the living area;
- d. if the controls are communicating TRVs or programmable TRVs they are fitted to all heat emitters within that zone;
- e. the time and temperature controlled zones, taken together, cover at least 80% of the dwelling floor area; additionally, for wet systems:
- f. timing does not depend on a shared time switch or programmer controlling all zones simultaneously;
- g. boiler interlock is assured by detecting and reacting (by shutting down the boiler electrically) to the condition in which there is no call for heat from any of the zones;
- h. if domestic hot water is heated by the same device as space heating it has separate time and temperature control independent of the space heating controls.

#### **9.4.15 Weather compensator**

A device, or feature within a device, which maintains the temperature inside the building by sensing and limiting the temperature of the water circulating through the heat generator and heat emitters in relation to the temperatures measured outside the building. This control type is equivalent to the Ecodesign regulation (811/2013) temperature control Class II (for modulating heat generators) and Class III (for on/off heat generators).

Note. Weather compensators recognised for SAP are included in the Product Characteristics Database.

#### **9.4.16 Enhanced weather compensator**

A device, or feature within a device, which maintains the temperature inside the building by sensing and limiting the temperature of the water circulating through the heat generator and heat emitters in relation to the temperatures measured inside and outside the building. This control type is equivalent to the Ecodesign regulation (811/2013) temperature control Class VI (for modulating heat generators) and Class VII (for on/off heat generators).

Note. Weather compensators recognised for SAP are included in the Product Characteristics Database.

#### **9.4.17 Load compensator**

A device, or feature within a device, which adjusts the temperature of the water circulating through the heating system according to the temperature measured inside the building. No efficiency credit is awarded for this control type.

#### 9.4.18 Enhanced load compensator

A device, or feature within a device, which maintains the temperature inside the building by sensing and limiting the temperature of the water circulating through the heat generator and heat emitters in relation to the temperature measured inside the building. This control type is equivalent to the Ecodesign regulation (811/2013) temperature control Class V and VIII (for modulating heat generators only).

Note. Enhanced load compensators recognised for SAP are included in the Product Characteristics Database.

#### 9.4.19 Controls for electric storage heaters

There are three types of control that can be used with electric storage heaters - manual charge control, automatic charge control, SELECT-type control and, for high heat retention storage heaters, input and output controls as defined in 9.2.8.

Automatic charge control can be achieved using internal thermostat(s) or an external temperature sensor to control the extent of charging of the heaters. Availability of electricity to the heaters may be controlled by the electricity supplier on the basis of daily weather predictions (see 24-hour tariff, 12.4.3); this should be treated as automatic charge control.

A SELECT-type controller has electronic sensors throughout the dwelling linked to a central control device. It monitors the individual room sensors and optimises the charging of all the storage heaters individually (and may select direct acting heaters in preference to storage heaters).

## 10 SPACE COOLING REQUIREMENT

The space cooling requirement should always be calculated (section 8c of the worksheet). It is included in the DER and ratings if the dwelling has a fixed air conditioning system. The cooling requirement is based on a standardised cooling pattern of 6 hours/day operation and cooling of part of or all the dwelling to 24°C. Details are given in Tables 10a and 10b and the associated equations.

## 11 FABRIC ENERGY EFFICIENCY

**This section will be updated in future to take account of changes to Building Regulations.**

Fabric Energy Efficiency is defined as the space heating and cooling requirements per square metre of floor area, obtained at worksheet (109) when calculated under the following conditions:

- climate is UK average for heating and cooling
- natural ventilation with intermittent extract fans
- 2 extract fans for total floor area (TFA) up to 70 m<sup>2</sup>, 3 for TFA > 70 m<sup>2</sup> and up to 100 m<sup>2</sup>, 4 for total floor area > 100 m<sup>2</sup>; set chimneys, flues and passive vents to zero.
- for calculation of heat gains from the hot water system worksheet (46) to (61) inclusive and (63) are set to zero (equivalent to an instantaneous water heater)
- fixed lighting capacity (lm) = 185 x TFA, efficacy of fixed lighting = 66.9 lm/W
- column (B) of Table 5 is used for internal gains in the heating calculation
- column (A) of Table 5 is used for internal gains in the cooling calculation
- overshadowing of windows not less than average (i.e. very little is changed to average)
- no heat gains from pumps or fans
- the heating system has responsiveness 1.0 and control type 2, no temperature adjustment, temperature and heating periods according to Table 9 irrespective of the actual heating system
- cooled fraction is 1.0

Other data items are those for the actual dwelling. The above are special conditions for calculation of Fabric Energy Efficiency and do not apply to other calculations.

## 12 TOTAL ENERGY USE AND FUEL COSTS

### 12.1 Energy use

The annual energy use is calculated for the following items:

- main space heating system(s);
- secondary space heating;
- space cooling



- domestic hot water heating;
- electricity for instantaneous electric showers
- electricity for pumps and fans (including mechanical ventilation if present);
- electricity for lighting.

## 12.2 Fuel prices

Fuel costs are calculated using the fuel prices given in Table 12. The fuel prices given are averaged over the previous three years and across regions. Other prices must not be used for calculation of SAP ratings.

Since fuels have to relate to realistic heating systems it is important that practical combinations of fuel types are used.

## 12.3 Electricity tariff

The electricity tariff is specified as one of:

- standard tariff;
- 7-hour off-peak
- 10-hour off-peak
- 18-hour tariff
- 24-hour heating tariff

The 24-hour tariff is used only with specifically-designed electric storage systems (see 12.4.3). Otherwise a dwelling can have standard, 7-hour or 10-hour tariff.

The following systems need an off-peak tariff:

- electric storage heaters (7, 10 or 24 hour)
- electric underfloor heating if marked "off-peak tariffs" in Table 4a (7 or 10 hour)
- electric dry core or water storage boiler (7 hour)
- electric CPSU (10 or 18 hour)
- dual electric immersion (7, 10 or 24 hour)

and the data are inconsistent if standard tariff is indicated when any of the above are specified.

On the other hand the 7-hour or 10-hour tariff is possible with other systems. See also 12.4.3.

If the dwelling is on a 7-hour or a 10-hour tariff the proportions of electricity applied at the high and low rates are defined in Table 12a.

## 12.4 Main fuel types

Main space heating systems may use any of the fuel types listed in Table 12 as long as they are relevant to the particular heating system. Specifying the main heating fuel is usually straightforward but the following points should be borne in mind.

### 12.4.1 Gas systems

Conventional gaseous fuels are mains gas, bulk LPG and bottled gas. Bottled gas is normally used only with gas room heaters. In dwellings where the main heating system uses mains gas or bulk LPG, any gas-fired secondary system normally uses the same fuel as the main system (although exceptions to this can occur). The use of biogas (usually from anaerobic digestion) is subject to assurance of supply.

### 12.4.2 Oil systems

For appliances using mineral oils, use the data in Table 12 for heating oil.

For appliances that can use either mineral oil or liquid biofuel, the factors (for price, CO<sub>2</sub> emissions or primary energy) correspond to the average UK consumption of these fuels for domestic heating. At present they are the same as those for mineral oil.

For appliances that use specific blends of mineral and liquid biofuels the applicable factor is a weighting of those for the constituent parts. At present the only such fuel is B30K (see Table 12).

Biodiesel, derived wholly from vegetable sources or from wholly biomass sources, is applicable to appliances that can use only the fuel concerned.

### 12.4.3 Electric systems

SAP provides for five electricity tariffs. The standard tariff is the normal domestic supply.

7-hour tariff is generally known as Economy-7 in England, Wales and Northern Ireland and Economy White Meter in Scotland. There are two unit prices for electricity, depending on time of day. This tariff should be selected when the low-rate availability is during a single period overnight: the actual duration can be between 7 and 8½ hours. When a dwelling is on the 7-hour off-peak tariff, all electricity is charged at the low rate during the low-rate period and at the high rate at other times. Storage heaters are arranged to be charged only during the low-rate period; for other electricity uses (including secondary heating, pumps and fans, lighting and water heating) see Tables 12a and 13 for proportions of electricity used at the high and low rates. This tariff is used in SAP for between 7 and 9 hours of low-rate electricity per day.

The 10-hour tariff provides 10 hours of low-rate electricity in three periods (typically one during the night, one in the afternoon and one in the evening). It may be described as Economy-10. When a dwelling is on the 10-hour off-peak tariff, all electricity is charged at the low rate during the low-rate period and at the high rate at other times. Storage heaters are arranged to be charged only during the low-rate period; for other electricity uses (including secondary heating, pumps and fans, lighting and water heating) see Tables 12a and 13 for proportions of electricity used at the high and low rates.

The 18-hour tariff is only for use with electric CPSUs with sufficient energy storage to provide space (and possibly water) heating requirements for 2 hours. Electricity at the low-rate price is available for 18 hours per day, with interruptions totalling 6 hours per day, with the proviso that no interruption will exceed 2 hours. The low-rate price applies to space and water heating, while electricity for all other purposes is at the high-rate price. The tariff is not available in all areas of the UK and should not be assumed based on the presence of an electric CPSU.

The 24-hour tariff is for use with storage based systems where the main heating, secondary heating and water heating are all charged at the 24-hour rate. The storage heaters may be recharged at any time of the day with the recharging being remotely controlled by the electricity company. The 24-hour tariff is used only with whole-dwelling heating systems which are designed for about 60% storage and 40% direct-acting heaters. Lights, appliances etc use standard tariff. It is available only in certain areas.

Integrated storage/direct systems comprise:

- a) electric storage heaters with reduced storage capacity but incorporating a direct-acting radiant heater, designed to provide about 80% of the heat output from storage and about 20% from direct-acting;
- b) underfloor heating designed to take about 80% of the heating needs at off-peak times (low rate) and about 20% at on-peak times (high rate). This heating can be controlled by a "low (off-peak) tariff control" which optimises the timing and extent of the off-peak charge according to outside temperature and the quantity of stored heat. Low tariff control optimises the storage of heat in the floor during the low-rate period, and is assessed using a higher system responsiveness.

A secondary system is used in the calculation when the main system is electric storage heaters or off-peak electric underfloor heating (portable electric heaters if no secondary system is identified), see Appendix A.

### 12.4.4 Solid fuel systems

Independent boilers can be fuelled by anthracite or wood; some models are 'multi-fuel' able to use either. For solid fuel open room fires the fuel would generally be house coal, smokeless fuel or wood. For further details see Table 12b. Some pellet boilers and stoves may be room sealed, in which case the flue ventilation loss (see section 2) does not apply.

Independent boilers that provide domestic hot water usually do so throughout the year. With open fire back boilers or closed room heaters with boilers, an alternative system (electric immersion) may be provided for heating water in summer. In that case water heating is provided by the boiler for months October to May and by the alternative system for months June to September.

### 12.4.5 Smoke controls areas

Outside Smoke Control Areas any fuel can be used subject to the manufacturer's instructions for the appliance concerned.

Within Smoke Control Areas solid fuel may be used if:

- (a) it is an Authorised Smokeless Fuel that has been approved by Parliamentary Statutory Instrument for burning in a Smoke Control Area, or
- (b) it will be used on an Exempted Appliance that has been approved by Parliamentary Statutory Instrument for installation in a Smoke Control Area (the exemption applies to a specific fuel or fuels for the appliance concerned).

Fuel	Limitation in Smoke Control Areas
House coal*	Not permitted
Anthracite**	-
Smokeless	Authorised smokeless fuel only
Wood logs, wood chips, wood pellets	Exempted appliance only
Dual fuel*	Not permitted

\* The calculation cannot be considered as valid under these conditions  
 \*\* Anthracite is natural smokeless fuel that is permitted in Smoke Control Areas

Information on Smoke Control Areas is provided at [www.uksmokecontrolareas.co.uk](http://www.uksmokecontrolareas.co.uk) by local authority area. If it is not known whether it is a Smoke Control Area the applicable statement from the above table is qualified by "if the dwelling is in a Smoke Control Area".

### 12.5 Secondary fuel types

Secondary heating systems and applicable fuel types are taken from the room heaters section of Table 4a.

### 12.6 Water heating fuel types

Water heating may be provided by the main heating system or it may be supplied using an independent water heating system.

Whenever water heating is supplied by a system using off-peak electricity it is assumed that a proportion of the water heating will, nevertheless, take place at on-peak times (and so be charged at the high rate). This proportion is calculated using Table 13 and the percentage is dependent on the total floor area and the cylinder size. This table should be linearly interpolated (in both directions where necessary) for intermediate values. The limits of cylinder size in the table are cut-off points, so that if, for instance, the cylinder size used is 105 litres, the values for 110 litres should be used instead.

### 12.7 Electricity for pumps and fans

An allowance for the electricity used has to be made for systems that include any of the following:

- central heating pump;
- boiler with fan assisted flue;
- warm air heating system fans;
- whole house mechanical ventilation;
- keep-hot facility (electric) for gas combi boilers

Where there is an off-peak tariff the proportions of electricity at the high and low rates are given in Table 12a. Note that the allowance in this section for fan-assisted flues only applies for a main heating system – fan-assisted flues for secondary heaters should not be counted. Data is given in Table 4f.

### 12.8 Electricity for lighting

The electricity used for lighting is calculated according to the procedure in Appendix L. The calculation allows for low-energy lighting provided by fixed outlets (both dedicated fittings and compact fluorescent lamps) on the basis of the proportion of the fixed outlets that have low-energy fittings.

### 13 ENERGY COST RATING

The SAP rating is related to the total energy cost by the equations:

$$\text{ECF} = \text{deflator} \times \text{total cost} / (\text{TFA} + 45) \quad (7)$$

$$\text{if ECF} \geq 3.5, \quad \text{SAP 2012} = 117 - 121 \times \log_{10}(\text{ECF}) \quad (8)$$

$$\text{if ECF} < 3.5, \quad \text{SAP 2012} = 100 - 13.95 \times \text{ECF} \quad (9)$$

where the total cost is calculated at worksheet (255) or (355) and TFA is the total floor area of the dwelling at worksheet (4).

The SAP rating takes into account energy for lighting, and also energy generated in the dwelling using technologies like micro-CHP or photovoltaics.

The SAP rating scale has been set so that SAP 100 is achieved at zero-ECF. It can rise above 100 if the dwelling is a net exporter of energy. The SAP rating is essentially independent of floor area.

The SAP rating is rounded to the nearest integer. If the result of the calculation is less than 1 the rating should be quoted as 1.

Energy efficiency rating bands are defined by the SAP rating according to Table 14.

### 14 CARBON DIOXIDE EMISSIONS AND PRIMARY ENERGY

CO<sub>2</sub> emissions attributable to a dwelling are those for space and water heating, ventilation and lighting, less the emissions saved by energy generation technologies.

The calculation should proceed by following the appropriate section of the SAP worksheet, designed for calculating carbon dioxide emissions for:

- a) individual heating systems and heat networks without combined heat and power (CHP); or
- b) heat network with CHP or utilising waste heat from power stations.

The Environmental Impact Rating (EI rating) is related to the annual CO<sub>2</sub> emissions by:

$$\text{CF} = (\text{CO}_2 \text{ emissions}) / (\text{TFA} + 45) \quad (10)$$

$$\text{if CF} \geq 28.3 \quad \text{EI rating} = 200 - 95 \times \log_{10}(\text{CF}) \quad (11)$$

$$\text{if CF} < 28.3 \quad \text{EI rating} = 100 - 1.34 \times \text{CF} \quad (12)$$

where the CO<sub>2</sub> emissions are calculated at (272) or (383) and TFA is the total floor area of the dwelling at (4).

The EI rating scale has been set so that EI 100 is achieved at zero net emissions. It can rise above 100 if the dwelling is a net exporter of energy. The EI rating is essentially independent of floor area.

The EI rating is rounded to the nearest integer. If the result of the calculation is less than 1 the rating should be quoted as 1.

Environmental impact rating bands are defined by the EI rating according to Table 14.

Primary energy is calculated in the same way as CO<sub>2</sub> emission using the primary energy factors in Table 12 in place of the CO<sub>2</sub> emission factors.

## 15 BUILDING REGULATIONS AND DWELLING EMISSIONS RATE (DER)

**This section will be updated in future to take account of any changes to Building Regulations. The current wording is taken from SAP 2012 and is not necessarily applicable to SAP 10.0.**

Building Regulations may refer to outputs from SAP as a method of demonstrating compliance with regulations for the conservation of fuel and power and/or limitation of energy use.

The current requirements of regulations can be checked against documents available at:

England	<a href="http://www.communities.gov.uk/">http://www.communities.gov.uk/</a>
Wales	<a href="http://wales.gov.uk/topics/planning/buildingregs/?lang=en">http://wales.gov.uk/topics/planning/buildingregs/?lang=en</a>
Scotland	<a href="http://www.scotland.gov.uk/bsd">www.scotland.gov.uk/bsd</a>
Northern Ireland	<a href="http://www.buildingregulationsni.gov.uk">www.buildingregulationsni.gov.uk</a>

As at the date of this document, Building Regulations in all four jurisdictions mentioned above place limitations on the permissible annual CO<sub>2</sub> emissions from new dwellings, expressed in kilograms per square metre of floor area (kg/m<sup>2</sup>). This quantity, when calculated taking account of specific requirements in the applicable regulatory document and expressed in kilograms per unit floor area to two decimal places, is known as the Dwelling Emissions Rate, or DER. The applicable regulatory document may impose specific conditions for the calculation of the DER (such as the version of SAP to be used), which must be followed for DER calculations.

Appendix R gives reference values to define a notional dwelling, which may be referred to in Building Regulations in connection with establishing a target fabric energy efficiency and/or a target CO<sub>2</sub> emissions rate.

## References

1. **Anderson B R, A J Clark, R Baldwin and N O Milbank**, *BREDEM The BRE Domestic Energy Model: background, philosophy and description*. BRE Report: BR 66, BRE, Garston, 1985
2. **Henderson G and L D Shorrock**, *BREDEM - BRE Domestic Energy Model - testing the predictions of a two zone model*, Build. Serv. Eng. Res. Technol., 7(2) 1986, pp87-91
3. **Shorrock L D,, Macmillan S, Clark J and Moore G**, *BREDEM-8, a Monthly Calculation Method for Energy Use in Dwellings: Testing and Development*, Proceedings of Building Environmental Performance '91, BEPAC 1991
4. **Shorrock L D, Dunster J E, Seale C F, Eppel H and Lomas K J**, *Testing BREDEM-8 Against Measured Consumption Data and Against Simulation Models*, Proceedings of Building Environmental Performance '94, BEPAC 1994
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7. **Anderson B R, Chapman PF, Cutland N G, Dickson C M, Henderson G, Henderson J H, Iles P J, Kosmina L and Shorrock L D**. *BREDEM-12 Model description – 2001 update*. BRE, Garston, 2002.
8. **Henderson J H and Hart J M**, *BREDEM 2012*, BRE, Garston, 2013.
9. **CIBSE Guide A3**, The Chartered Institution of Building Services Engineers, CIBSE, London, 2006

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 Fax 01344 328005  
[www.brebookshop.com](http://www.brebookshop.com)

## List of standards referred to in this document

Reference	Title	Content
BS EN ISO 6946	Building components and building elements – Thermal resistance and thermal transmittance – Calculation method	Calculation of U-values for walls and roofs.
BS EN ISO 13789	Thermal performance of buildings – transmission and ventilation heat transfer coefficients – Calculation method	Heat loss rate from whole building

Reference	Title	Content
BS EN ISO 10456	Building materials and products – Hygrothermal properties – Tabulated design values and procedures for determining declared and design thermal values	Lists of thermal data for materials
BS EN ISO 10077-1	Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: General	U-values for windows and doors
BS EN ISO 10077-2	Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames	U-values for window frames
BS EN ISO 12567	Thermal performance of windows and doors – Determination of thermal transmittance by hot box method	U-value measurement for windows and doors
BS EN ISO 13370	Thermal performance of buildings – Heat transfer via the ground – Calculation methods	U-values for floors
BS EN ISO 13790	Energy performance of buildings – Calculation of energy use for space heating and cooling	Energy calculations
BS EN 13203-2	Gas-fired domestic appliances producing hot water – Part 2: Assessment of energy consumption	Efficiency of gas combi boilers for DHW heating.
OFTEC Oil Firing Product Standard OPS 26	Guidance for the use of BS EN 13203-2:2006 for liquid fuel fired combination boilers up to 70 kW rated input and with up to 100 litres hot water storage capacity	Efficiency of oil combi boilers for DHW heating.
BS EN 16147	Heat pumps with electrically driven compressors – Testing and requirements for marking of domestic hot water units	Efficiency of heat pumps for DHW heating
BS EN 60531	Household electric thermal storage room heaters – Methods for measuring performance	Characteristics of storage heaters
BS 7977-1	Specification for safety and rational use of energy of domestic gas appliances – Part 1: Radiant/convector	Gas fires
CIBSE/ADE	Heat Networks: Code of Practice for the UK	Defines minimum performance requirements for heat networks
BS EN 15316-4-3	Energy performance of buildings — Method for calculation of system energy requirements and system efficiencies	Performance of solar thermal systems

British Standards are available from:

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 W4 4AL  
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 Fax: 020 8996 7001  
[www.bsigroup.com](http://www.bsigroup.com)

## Appendix A: Main and secondary heating systems

### A1 General principles

The **main heating system** is that which heats the largest proportion of dwelling. It is a heating system which is not usually based on individual room heaters (although it can be), and often provides hot water as well as space heating. Main heating systems are either identified via the Product Characteristics Database or are categorised on the basis of the generic types in Tables 4a and 4b.

Occasionally there may be two main heating systems, for example two separate boilers used to heat different parts of the dwelling or a system that utilises more than one heat generator. The total space heating requirement (98) is divided between the two systems in proportion to the amount of heat provided by each system. Where the two systems heat separate parts of the dwelling, unless specified otherwise for particular systems, the proportion of heat provided by each system should be taken as the relative heated floor area served by each system. The calculation of the space heating requirement uses the characteristics (responsiveness and control type) weighted for the two systems (see Tables 9b and 9c). Separate efficiencies, costs and emission factors are then applied for each system. The following restrictions apply:

- system 1 always heats the living area;
- heat networks, micro-CHP and heat pumps from the database can be only main system 1, except that a heat pump from the database providing DHW only can be assigned to main system 2 with a space heating fraction of zero;

The **secondary heating system** is a room heater type, taken from the room heaters section of Table 4a.

Only fixed secondary heaters are included in a description of the dwelling (e.g. a gas fire, a chimney and hearth capable of supporting an open fire, a wall-mounted electric fire).

Except as mentioned in the next paragraph, portable heaters are not counted for the purposes of SAP assessments: these are characterised by being:

- completely free standing and self-supporting on feet, legs or base on the floor, i.e. not wall mounted or specifically designed for a fireplace, and in the case of gas or oil heaters containing a built-in fuel store; and
- readily and easily transferred and relocated from one room to another, in the case of an electric heater having a lead and a plug.

A secondary system is always included for the SAP calculation when the main system (or main system 1 when there are two systems) is electric storage heaters or off-peak electric underfloor heating. This applies to main heating codes 401 to 407, 409 and 421. Portable electric heaters (693) are used in the calculation if no secondary system has been identified. SAP software inserts portable electric heaters for the calculation in such cases.

For detailed selection rules for main and secondary systems in existing dwellings see A2 below.

*Note that Building Regulations or other regulations may make additional specifications in relation to secondary heaters, which should be followed in the case of compliance calculations.*

The SAP calculation is based on the characteristics of the dwelling and the systems installed and not on the heating practices of the occupying household. That does not preclude further estimates of energy consumption being made to take account of actual usage. Such estimates are not part of SAP but could form the basis of advice given to the occupying household on how to make best use of the systems at their disposal.

### A2 Procedure for identifying main and secondary heating systems in existing dwellings

#### A2.1 Identifying the main system in existing dwellings

- (1) If there is a central system that provides both space and water heating and it is capable of heating at least 30% of the dwelling, select that system as the main heating system. If there is no system that provides



both space and water heating, then select the system that has the capability of heating the greatest part of the dwelling. For this purpose only, habitable rooms should be considered (i.e. ignore heaters in non-habitable rooms).

- (2) If two main systems are identified and both systems heat the living area, main system 1 is taken as heating most habitable rooms or, if both heat the same number of habitable rooms, the one that also provides water heating;
- (3) If there is still doubt about which is the main system, or which is main system 1, select the system that supplies useful heat to the dwelling at lowest cost (obtained by dividing fuel price by efficiency).

## **A2.2 Identifying the secondary system in existing dwellings**

In some cases several fixed secondary heaters may be present in the dwelling. The rules for identifying the secondary heating system are:

- (1) If a fixed secondary heater is found in a habitable room, that heater is the secondary, and any fixed secondary heaters in non-habitable rooms are disregarded.
- (2) If there is no fixed secondary heater in any habitable room, but there is a fixed heater in a non-habitable room, that heater is the secondary.
- (3) If no fixed secondary heater is identified in either habitable or non-habitable room, specify “No secondary heater”; SAP calculation will assume electric room heaters for the unheated habitable rooms.

If two types of secondary heater are present, the fixed heater which heats the greater number of rooms should be specified as the secondary system. If that condition does not resolve the choice, the one with the lowest cost (obtained by dividing fuel price from SAP Table 12 divided by the efficiency of the room heater) should be specified.

## **A3 Dwellings with inadequate heating systems**

### **A3.1 New dwellings**

The SAP assumes that a good standard of heating will be achieved throughout the dwelling. For dwellings in which the heating system is not capable of providing the standard, it should be assumed that the additional heating is provided by electric heaters, using the fraction given in Table 11 (but see also A3.3). For new dwellings that have no heating system specified, it should be assumed that all heat will be provided by electric heaters using electricity at the standard domestic tariff.

### **A3.2 Existing dwellings**

Some existing dwellings have heaters only in a limited number of rooms, generally gas or electric fires. In these cases the usual basis of calculation, that the dwelling is fully heated, still applies. Rooms without heaters are assumed to be heated by electric room heaters. The choice between main and secondary heating for the purposes of the calculation is decided as follows.

- (1) Count the number of habitable rooms and the number heated habitable rooms (for the definition of habitable rooms see S9.1 in Appendix S).
- (2) If 25% or less of the habitable rooms are actually heated, and are heated by room heater(s) using a fuel other than electricity, the (assumed) electric system is the main system (or main system 1 when there are two) for the purposes of the calculation and the other fuel is the secondary. This applies only if the identified main heater is a room heater and there is no identified secondary heater, and is subject to A3.3 below. If water heating is from the main system (e.g. the room heater has a back boiler) the water heating becomes from the secondary system for the calculation. A heated room means one with a heat emitter in the room.
- (3) If the number of habitable rooms actually heated is more than 25% but there is no identified secondary heater according to the rules in A2.2, the heaters in these rooms are the main system and the (assumed) electric heaters are the secondary.

- (4) If the number of habitable rooms actually heated is more than 25% and a secondary heater is identified, the procedure for assigning main and secondary heating systems outlined in section A2 applies.

*Examples.* A house with 6 habitable rooms with one gas fire would be treated as being electrically heated with a gas secondary heater (1 room out of 6). If there were two gas fires (2 rooms out of 6), the gas fires are the main heating and electricity the secondary. If there were 4 habitable rooms, and one gas fire (1 out of 4), the main heating would be electric and the gas fire the secondary.

### **A3.3 Highly insulated small dwellings**

In the case of highly insulated small dwellings, item (1) in A3.2 may not be realistic, for example a 3 kW gas fire could suffice to provide most of the heating needs. Accordingly, if the design heat loss (DHL) is less than 3 kW, the heating in the main room is the main system irrespective of the number of rooms heated. For this purpose, DHL is the annual average heat loss coefficient as calculated at worksheet (39), multiplied by a design temperature difference of 20 K.

Note. When considering improvement measures, this condition is tested only for the existing dwelling.

### **A3.4 Broken heating systems or no heating system**

SAP assumes that the installed heating systems are operational and takes no account of whether they are working or not. However, in the case where the main heating unit (e.g. boiler) is missing and thus the dwelling has no installed main heating system, or if there is no heating system present at all, the calculation should be done for main heating as direct electric heaters in all rooms (no secondary heaters).

## **A4 Description of the dwelling's heating systems and RdSAP software implementation**

A SAP assessor should record, for the purposes of entry into SAP calculation software, the actual heating systems (as found in the dwelling when surveyed), together with the number of habitable rooms and the number of heated habitable rooms. Where case A3.2 (1) applies, the description of the dwelling includes the actual main system. Where a choice has to be made between alternative systems, as described in Section A2, the SAP assessor should make the choice according to the circumstances existing in the dwelling while recording in a separate note any other fixed heaters present.

Software implementing the SAP calculation procedure then applies the remaining rules of this Appendix, namely:

- a) If there is no heating system, assign electric heaters as the main system heating all rooms (no secondary system).
- b) If 25% or less of the habitable rooms are heated and their heating is by a room heater (not electric), assign electric heaters as the main system and the identified room heaters as the secondary system, applying the secondary fraction according to Table 11 for electric room heaters as the main system. (This is not done when the condition in A3.3 applies.)

If two main heating systems have been identified (e.g. a gas fire in one room, a coal fire in another room, plus 6 unheated habitable rooms) then:

- assign electric heaters as main system 1
- assign the room heater entered as main system 1 as the secondary system
- main system 2 remains as it is
- set the fraction of heat from main system 2 equal to heated habitable rooms divided by total habitable rooms

- c) Otherwise if there are any unheated habitable rooms and no secondary system has been identified, undertake the calculation with electric secondary heating (portable electric heaters).
- d) If any fixed secondary heater has been identified, the calculation proceeds with the identified secondary heater.

e) An assumed heater, where main or secondary, is an electric portable heater. In case of main heating it does not have thermostatic control.

Table 11 gives the fraction of the heating that is assumed to be supplied by the secondary system. The treatment of secondary systems is not affected by any control options for the secondary system.

## Appendix B: Gas and oil boiler systems, boilers with a thermal store, and range cooker boilers

### B1 Boilers in the database

The Product Characteristics Database (see section 9.2.1) contains, in addition to efficiency, all the boiler parameters relevant to SAP calculations.

### B2 Gas and oil boiler systems in Table 4b

General definitions of the various modern boiler types are given in Appendix D. Table 4b gives efficiency values for use when measured data are not available. The following notes give guidance for the categories in Table 4b.

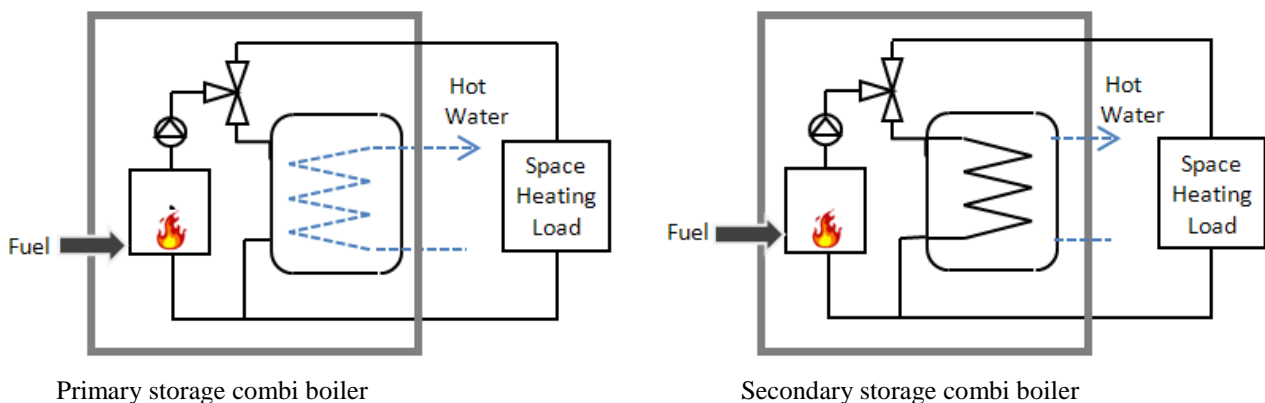
#### B2.1 Combination boilers

Table 4b does not distinguish between the sub-types of combination boiler, and the values given for 'combi' apply to all sub-types (on/off or modulating, instantaneous or storage).

For definitions of storage combination boilers see Appendix D.

A combination boiler with an internal hot water store may be either:

- Primary - a primary water store contains mainly water which is common with the space heating circuit.
- Secondary - a secondary water store contains potable water which is directly usable as domestic hot water.



**Figure B1 Primary and secondary storage combi boilers**

The essential difference between a CPSU (see section B2.5) and a storage combination boiler with a larger primary store is that in the case of a CPSU the feed to the space heating circuit is taken from the store, while in the case of a storage combi with a larger primary store, the store does not feed the space heating circuit.

#### B2.2 Boilers 1998 or later

If the ignition type is not known, a boiler with a fan-assisted flue may be assumed to have automatic ignition, and one with an open flue to have a permanent pilot light.

#### B2.3 Boilers with fan-assisted flue

'Low thermal capacity' means a boiler either having a copper heat exchanger or having an internal water content not exceeding 5 litres. If the position is uncertain the category of 'high thermal capacity' should be used.

#### B2.4 Boiler selected by date

The date refers to the year of manufacture of the boiler. If this is uncertain the older category should be used.

#### B2.5 Combined Primary Storage Unit (CPSU)

A CPSU is defined in Appendix D. The store must be at least 70 litres - if the store is less than 70 litres, the appliance should be treated as a storage combination boiler. A schematic illustration of a CPSU is shown in Figure B2.

Note: If the store is a different appliance from the boiler (ie contained within a separate overall casing) the system should be treated as a boiler with a thermal store as described in B3.

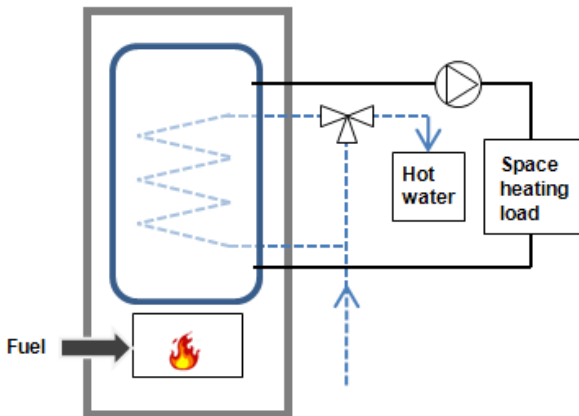


Figure B2 Combined primary storage unit (CPSU)

### B3 Boilers with a thermal store

All systems described in this section have hot water stores as a separate appliance from the boiler.

#### B3.1 Integrated thermal store

An integrated thermal store is designed to store primary hot water, which can be used directly for space heating and indirectly for domestic hot water. The heated primary water is circulated to the space heating (e.g. radiators). The domestic hot water is heated instantaneously by transferring the heat from the stored primary water to the domestic hot water flowing through the heat exchanger. A schematic illustration of an integrated thermal store is shown in Figure B3.

For an appliance to qualify as an integrated thermal store, the specification for integrated thermal stores<sup>9</sup> must be complied with, and at least 70 litres of the store volume must be available to act as a buffer to the space heating demand. If the HWA specification is not met then the device should be treated like a conventional boiler and hot water cylinder. If only the volume requirement is not met, then the device may be treated as a hot water only thermal store.

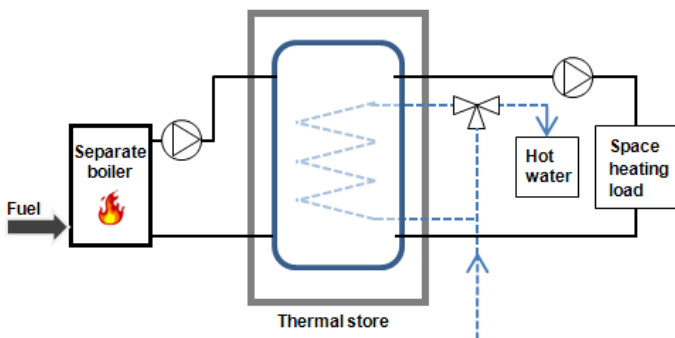


Figure B3 Integrated thermal store

#### B3.2 Hot water only thermal store

A hot water only thermal store is designed to provide domestic hot water only and is heated by a boiler. The domestic hot water is heated by transferring the heat from the primary stored water to the domestic hot water flowing through the heat exchanger, the space heating demand being met directly by the boiler. A schematic illustration of a hot water only thermal store is shown in Figure B4.

<sup>9</sup> Performance Specification for Thermal Stores. Obtainable from the Hot Water Association ([www.hotwater.org.uk](http://www.hotwater.org.uk))

For an appliance to qualify as a hot water only thermal store, the HWA specification for hot water only thermal stores must be complied with. If this requirement is not met then the device should be treated like a conventional boiler and hot water cylinder.

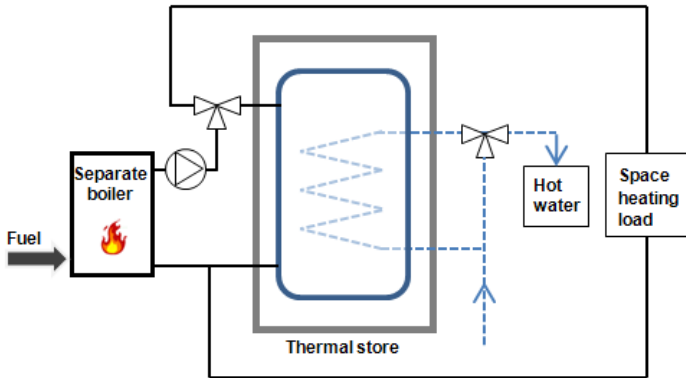


Figure B4 Hot water only thermal store

## B4 Range cookers

Range cookers are flued cooking appliances predominantly constructed of cast iron designed to provide some heat from their case into the space in which they are located. There are three types.

### B4.1 Range cooker with boiler for space heating

This type provide an independent water heating function for space heating in addition to the cooking function. There are two design variations:

- (i) **Twin burner range cooker/boiler** – an appliance with two independently controlled burners, one for the cooking function, one for the water heating function for space and/or water heating
- (ii) **Single burner range cooker/boiler** – an appliance with a single burner that provides a cooking function and a water heating function for space and/or water heating

For the twin burner type, the efficiency can be can be from the Product Characteristics Database, manufacturer’s declaration or Table 4a/4b, as explained in section 9.2.2 of this document.

For the single burner type, the efficiency should be obtained from Table 4a/4b.

### B4.2 Single burner range cooker/water heater

This type provides a cooking function and some heating of domestic hot water.

### B4.3 Single burner dry heat range cooker

This type is an appliance with a single burner that provides a cooking function. It is not included in SAP calculations.

## Appendix C: Heat networks, including those with Combined Heat and Power (CHP) and those that recover heat from power stations

### C1 Heat network definition

Heat networks are characterised as systems where heat is generated and supplied by a network and heat generator(s) that is located outside of the dwellings it serves. Various descriptive words may be assigned to such networks for categorisation purposes, such as “district”, “communal” and “community”. For SAP purposes, such network variations need not be considered.

CHP (Combined heat and Power) is defined as the simultaneous generation of heat and power in a single process.

There are two principal ways of producing heat for heat networks by a dedicated heat generator (but see also section C5):

- heat produced by boilers only (Figure C1);
- heat produced by a combination of boilers and CHP units (Figure C2).

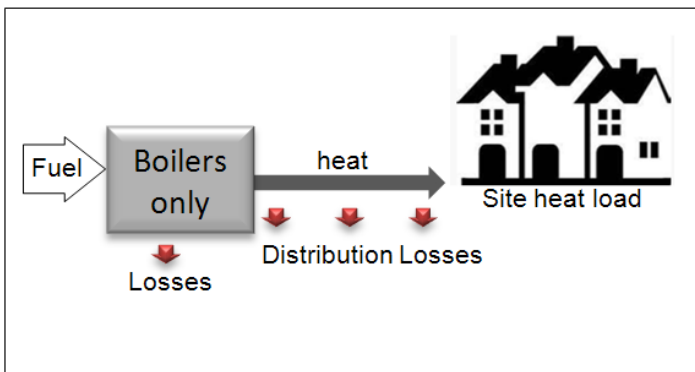


Figure C1: Heat networks with heat supplied by boilers only

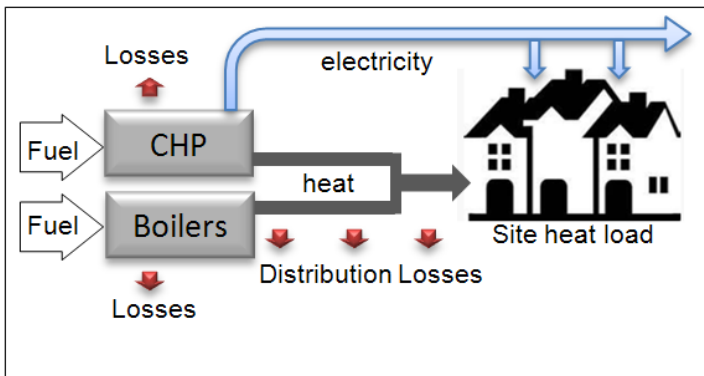


Figure C2: Heat networks with heat supplied by a combination of boilers and CHP

For heat networks with CHP, the CHP unit is the primary heat source, and back-up boilers of conventional design are used when the heat output of the CHP unit is insufficient to meet the instantaneous demand. The proportion of heat from CHP and from boilers varies from installation to installation.

The annual proportions of heat from the CHP and from conventional boilers, and the heat and electrical efficiencies of the CHP for the calculation of CO<sub>2</sub> emissions are held in the Products Characteristics Database for the heat network. If the network is not held in the database, these should be obtained either on the basis of operational records or in the case of a new network on the basis of its design specification. Heat efficiency is defined as the annual useful heat supplied by the CHP divided by the total annual fuel input, based on gross calorific value, and excluding any dumped heat (see Figure C3). The power efficiency is the total annual electrical power output divided by the total annual fuel input.

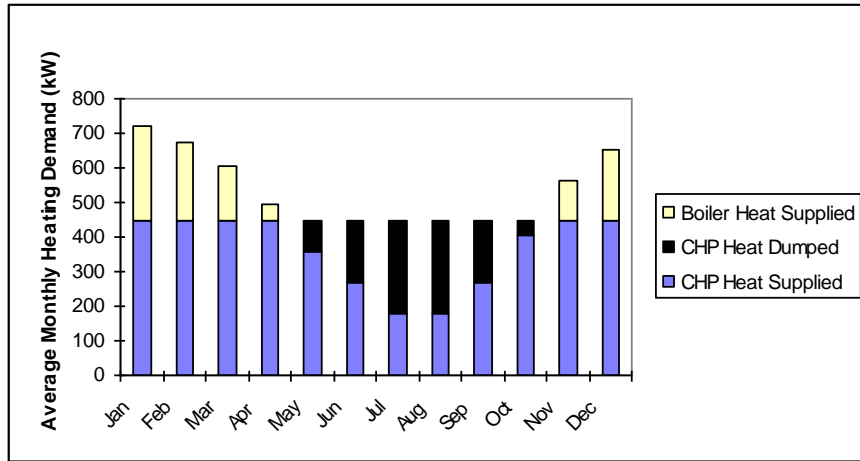


Figure C3: An example of a heat profile chart

The price of heat for heat networks is taken from Table 12. This price incorporates bulk rates for buying the fuel used in the heat generator, operating costs, energy used in pumping the hot water and, in the case of CHP, receipts from the sale of the electricity generated. The factor in Table 4c(3) allows for controls and charging method.

For the calculation of CO<sub>2</sub> emissions, the efficiency to be used is that of the heat generator. A default figure is given in Table 4a for boilers connected to heat networks but, if known, the actual efficiency of the heat generators should be used instead (see C2). For CHP units, the efficiency can be specified as either (a) the heat efficiency and the power efficiency, or (b) the overall efficiency and the heat-to-power ratio.

Section 12b of the SAP worksheet includes provision for a credit of CO<sub>2</sub> emissions for electricity generated by CHP. This credit is available whether or not the electricity is provided directly to the dwellings concerned; the only requirement is that the CHP provides heat to the dwelling via a heat main.

Performance data for specific heat networks is included in the Products Characteristics Database and should be used when available.

## C2 Boiler efficiency

The gross efficiency of boilers connected to heat networks is assessed for SAP purposes in the same way as for domestic boilers. The procedures referred to in Appendix D should be followed, including for boilers with rated output over 400 kW, except that the winter gross efficiency is used for all parts of the year (thus a separate summer gross efficiency need not be calculated or declared).

Where boilers of different efficiency are used in combination they are entered separately in worksheet (303b) to (303e) and corresponding subsequent lines. Alternatively, boilers using the same fuel may be treated as if they were a single boiler by assigning an average gross efficiency and total fraction calculated as follows:

$$\eta_{\text{average}} = \frac{\sum_{j=1}^n f_j}{\sum_{j=1}^n \frac{f_j}{\eta_j}} \quad \text{and} \quad f_{\text{total}} = \sum_{j=1}^n f_j$$

where

n is the number of boilers

f<sub>j</sub> is the fraction of annual heat provided by boiler j

η<sub>j</sub> is the winter gross efficiency of boiler j calculated as referred to in Appendix D

## C3 Heat distribution

### C3.1 Distribution loss

Heat network distribution heat losses are accounted for by multiplying the heat to be delivered by the heat network by a 'distribution loss factor' (DLF), calculated as:



$$\text{Distribution Loss Factor (DLF)} = \text{Heat generated} \div \text{Heat delivered}$$

‘Heat delivered’ is defined as the amount of heat supplied to the buildings connected to the heat network. It is measured at the interface between the heat network and the connected building, whether domestic or non-domestic. Note: In the case of a block of flats, it is the heat supplied to individual flats (dwellings) within the block. For example, a heat network distribution loss of 40% represents a DLF of 1.67 ( $100 \div (100-40)$ ).

Figure C4 displays the process for inputting heat network DLF values into SAP software. Default DLF values for networks compliant and not compliant with the CIBSE/ADE ‘Heat Networks: Code of Practice for the UK’ are entered in the PCDB for selection by the SAP assessor. This will facilitate future amendment if sufficient evidence becomes available.

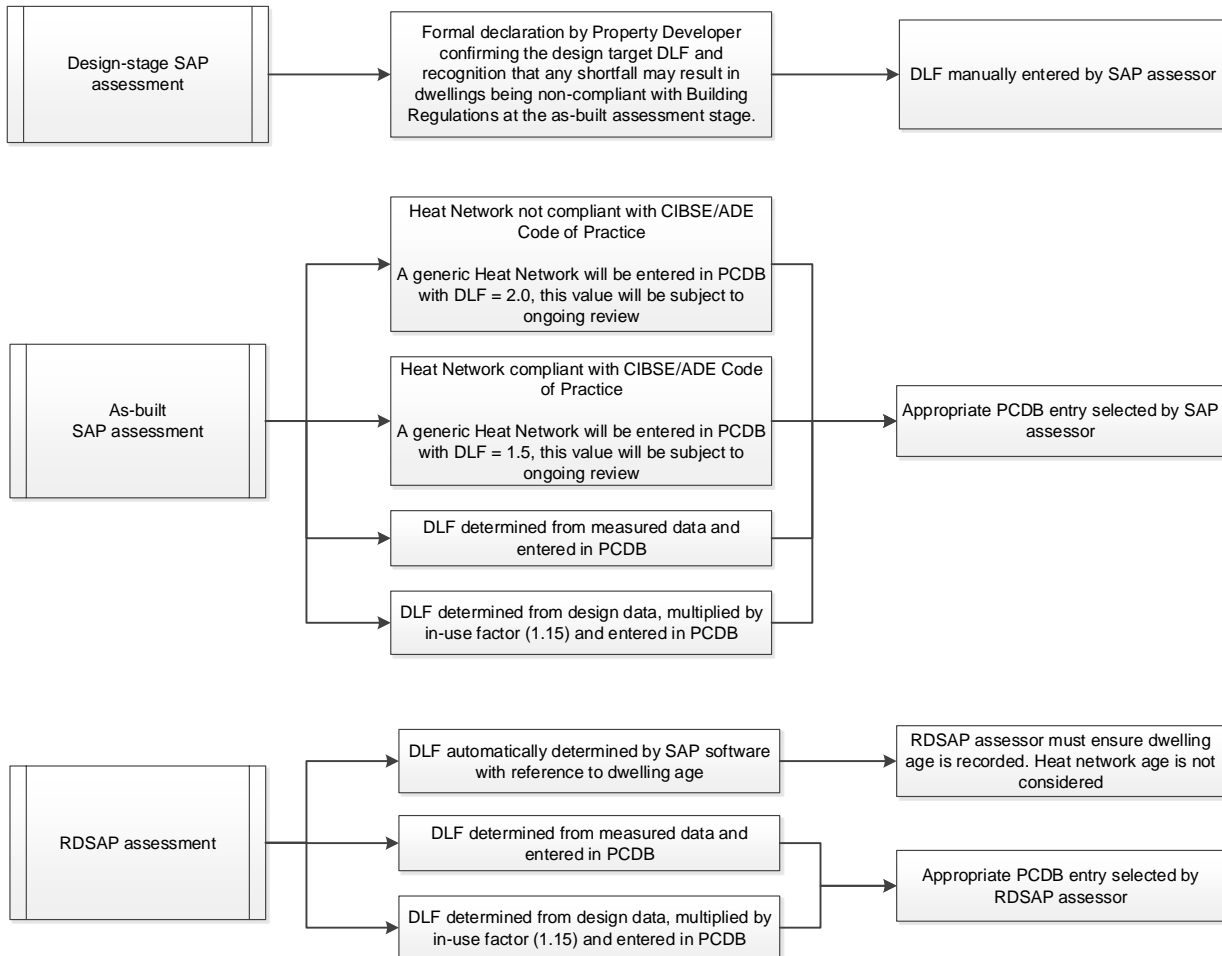


Figure C4: Distribution Loss Factor input process

For the purposes of SAP assessments, either design-stage or as-built, the network specific heat loss, expressed as a DLF, can be determined using actual consumption data and entered in the Product Characteristics Database (PCDB)<sup>10</sup>. Where network heat losses are estimated for the purpose of PCDB entry, the DLF includes an in-use factor of 1.15 (applied by the PCDB administrator during processing and subject to ongoing review).

For design-stage SAP assessments, a DLF of  $\geq 1$  can be manually entered by the SAP assessor. The entered DLF 0 will require a suitable formal notification by the Property Developer to be supplied to the SAP assessor; this must confirm the design target DLF. Any shortfall in the DLF during construction may result in non-compliance with the Building Regulations at the as-built assessment stage.

For as-built SAP assessments, a default DLF of 1.5 is applied if the heat network is designed and commissioned in accordance with the CIBSE/ADE ‘Heat Networks: Code of Practice for the UK’. This will require that the SAP assessor receives evidence via a certificate or headed letter from both the network designer and commissioning engineer, both of whom must have the necessary authority and competence to make such declarations.

<sup>10</sup> See: <http://www.ncm-pcdb.org.uk>

For as-built SAP assessments for new dwellings supplied by heat networks, a default DLF of 2.0 is applied if the network is not designed and commissioned in accordance with the CIBSE/ADE 'Heat Networks: Code of Practice for the UK'.

For undertaking RdSAP assessments of existing buildings, Table 12c provides Distribution Loss Factors by dwelling age.

### **C3.2 Energy for pumping**

CO<sub>2</sub> emissions associated with the electricity used for pumping water through the distribution system are allowed for by adding electrical energy equal to 1% of the energy required for space and water heating. For heat networks that are recorded in the PCDB, actual electrical pumping energy will be included in the data record (though this may be an estimate).

## **C4 Heat networks that recover waste heat from power stations**

This includes waste heat from power stations rated at more than 10 MW electrical output and with a power efficiency greater than 35% (otherwise the system should be considered as CHP).

For heat networks that recover heat from power stations, the waste heat is the primary heat source, and secondary boilers of conventional design are used when the available waste heat is insufficient to meet the instantaneous demand. The proportions of heat from the power station and from the conventional boilers will be held in the Product Characteristics Database for the heat network. Otherwise, these should be estimated, either on the basis of operational records or in the case of a new network on the basis of its design specification.

*Note: The applicable emission factor in Table 12 reflects emissions associated with the electricity used for pumping the water from the power station.*

## **C5 Permutations of heat generators**

Possible heat network configurations include (and can be combinations of) the following:

1. A single boiler or set of boilers all using the same fuel. In the case of a set of boilers the average seasonal efficiency for the boilers is used for the calculation (see C2).
2. Two or more boilers or two or more sets of boilers, using different fuels such as mains gas and biomass. In this case the total heat requirement is divided between the boilers or sets of boilers according to the design specification of the overall system. Different average seasonal efficiencies apply to the sets of boilers and the CO<sub>2</sub> emissions are calculated using the emission factors of the respective fuels.
3. CHP units and boiler(s), calculations according to section C1.

If there are two or more boilers or two or more sets of boilers using different fuels (in addition to the CHP units) the heat requirement from boilers is divided between the boilers or sets of boilers according to the design specification of the overall system. Different average seasonal efficiencies apply to the sets of boilers and the CO<sub>2</sub> emissions are calculated using the emission factors of the respective fuels.

4. Utilisation of waste heat from a power station topped up by boilers.
5. Geothermal heat topped up by boilers.
6. An electrically driven heat pump with various possibilities as to heat source, such as the ground or waste heat from an industrial process. The calculation is essentially the same as that for boiler systems, with the annual efficiency<sup>11</sup> for the heat pump system being used in place of boiler efficiency. The annual efficiency should take account of winter and summer operation as appropriate and of the temperature of the heat source.

SAP software should allow for combinations of up to five of the above heat sources for a heat network.

## **C6 Heat network providing DHW only**

Some heat networks provide DHW only, with the space heating provided by heaters in each dwelling.

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<sup>11</sup> To be determined using a method consistent with that for domestic heat pumps, see Appendix N.

In this case the specification and calculation of space heating is the same as for a dwelling not connected to a heat network.

Heat for a DHW-only heat network can be supplied by:

- Boilers
- Heat pumps
- CHP unit

SAP software should allow for up to two heat sources for a DHW-only heat network.

Data required are:

- fuel used by heat network (same fuel options as for network providing space and water heating)
- efficiency of boilers, heat pump or CHP
- if CHP, the heat-to-power ratio
- distribution loss factor (Section C3.1)
- whether a Heat Interface Unit (HIU) is within the dwelling (see Section 4.3)
- whether a hot water cylinder is within the dwelling and if so its volume plus either its measured loss factor or its insulation type and insulation thickness (see Section 4.3)

Note: If the presence of a HIU is unknown, it should not be specified. If a hot water cylinder is present, but the specification is unknown, default cylinder details should be entered, see Section 4.3. If both HIU and cylinder are present, heat losses from both should be included. If neither are present, default cylinder details should be entered.

Allow for the control factor from Table 4c(3), for the distribution loss factor as in C3.1 and pumping energy as in C3.2. Include one-half of the normal heat network standing charge in the calculation of fuel costs unless the space heating is also a heat network (see next paragraph).

This also allows for the case where the heat network is different for space heating and for water heating. Separate heat network parameters apply to each system including heat distribution characteristics. In this case the total standing charge is the normal heat network standing charge.

## **C7 Biofuel CHP**

For heat networks with CHP, it is possible for the total CO<sub>2</sub> emissions calculated at (373) to be negative. Once this quantity becomes negative, it becomes advantageous to increase the heating requirements of the dwellings, e.g. by removing insulation. Accordingly (373) should be set to zero unless the dwellings served by the heat network have a high standard of thermal insulation. That can be taken to be applicable in the case of new-build dwellings if the provisions for fabric insulation of the dwelling conform with the current requirements of Building Regulations, or for existing dwellings with a Heat Loss Parameter (HLP) of less than 2.

## **Appendix D: Method of determining seasonal efficiency values for gas, oil and solid fuel boilers**

This appendix provides boiler type definitions and the process for utilising gas, oil and solid fuel boiler efficiency data held in the Product Characteristics Database. This data has arisen from conformity with the Ecodesign regulations 811/2013 and 813/2013. The method for deriving seasonal efficiency values for these boiler types is contained within a supporting document available at: [www.ncm-pcdb.org.uk](http://www.ncm-pcdb.org.uk).

### **D1 Definitions**

Except for D1.1 these definitions apply only to boilers fuelled by gas or oil.

#### **D1.1 Boiler**

A gas, liquid or solid fuelled appliance designed to provide hot water for space heating. It may (but need not) be designed to provide domestic hot water as well.

#### **D1.2 Condensing boiler**

A boiler designed to make use of the latent heat released by the condensation of water vapour in the combustion flue products. The boiler must allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain. 'Condensing' may only be applied to the definitions D1.5 and D1.10 inclusive. Boilers not so designed, or without the means to remove the condensate in liquid form, are called 'non-condensing'.

#### **D1.3 Modulating boiler**

A boiler with the capability to vary the fuel burning rate, whilst maintaining continuous burner firing, to achieve a heat output no greater than 30% of nominal heat output. 'Modulating' may be applied to the definitions D1.5 and D1.10 inclusive.

#### **D1.4 On/off boiler**

A boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing or a boiler unable to achieve a heat output of 30% or less whilst continuously firing. This includes those with alternative burning rates set once only at time of installation, referred to as range rated. 'On/off' may be applied to the definitions D1.5 and D1.10 inclusive.

#### **D1.5 Regular boiler**

A boiler which does not have the capability to provide domestic hot water directly (i.e. not a combination boiler). It may nevertheless provide domestic hot water indirectly via a separate hot water storage cylinder.

#### **D1.6 Combination boiler**

A boiler with the capability to provide domestic hot water directly, in some cases containing an internal hot water store.

#### **D1.7 Instantaneous combination boiler**

A combination boiler without an internal hot water store, or with an internal hot water store of capacity less than 15 litres.

#### **D1.8 Storage combination boiler**

A combination boiler with an internal hot water store (primary or secondary/potable water) of capacity at least 15 litres but less than 70 litres.

OR

A combination boiler with an internal secondary/potable hot water store of capacity at least 70 litres.

OR

A combination boiler with an internal primary hot water store of capacity at least 70 litres, in which the feed to the space heating circuit is not taken directly from the store. Stored heat is only used for potable hot water service, i.e. via a heat exchanger. If the store is at least 70 litres and the feed to the space heating circuit is taken directly from the store, treat as a CPSU (D1.9).

### D1.9 Combined primary storage unit (CPSU)

A single appliance designed to provide both space heating and the production of domestic hot water, in which there is a burner that heats a thermal store which contains mainly primary water which is in common with the space heating circuit. The store must have a capacity of at least 70 litres and the feed to the space heating circuit must be taken directly from the store.

### D1.10 Low temperature boiler

A non-condensing boiler designed and tested as a low temperature boiler, as defined by EN 15502-1. These are not recognised by the calculation method associated with this appendix.

### D1.11 Keep-hot facility

A facility within an instantaneous combination boiler whereby water within the boiler may be kept hot while there is no demand. The water is kept hot either (i) solely by burning fuel, or (ii) by electricity, or (iii) both by burning fuel and by electricity, though not necessarily simultaneously.

## D2 Method for calculating efficiencies for gas and oil boilers

The efficiencies calculated and held in the PCDB are:

- Winter and summer seasonal efficiencies for SAP calculations. The winter seasonal efficiency ( $\eta_{\text{winter}}$ ) is used for space heating. The summer seasonal efficiency ( $\eta_{\text{summer}}$ ) applies to water heating in summer; the water heating efficiency in winter is derived from both.
- The comparative hot water efficiency is a general indicator of efficiency for boilers; it is not used for SAP calculations.<sup>12</sup>

### D2.1 Using efficiency values from the PCDB

#### (1) Space heating

The efficiency is the winter seasonal efficiency  $\eta_{\text{winter}}$  (from PCDB record or Table 4b), increased if appropriate by an increment from Table 4c/Appendix D2.2.

#### (2) Water heating by a boiler for which EN 13203-2 or OPS 26 data is not available<sup>13</sup>

If the boiler provides both space and water heating, and the summer seasonal efficiency is lower than the winter seasonal efficiency, the efficiency is a combination of winter and summer seasonal efficiencies according to the relative proportion of heat needed from the boiler for space and water heating in the month concerned:

$$\eta_{\text{water}} = \frac{Q_{\text{space}} + Q_{\text{water}}}{\frac{Q_{\text{space}}}{\eta_{\text{winter,monthly}}} + \frac{Q_{\text{water}}}{\eta_{\text{summer}}}} \quad (\text{D1})$$

If both space heating (98)<sub>m</sub> and water heating (64)<sub>m</sub> demand is zero in any month,  $\eta_{\text{water,monthly}} = \eta_{\text{summer}}$

where

$Q_{\text{space}}$  (kWh/month) is the quantity calculated at (98)<sub>m</sub> multiplied by (204) or by (205);

$Q_{\text{water}}$  (kWh/month) is the quantity calculated at (64)<sub>m</sub>;

$\eta_{\text{winter}}$  and  $\eta_{\text{summer}}$  are the winter and summer seasonal efficiencies (from Table 4b). For the purposes of equation (D1),  $\eta_{\text{winter}}$  does not include any efficiency adjustment due to design flow temperature or controls - see Table 4c and D2.2.

If the summer efficiency is higher than the winter value, or if the boiler provides water heating only,

$\eta_{\text{water,monthly}} = \eta_{\text{summer}}$  for all months.

#### (3) Water heating by a gas or oil combi boiler where test data according to EN 13203-2 (gas) or OPS 26 (oil) are available in the PCDB record<sup>13</sup>

<sup>12</sup> For combination boilers and CPSUs it is determined in accordance with EN 13203-2 load profile M test results. For regular boilers or combination boilers and CPSUs not tested in accordance with that standard, an alternative procedure is provided.

<sup>13</sup> The existence of suitable EN13203-2 or OPS26 test data in the PCDB will be detected by SAP software.

Follow the same procedure defined in (2) above, except take  $\eta_{\text{winter}}$  and  $\eta_{\text{summer}}$  from PCDB record (instead of Table 4b) as appropriate.

When the summer efficiency is higher than the winter value, the water heating efficiency is the same as the summer efficiency for all months. In this case different procedures apply to the calculation of storage loss (for a storage combi boiler) and additional combi loss, see Tables 3b and 3c.

## D2.2 Efficiency corrections for condensing boilers from the PCDB

SAP provides condensing boiler space heating efficiency calculations ( $\eta_{\text{winter}}$ ) that are corrected for the following range of situations<sup>14</sup>:

- a) Modulating boilers without enhanced load or weather compensation (Ecodesign Class I)
- b) On/off boilers without enhanced load or weather compensation (Ecodesign Class I or IV controls)
- c) Modulating boilers with Ecodesign Class II, V or VIII controls
- d) On/off boilers with Ecodesign Class III controls
- e) Modulating boilers with Ecodesign Class VI controls
- f) On/off boilers with Ecodesign Class VII controls
- g) The above variations at five emitter design temperatures and for three fuels (90 combinations)

For efficiency corrections relating to Ecodesign control class<sup>15</sup>, only where a controller is compatible with the condensing boiler and compliant with the relevant definition, as declared by the manufacturer, then entered in the PCDB, can an efficiency credit be awarded.

Tables D1, D2 and D3 display efficiency corrections derived generically for on/off and modulating boilers. These are compared against an emitter system design return temperature of 60°C – the default base case.

The tables provide for four design flow temperatures categories. The design flow temperature can be designed and specified by a suitably qualified person, then recorded and reported to the SAP assessor via a design, installation and commissioning certificate in accordance with the requirements of SAP – see Section 9.3.

For design flow temperatures that are not categorised, SAP software will enable the entry of specific design flow temperatures, providing linear interpolation between categories. For design flow temperatures above 80°C, the efficiency correction for 80°C is used. For design flow temperatures below 35°C, the efficiency correction for 35°C is used.

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<sup>14</sup> This treatment does not apply to non-condensing boilers.

<sup>15</sup> See section 9.4 for details of how Ecodesign temperature control class definitions relate to SAP definitions.

<b>Mains gas</b>	Efficiency adjustment for various control and emitter temperature options (% gross points)			
Design flow/return temperature (°C)	80/60 or 70/60	55/47.1	45/38.6	35/30
<b>On/off boiler</b>				
Class I or IV (Room thermostat or TPI)	0%	2.3%	5.2%	7.2%
Class III (Weather compensator)	0.9%	3.5%	6.0%	7.7%
Class VII (Enhanced weather compensator)	2.3%	5.4%	7.2%	8.7%
<b>Modulating boiler</b>				
Class I (Room thermostat)	0%	2.4%	5.5%	7.8%
Class II, V and VIII (Weather compensator or Enhanced load compensator)	0.7%	3.4%	6.1%	8.0%
Class VI (Enhanced weather compensator)	1.8%	5.0%	6.9%	8.4%

Table D1 - Efficiency improvement values for main gas condensing boilers with various control and design flow temperature options

<b>LPG</b>	Efficiency adjustment for various control and emitter temperature options (% gross points)			
Design flow/return temperature (°C)	80/60 or 70/60	55/47.1	45/38.6	35/30
<b>On/off boiler</b>				
Class I or IV (Room thermostat or TPI)	0%	1.7%	4.1%	6.1%
Class III (Weather compensator)	1.0%	2.7%	4.9%	6.7%
Class VII (Enhanced weather compensator)	2.2%	4.3%	6.1%	7.6%
<b>Modulating boiler</b>				
Class I (Room thermostat)	0.0%	1.9%	4.5%	6.8%
Class II, V and VIII (Weather compensator or Enhanced load compensator)	0.9%	2.7%	5.1%	7.0%
Class VI (Enhanced weather compensator)	1.8%	4.0%	5.9%	7.4%

Table D2 - Efficiency improvement values for LPG condensing boilers with various control and design flow temperature options

<b>Oil</b>	Efficiency adjustment for various control and emitter temperature options (% gross points)			
Design flow/return Temperature (°C)	80/60 or 70/60	55/47.1	45/38.6	35/30
<b>On/off boiler</b>				
Class I or IV (Room thermostat or TPI)	0%	1.2%	2.9%	4.9%
Class III (Weather compensator)	0.7%	2.0%	3.6%	5.5%
Class VII (Enhanced weather compensator)	1.7%	3.2%	4.9%	6.4%
<b>Modulating boiler</b>				
Class I (Room thermostat)	0%	1.3%	3.1%	5.4%
Class II, V and VIII (Weather compensator or Enhanced load compensator)	0.4%	1.9%	3.7%	5.7%
Class VI (Enhanced weather compensator)	1.2%	2.7%	4.5%	6.1%

Table D3 - Efficiency improvement options for oil condensing boilers with various control and design flow temperature options



## Appendix E: Method of determining seasonal efficiency for gas, oil and solid fuel room heaters

*Note: The data and equations in this appendix are for manufacturers to calculate seasonal efficiency for declaration purposes. They are not to be used by SAP assessors.*

This appendix sets out the method to be used to determine the seasonal efficiency for gas, oil and solid fuel room heaters. It applies to room heaters used as main heating or as secondary heating.

### E1 Efficiency determination

Only test results obtained by one of the recognised methods given in Table E1, Table E2 and Table E3 may be used to establish a seasonal efficiency for SAP calculations. The methods give comparable results.

**Table E1 : Recognised efficiency test methods for gas room heaters**

Reference	Title	Applies to (code in Table 4a or 4b)
BS EN 613:2001	Independent gas-fired convection heaters	609
BS EN 13278:2013	Open-fronted gas-fired independent space heaters	607
BS EN 1266:2002	Independent gas-fired convection heaters incorporating a fan to assist transportation of combustion air and/or flue gases	610
BS 7977-1:2009+A1:2013	Specification for safety and rational use of energy of gas domestic appliances. Part 1: Radiant/Convectors	603, 604, 605, 606
BS 7977-2:2003	Specification for safety and rational use of energy of gas domestic appliances. Part 2: Combined appliances: Gas fire/back boiler	109

**Table E2 : Recognised efficiency test method for oil room heaters**

Reference	Title	Applies to (code in Table 4a or 4b)
OFS A102:1999	Oil fired room heaters with atomising or vaporising burners with or without boilers, heat output up to 25 kW	131, 132, 621, 622, 623, 624

**Table E3 : Recognised efficiency test methods for solid fuel room heaters**

Reference	Title	Applies to (code in Table 4a)
BS EN 13229:2001	Inset appliances including open fires fired by solid fuels – Requirements and test methods	156, 631, 632
BS EN 13240:2001	Room heaters fired by solid fuel - Requirements and test methods	158, 633, 634
BS EN 14785:2006	Residential space heating appliances fired by wood pellets – Requirements and test methods	159, 635, 636

Efficiency test results are normally calculated using the net calorific value of fuel. Before a declaration can be made, conversion to gross must be carried out by multiplying the efficiency by the appropriate conversion factor given in Table E4.

**Table E4: Efficiency conversion factors**

Fuel	Net-to-gross conversion factor
Natural gas	0.901
LPG (propane or butane)	0.921
Oil (kerosene or gas oil)	0.937
Biodiesel or bioethanol	0.937
House coal	0.97
Anthracite	0.98
Manufactured smokeless fuel	0.98
Wood logs	0.91
Wood chips	0.91
Wood pellets	0.91

## E2 Declaring the efficiency of gas, oil and solid fuel room heaters

Manufacturers' declarations so calculated should be accompanied by the following form of words:

"The net efficiency of this appliance has been measured as specified in [insert appropriate entry from Table E1, Table E2 or Table E3] and the result after conversion to gross using the appropriate factor from Table E4 of SAP 2009 is [x]%. The test data have been certified by [insert name and/or identification of Notified Body]. The gross efficiency value may be used in the UK Government's Standard Assessment Procedure (SAP) for energy rating of dwellings."

## Appendix F: Electric CPSUs

An electric CPSU is a central heating system providing space and domestic water heating. Primary water heated mainly or entirely during low-rate periods is stored in a thermal store. It can use the electric 10-hour or 18-hour tariff.

The space heating circuit operates in the same way as a wet central heating system, with controls appropriate for wet systems. For domestic hot water, secondary water flows directly from the cold mains into a heat exchanger, where it is heated by the hot water in the store before being delivered to the taps.

The heat losses from the CPSU are calculated, as for other hot water storage vessels, in Section 4 of the calculation, using data from Table 2 or Table 2b.

### F1 Electric CPSUs using 10-hour electricity tariff

The CPSU draws some electricity at the high rate and some at the low rate. The high-rate fraction is calculated as follows. The procedure below applies to worksheet (201) onwards.

1. Calculate the high-rate fraction (for each month) using the following methodology:

a) Calculate minimum external temperature for which the stored heat can satisfy the demand temperature

$$T_{\min} = \frac{[(39)_m \times (93)_m] - C_{\max} + [1000 \times (45)_m \div (24 \times n_m)] - (95)_m}{(39)_m} \quad (\text{F1})$$

$n_m$  is the number of days in the month.  $C_{\max}$  is the low-rate heat available irrespective of power rating of the heating element, calculated using the formula:

$$C_{\max} = 0.1456 \times V_{\text{CS}} \times (T_w - 48) \quad (\text{F2})$$

where  $V_{\text{CS}}$  is the CPSU capacity in litres and  $T_w$  is winter operating temperature in °C.

In equations (F1) to (F4) items written as  $(39)_m$  etc. are references to worksheet numbers.

b) Calculate high-rate energy required

$$\begin{aligned} \text{if } T_{\min} - T_e = 0, \quad E_{\text{on-peak}} &= 0.024 \times (39)_m \times n_m \\ \text{otherwise} \quad E_{\text{on-peak}} &= \frac{0.024 \times (39)_m \times n_m \times (T_{\min} - T_e)}{1 - \exp(-(T_{\min} - T_e))} \end{aligned} \quad (\text{F3})$$

where  $T_e$  is the external temperature for month  $m$ .

2. For June to September (water heating only) set the high-rate fraction to 0. For other months calculate the high-rate fraction

$$F = \frac{E_{\text{on-peak}}}{(98)_m + (45)_m} \quad (\text{F4})$$

3. Apply the high-rate price to fraction  $F$  of the heating requirement (both space and water) and the low-rate price to fraction  $(1 - F)$ .

4. Enter the applicable value for central heating pump (Table 4f) in worksheet (230c).

### F2 Electric CPSUs using 18-hour electricity tariff

The 18-hour low rate applies to all space heating and water heating provided by the CPSU. The CPSU must have sufficient energy stored to provide heating during a 2-hour shut-off period. The 18-hour high rate applies to all other electricity uses.

## Appendix G: Flue gas heat recovery systems and Waste water heat recovery systems

### G1 Flue gas heat recovery systems (FGHRS)

When fitted to a condensing boiler a flue gas heat recovery system (FGHRS) recovers heat from the flue products to pre-heat the domestic hot water supply. Passive flue gas heat recovery devices (PFGHRD)<sup>16</sup> are a subset of FGHRS.

The boiler can be fired by mains gas, LPG or oil. The heat recovered is mostly from condensation of water vapour in the flue products and the application of an FGHRS is restricted to condensing boilers because non-condensing types are not generally adequately protected against the corrosive effects of condensate. For non-condensing boilers they would also alter the buoyancy characteristics of the combustion products posing a potential safety hazard. Where the device has a FGHRS heat store, energy recovered during space heating production can also be used to later offset the heat required for providing domestic hot water.

Data for FGHRS are brought into SAP calculations via the Product Characteristics Database (PCDB). The SAP assessor selects the FGHRS being used from a list offered by the software, identifying the device by means of brand name and model. The software then fetches the parameters needed from the PCDB.

A FGHRS is an option only if:

- main heating is from a boiler fired by mains gas, LPG or oil, and
- the boiler is a condensing type, and
- the fuel to which the FGHRS data apply is the same as the boiler fuel, and
- the boiler type is one of those to which the FGHRS data apply.

It is not relevant if the above conditions do not apply.

Note. The gains from the water heating system  $(65)_m$  must be calculated before the calculation of space heating. If there is an FGHRS the output from the water heater  $(64)_m$  is amended after calculation of space heating to include  $(63)_m$ . This does not create a circularity because the water heating gains are not affected by the FGHRS and can be calculated before  $(63)_m$  and  $(64)_m$  are known.

If there is also a WWHRS see section G5.

#### G1.1 FGHRS without a FGHRS heat store

If the FGHRS has no heat store calculate the saving in each month by:

$$S_m = K_{f1} \times K_n \times Q_{hw,m} \quad (G1)$$

where

- $S_m$  is the saving in month m due to the FGHRS;
- $K_{f1}$  is the useful fraction of heat recovered directly in a hot-water-only test (from PCDB record);
- $K_n$  is defined by (G7) below;
- $Q_{hw,m}$  is the energy content of water heated by the boiler in month m. This is worksheet  $(45)_m$  less any saving for a WWHRS calculated by equation (G10) and less any solar input calculated by equation (H1) in Appendix H.

#### G1.2 FGHRS with a FGHRS heat store

The heat store is within the FGHRS. In addition, there can be a close-coupled store (see G1.5) which can be heated also by a PV array (see G1.6).

The energy saving depends on the monthly hot water usage and space heating requirement. A data record for an FGHRS includes two sets of coefficients a, b and c defining a set of equations relating energy saving in kWh to hot water provided by the boiler,  $Q_{hw,m}$ , for different space heating requirements (typically 6 equations). One set of coefficients applies to instantaneous combi boilers without a keep-hot facility and without a close-coupled store, the other applies to all other boiler types. If there is also a WWHRS, see section G5 below.

<sup>16</sup> A PFGHRD is passive (does not consume electricity) whereas an FGHRS may do; also a PFGHRD is a single component whereas an FGHRS may consist of separate individual components that are not contained within a single package when installed.

If  $Q_{hw,m} \leq 0$  set the saving for month  $m$  to zero.

Otherwise the equations, valid in the range  $80 \leq Q_{hw,m} \leq 309$ , are of the form:

$$S_{0,m} = a \times \ln(Q_{hw,m}) + b \times Q_{hw,m} + c \quad (G2)$$

where

$S_{0,m}$  is the energy saving in month  $m$ , in kWh

$Q_{hw,m}$  is the energy content of water heated by the boiler in month  $m$ . This is worksheet (45)<sub>m</sub> less any saving for a WWHRS calculated by equation (G10) and less any solar input calculated by equation (H1) in Appendix H.

$\ln$  denotes natural logarithm

If  $Q_{hw,m} < 80$ , use equation (G2) with  $Q_{hw,m} = 80$  and multiply the result by  $Q_{hw,m} \div 80$

If  $Q_{hw,m} > 309$ , use equation (G2) with  $Q_{hw,m} = 309$ .

For each fuel for which the device has been tested there is a PCDB record containing:

- a) whether an internal or external heat store is fitted;
- b) the useful fraction of heat recovered directly in a hot-water-only test,  $K_{f1}$ , for use with an instantaneous combi boiler without a keep hot facility and without a close-coupled store (see G1.5);
- c) the total fraction of heat recovered directly in a hot-water-only test,  $K_{f2}$ , for use with all other boiler types;
- d) annual electrical consumption in kWh/year, if any;
- e) first set of coefficients  $a$ ,  $b$  and  $c$  for a range of space heating requirements applicable to an instantaneous combi boiler without a keep-hot facility and without a close-coupled store (assumes the FGHRs reduces the amount of luke-warm water rejected);
- f) second set of coefficients  $a$ ,  $b$  and  $c$  for a range of space heating requirements applicable to all other boiler types and combi configurations (assumes no water is rejected).

The procedure is defined by steps 1) to 8).

- 1) Obtain the 12 monthly space heating requirements of the main heating system,  $Q_{sp,m}$  (values for the months June to September are zero).

If fitted to the first main heating system:

$$Q_{sp,m} = (98)_m \times (204) \quad (G3)$$

If fitted to the second main heating system:

$$Q_{sp,m} = (98)_m \times (205) \quad (G4)$$

$Q_{sp,m} = 0$  if the boiler with the FGHRs does not provide space heating.

- 2) From the PCDB record, obtain the coefficients  $a$ ,  $b$  and  $c$  for the space heating requirement immediately above ( $Q_{sp1,m}$ ) and below ( $Q_{sp2,m}$ ) the actual monthly space heating requirements  $Q_{sp,m}$ . If the boiler is an instantaneous combi without keep-hot facility and without a close-coupled store (see G1.5) use the first set of coefficients  $a$ ,  $b$  and  $c$ ; for any other type of boiler use the second set of coefficients and apply a correction according to the water storage arrangement in step 7). If  $Q_{sp,m}$  is exactly equal to a value in the PCDB omit steps 3) and 4) and use the corresponding coefficients to calculate the monthly savings,  $S_{0,m}$ , according to equation (G2).
- 3) Calculate the estimated monthly saving for the space heating requirements immediately above ( $Q_{sp1,m}$ ) and below ( $Q_{sp2,m}$ ) the actual requirement using equation (G2).
- 4) Using linear interpolation, calculate the monthly saving,  $S_{0,m}$ , for the each monthly space heating requirement ( $Q_{sp,m}$ ) of the main heating system from the saving for space heating requirements immediately above ( $Q_{sp1,m}$ ) and below ( $Q_{sp2,m}$ ).
- 5) If  $S_{0,m}$  is negative set it to zero.
- 6) If  $Q_{sp,m}$  is greater than the largest value of space heating requirement in the PCDB record, calculate the saving using the equation for the largest value of space heating requirement in the PCDB record.

- 7) For instantaneous combi boilers without a keep-hot facility and not connected to a close-coupled store (see G1.5), set  $S_m = S_{0,m}$  and omit this step.

Otherwise amend the savings to include the heat recovered while heating the hot-water store according to the water storage arrangement as follows.

- a. In the case of a combi boiler with keep-hot facility,

$$S_m = S_{0,m} + 0.5 \times K_{f2} \times (Q_{c,m} - Q_{ce,m}) \quad (G5)$$

where

- $S_m$  is the saving in month m due to the FGHRs;
- $S_{0,m}$  is the saving calculated at step 4);
- $K_{f2}$  is the total fraction of heat recovered directly in a hot-water-only test;
- $Q_{c,m}$  is the applicable combi loss in month m (Table 3a, 3b or 3c) as at (61)<sub>m</sub>;
- $Q_{ce,m}$  is the electrical energy used in month m by the keep-hot (Table 4f), if any;
- 0.5 allows for the lower heat transfer to the FGHRs store compared to heat transfer directly to the cold water feed.

- b. If the boiler is a storage combi, a regular boiler supplying a cylinder or thermal store, a CPSU, or an instantaneous combi connected to a close-coupled store,

If  $Q_{hw,m} \leq 0$  set  $S_m = 0$ , otherwise

$$S_m = S_{0,m} + 0.5 \times K_{f2} \times [Q_{loss,m} - (1 - K_n) \times Q_{hw,m}] \quad (G6)$$

where

- $S_m$  is the saving in month m due to the FGHRs;
- $S_{0,m}$  is the saving calculated at step 4);
- $K_{f2}$  is the total fraction of heat recovered directly in a hot-water-only test;
- $Q_{loss,m}$  is the total of the storage, primary and combi loss in month m, equal to (57)<sub>m</sub> + (59)<sub>m</sub> + (61)<sub>m</sub>;
- $K_n$  is related to the coincidence of hot-water draw-off and boiler firing and is given by equations (G7);
- $Q_{hw,m}$  is as defined below equation (G2).

$$\left. \begin{aligned} K_n &= 0 && \text{if } V_k \geq 144 \\ K_n &= 0.48 - V_k \div 300 && \text{if } 75 \leq V_k < 144 \\ K_n &= 1.1925 - 0.77 V_k \div 60 && \text{if } 15 < V_k < 75 \\ K_n &= 1 && \text{if } V_k \leq 15 \end{aligned} \right\} \quad (G7)$$

where

- $V_k$  is the storage volume in the case of a regular boiler, a secondary storage combi boiler or a close-coupled store;
- $V_k$  is 1.3 times the storage volume in the case of a primary storage combi or a CPSU.

Note 1 In the case of a twin-coil cylinder connected to a regular boiler,  $V_k$  is the volume of the cylinder less the dedicated volume for solar or WWHRs storage.

Note 2 In the case of a close-coupled store  $V_k$  is obtained from the PCDB record for the FGHRs. In other cases  $V_k$  is obtained from the PCDB record for the boiler (if applicable) or is supplied by the SAP assessor (e.g. volume of hot-water cylinder used with a regular boiler).

### G1.3 FGHRs adjustment to energy requirements for water heating

Include  $S_m$  (as negative values) in the calculation of (64)<sub>m</sub>.

If there are two boilers each with an FGHRs fitted, apply the savings for the boiler that provides domestic hot water.

**G1.4 FGHS electrical power**

Some systems may require electrical power. If that is the case a non-zero value (kWh/year) is included in the PCDB record which is added into (231).

**G1.5 FGHS using a close-coupled store**

A FGHS for an instantaneous combi boiler without a keep-hot facility may include a close-coupled store, containing primary water, as a package. This is in addition to any FGHS store. The close-coupled store is connected to the boiler by not more than 1.5 m of insulated pipework (primary loss = 0) and its heating is controlled by a time clock (so that 0.9 is applied to the loss factor in Table 2b). In this case the characteristics of the close-coupled store in the PCDB record (volume and heat store loss) and data from Tables 2b and 3a, 3b or 3c for an instantaneous combi boiler with a close-coupled store are used in section 4 of the SAP worksheet and the procedure in G1.2.

**G1.6 FGHS using a close-coupled store and a directly-powered photovoltaic array**

The close-coupled store in FGHS is kept warm by the combi boiler and maintained at 65°C by a separate channel that is controlled by a time clock. Electricity produced by the PV module feeds a low-voltage DC electric immersion heater within the close-coupled store via standard twin and earth mains cable. The store is subject to a maximum temperature of 85°C. There are no additional pumps and no power conversion to 230V AC. The procedure takes account of power loss in the connecting cable.

For these systems the PCDB record includes the fraction of PV power lost in the connecting cable, and user-supplied information is the installed kWp of the PV array and the orientation, tilt and overshadowing of the PV.

**Calculation of solar input**

The annual solar input, Q<sub>s</sub>, in kWh/year is calculated as follows.

Peak power of PV array		<input type="text"/>	(G1)
Annual solar radiation per m <sup>2</sup> from U3.3 for the orientation and tilt of the collector		<input type="text"/>	(G2)
Overshading factor = Z <sub>PV</sub> (from table M1)		<input type="text"/>	(G3)
Cable loss (provided in PCDB record)		<input type="text"/>	(G4)
Solar energy available	$0.84 \times (G1) \times (G2) \times (G3) \times [1 - (G4)] =$	<input type="text"/>	(G5)
Solar-to-load ratio	$(G5) \div \sum (45)_m =$	<input type="text"/>	(G6)
<i>if a WWHS or solar water heating is fitted this becomes <math>(G5) \div [\sum (45)_m - \sum S_m - Q_{s,w}]</math></i>			
Utilisation factor	if (G6) > 0, $1 - \exp[-1/(G6)]$ , otherwise enter "0" in (G7)	<input type="text"/>	(G7)
Volume of store, V <sub>k</sub> (provided in PCDB record)		<input type="text"/>	(G8)
Effective solar volume, V <sub>eff</sub> = 0.76 × (G8)		<input type="text"/>	(G9)
Daily hot water demand, V <sub>d,average</sub> , (litres)	(G10) = (43)	<input type="text"/>	(G10)
Volume ratio V <sub>eff</sub> /V <sub>d,average</sub>	$(G9) \div (G10) =$	<input type="text"/>	(G11)
Solar storage volume factor f(V <sub>eff</sub> /V <sub>d,average</sub> ) (not greater than 1.0)	$1 + 0.2 \times \ln(G11) =$	<input type="text"/>	(G12)
Annual solar input Q <sub>s</sub> (kWh)	$(G5) \times (G7) \times (G12) =$	<input type="text"/>	(G13)

Note: (43) and (45) are numbers of the main worksheet

The solar input (in kWh) for month m is

$$Q_{s,m} = -Q_s \times f_m \times n_m / 365 \tag{G8}$$

where f<sub>m</sub> is the solar irradiance for month m divided by the annual average solar irradiance for the applicable climate, orientation and tilt. Values of irradiance values on the horizontal are modified by the procedure in section U3.2 for orientation and tilt. The monthly values Q<sub>s,m</sub> are carried to (63)<sub>m</sub> of the main worksheet.

**G1.7 FGHRS combined with compensating controls and/or low temperature heating**

For FGHRS with a FGHRS heat store, multiply the monthly savings calculated at step 4, G1.2 by the factor in Table G1 below. Multiplication is not applicable to FGHRS without a FGHRS heat store (G1.1). Refer to 9.3, 9.4 and D2.2 for low temperature heating and compensating control definitions.

**Table G1: Factors for combining FGHRS with a FGHRS store and low temperature heating and/or compensating controls**

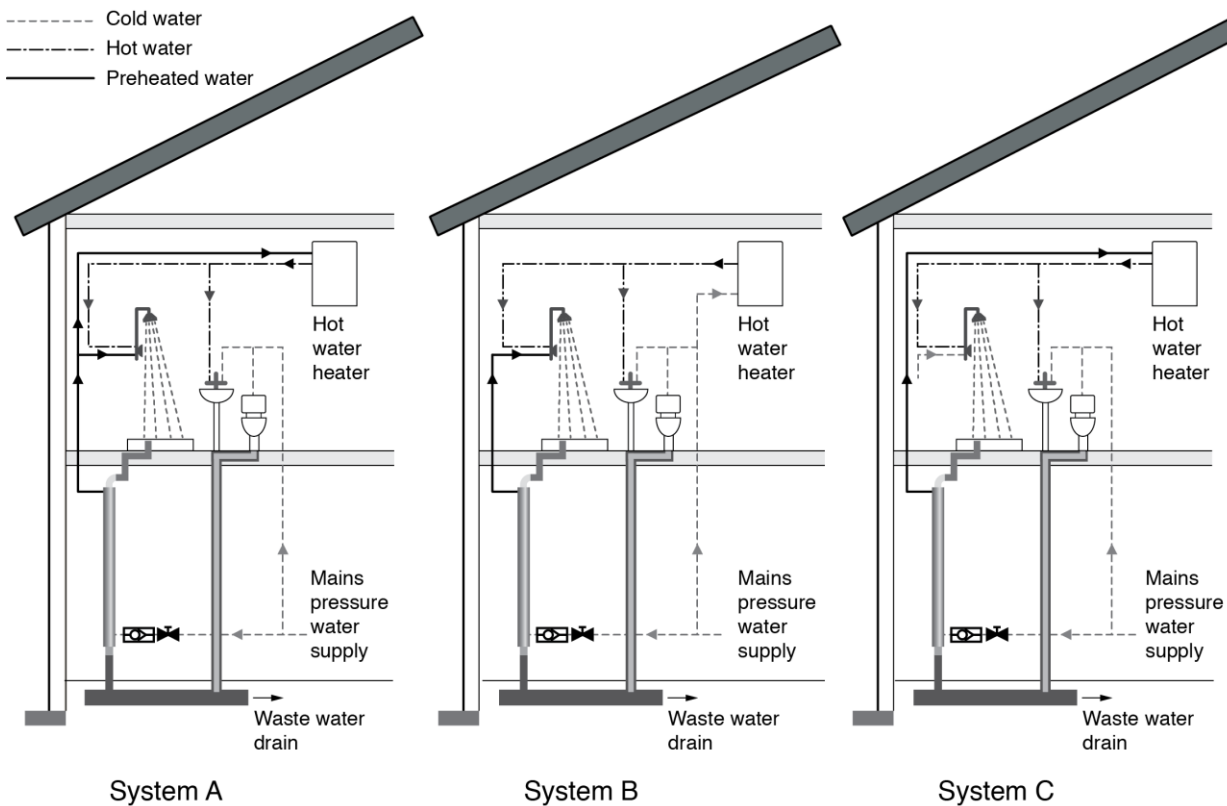
	Design flow/return Temperature (°C)			
	80/60 or 70/60	55/47.1	45/38.6	35/30
No compensation control	1.00	0.63	0.44	0.24
Weather or Enhanced Load Compensation	0.85	0.54	0.37	0.21
Enhanced Weather Compensation	0.61	0.40	0.28	0.15

**G2 Waste water heat recovery systems (WWHRS) - Instantaneous**

An instantaneous waste water heat recovery system uses a heat exchanger to recover heat from waste warm water as it flows through the waste plumbing system to pre-heat the cold water feed of a shower and a combi boiler or mains pressure hot water system (thermal store or unvented cylinder). The energy recovered depends on the temperature of the cold water feed to the dwelling (which varies by month) and the number and type of systems that are installed. The procedure described in this section deals with WWHRS linked to thermostatic mixer showers (where the shower water is a mixture of cold feed and that from the combi boiler or mains pressure hot water system). It is assumed that the WWHRS is located inside the heated envelope.

There are three types of plumbing arrangements for an instantaneous WWHRS (see Figure G1):

- System A: output of the heat exchanger is fed to *both* the shower *and* the combi boiler or hot water system
- System B: output of the heat exchanger is fed to the shower only
- System C: output of the heat exchanger is fed to the combi boiler or hot water system but not to the shower



**Figure G1: Instantaneous WWHRS configurations**

A WWHRS linked to an instantaneous electric shower (IES) is not covered by this procedure. However any IES present in the dwelling must be included in the total number of showers.



System data for WWHRs are brought into SAP calculations via the PCDB. The SAP assessor selects the WWHRs being used from a list offered by the software, identifying the device by means of brand name, model and system type and with reference to the Design Certificate or Installation & Commissioning Certificate<sup>17</sup> – this must have been supplied to the SAP assessor. More than one instantaneous WWHRs may be installed, but any second or subsequent WWHRs can be System B only. The software then fetches the parameters needed from the PCDB for each model, brand and system type identified.

If there is also an FGHRs see section G5.

### G2.1 Dwelling-specific data required for instantaneous WWHRs

Data on shower types and flow rates is collected as part of the hot water calculation described in Appendix J. The only additional data needed here is which shower outlets drain into each WWHRs.

### G2.2 Calculation procedure for Instantaneous WWHRs

1. Obtain performance data from the PCDB for each WWHRs present in the dwelling
2. Establish which shower outlets drain into each WWHRs (from SAP assessor inputs)
3. For each WWHRs,  $k$ , sum the monthly warm water volumes,  $V_{\text{shower},i,m}$  (litres/month), from Appendix J, step 1j, for each relevant shower outlet to obtain the total volume of warm water draining into it,  $V_{\text{WW},k,m}$  (litres/month).
4. Calculate the heat content of the warm water draining to each WWHRs,  $Q_{\text{WW},k,m}$  (kWh/month), with respect to the incoming cold water temperature for the month,  $T_{\text{cold},m}$  (°C), from Table J1, assuming warm water reaches the WWHRs at a temperature of 35°C.

$$Q_{\text{WW},k,m} = V_{\text{WW},k,m} \times (35 - T_{\text{cold},m}) \times 4.18 \div 3600 \quad (\text{G9})$$

5. Calculate the heat recovered by each WWHRs,  $S_{k,m}$  (kWh/month), by multiplying the heat available by the system's heat recovery efficiency,  $\eta_k$ , and utilisation factor,  $UF_k$ , both taken from the PCDB data entry.

$$S_{k,m} = Q_{\text{WW},k,m} \times \eta_k \times UF_k \quad (\text{G10})$$

6. Sum the heat recovered by each WWHRs to give the total saving from WWHRs,  $S_m$  (kWh/month)

$$S_m = \sum S_{k,m} \quad (\text{G11})$$

7. Include  $S_m$  (as negative values) in worksheet (63)<sub>m</sub>.

## G3 Waste water heat recovery systems (WWHRs) – Storage

A Storage WWHRs is a whole-house system whereby heat is extracted from waste water from baths and showers, and used to preheat the incoming cold water to a combi boiler or hot water system. The system may include a heat exchanger circulation pump and additional accessory pumps for satisfactory operation. Unlike an instantaneous WWHRs it does not require simultaneous waste and pre-heated water flow and so is able to recover heat from bath water. It is assumed that the storage WWHRs is located inside the heated envelope.

It is not possible to have more than one storage WWHRs, and a storage WWHRs cannot be applied in addition to an instantaneous WWHRs.

A storage WWHRs incorporates a storage volume,  $V_{\text{WW}}$ , dedicated to the recovered heat. There are two types:

- Combined: the dedicated storage volume is within the dwelling's hot water vessel  
 Separate: the dedicated storage volume is a separate vessel (typically for connection to instantaneous hot water heaters such as a combi boiler)

<sup>17</sup> See: [www.ncm-pcdb.org.uk](http://www.ncm-pcdb.org.uk)

Storage WWHRs products are tested with a separate or combined hot water vessel whose specification is defined by the manufacturer. The resulting performance data are valid when the dedicated storage volume is between  $V_{low}$  and  $V_{high}$ , where

- $V_{low}$  is the low end of the validity range of the dedicated storage volume;
- $V_{high}$  is the high end of the validity range of the dedicated storage volume.

If the dedicated volume is outside this range the energy savings are reduced (see G3.2 step 3).

$V_{low}$ ,  $V_{high}$  and the storage volume type are recorded in the PCDB record for a Storage WWHRs.

### G3.1 Dwelling-specific data required for Storage WWHRs

**Table G2 : Dwelling data required for Storage WWHRs**

Description of parameter	Symbol
Total number of baths present in dwelling	$B_{total}$
Number of baths whose waste water is routed through the WWHRs	$B_{recovery}$
Dedicated WWHRs storage volume (litres)	$V_{ww}$

The data required should be recorded in the Design Certificate or Installation & Commissioning Certificate (authored by the manufacturer) – this must have been supplied to the SAP assessor. The definition of  $V_{ww}$  is the same as that of dedicated solar volume for solar water heating, i.e. the volume of the cylinder below the coil heated by the boiler (or other heat generator). In the case of a combined (twin coil) cylinder it is the volume of the cylinder allocated to the WWHRs, see diagram H2 b) in Appendix H. In the case of a separate dedicated store  $V_{ww}$  is the volume of the separate store, see diagrams H2 a) and c) in Appendix H.

### G3.2 Calculation procedure for Storage WWHRs

1. Obtain data for the storage WWHRs from the PCDB.
2. Establish which showers and baths supply heat to the WWHRs (from SAP assessor inputs).
3. Calculate the volume of warm water available from instantaneous electric showers (IES) which drain to the WWHRs,  $V_{ww,IES,m}$  (litres/month), by summing the relevant monthly warm water volumes,  $V_{IES,j,m}$  (litres/month), from Appendix J, step 8d.
4. Calculate the volume of warm water available from other showers which drain to the WWHRs,  $V_{ww,shower,m}$  (litres/month), by summing the relevant monthly warm water volumes,  $V_{shower,i,m}$  (litres/month), calculated in Appendix J, step 1j.
5. Calculate the volume of warm water available from baths which drain to the WWHRs,  $V_{ww,bath,m}$  (litres/month), by multiplying the total warm water volume for baths,  $V_{bath,m}$  (litres/month), from Appendix J, step 2e, by the proportion of baths in the dwelling which drain to the WWHRs.
 
$$V_{ww,bath,m} = V_{bath,m} \times B_{recovery} \div B_{total} \quad (G13)$$
 ( $B_{recovery}$  and  $B_{total}$  are from table G2)
6. Calculate the quantity of heat contained in all shower water draining to the WWHRs,  $Q_{ww,shower,m}$  (kWh/month), with respect to the incoming cold water temperature for the month,  $T_{cold,m}$ , assuming warm water from showers reaches the WWHRs at a temperature of 35°C.
 
$$Q_{ww,shower,m} = (V_{ww,IES,m} + V_{ww,shower,m}) \times (35 - T_{cold,m}) \times 4.18 \div 3600 \quad (G14)$$
7. Calculate the heat content of bath water draining to the WWHRs,  $Q_{ww,bath,m}$  (kWh/month), with respect to the incoming cold water temperature for the month,  $T_{cold,m}$ , assuming bath water reaches the WWHRs at a temperature of 42°C. The volume of warm water used for baths each month,  $V_{warm,bath,m}$ , is taken from Appendix J, step 2b.
 
$$Q_{ww,bath,m} = V_{ww,bath,m} \times (42 - T_{cold,m}) \times 4.18 \div 3600 \quad (G15)$$

8. Sum the heat available from baths and showers to obtain the total amount of heat available to the WWHRs,  $Q_{\text{WW},m}$  (kWh/month).

$$Q_{\text{WW},m} = Q_{\text{WW,shower},m} + Q_{\text{WW,bath},m} \quad (\text{G16})$$

9. To calculate the heat recovered by the WWHRs,  $S_m$  (kWh/month), multiply the heat available by the system's heat recovery efficiency,  $\eta$ , and utilisation factor, UF, both taken from the PCDB data entry.

$$S_m = Q_{\text{WW},m} \times \eta \times \text{UF} \quad (\text{G17})$$

10. Apply the following adjustments to the saving based on the dedicated storage volume,  $V_{\text{ww}}$  (litres):

- |  |   |       |
|--|---|-------|
| <ol style="list-style-type: none"> <li>a. If <math>V_{\text{ww}} &lt; V_{\text{low}}</math>, multiply <math>S_m</math> by <math>(V_{\text{ww}} \div V_{\text{low}})</math></li> <li>b. If <math>V_{\text{ww}} &lt; V_{\text{high}}</math> and less than <math>2 \times V_{\text{high}}</math>, multiply <math>S_m</math> by <math>(2 - (V_{\text{ww}} \div V_{\text{high}}))</math></li> <li>c. If <math>V_{\text{ww}} &gt; 2 \times V_{\text{high}}</math> set <math>S_m = 0</math>.</li> </ol> | } | (G18) |
|--|---|-------|

11. Include  $S_m$  (as a negative value) in the calculation of worksheet (64)<sub>m</sub>.

### G3.3 Storage vessel heat loss

The heat loss from the volume  $V_{\text{ww}}$  is accounted for in the heat recovery efficiency. Consequently in the case of combined storage the vessel heat loss is reduced in the SAP calculation, see calculation of worksheet (57). No such adjustment applies in the case of separate storage.

### G3.4 Electricity for pump

The system may use an electric pump for heat exchanger operation or other accessory pumps. From the data record obtain the daily electricity used by the system ( $E_d$ ), calculate the annual electricity usage according to equation (G13) and include in worksheet at (230h) or (330h).

$$E_{\text{annual}} = 365 \times E_d \quad (\text{G19})$$

### G3.5 Solar water heating and a Storage WWHRs

The procedure does not allow for the case where a solar thermal system providing water heating and a Storage WWHRs are both present. A Storage WWHRs cannot be assessed in those circumstances (set  $S_m$  as defined in G3.2 to zero for each month, and omit the WWHRs at worksheet (230h) or (330h)).

## G4 PV diverters

'PV diverters' are devices which divert electrical energy from Photovoltaic (PV) systems to heat water using an electric immersion heater in a hot water cylinder. Such energy is surplus to the instantaneous electrical demand of the dwelling and would otherwise be exported to the electricity grid.

PV diverters increase the amount of PV generation that can be used within the dwelling and reduce running costs to the householder by offsetting the use of the main water heating system (e.g. a gas boiler). For optimum performance, hot water cylinders may be larger than typical practice.

To maximise the diversion of electricity, a dwelling with a PV diverter may store water at a higher temperature than typical practice, also increasing cylinder heat losses – this is reflected in a correction factor of 0.9.

If a PV diverter is recorded as present, the calculation procedure is:

1. Determine whether the PV diverter should be included in the calculation. To be included, each of the following conditions must be met:
  - a. A PV system must be present
  - b. There must be a hot water cylinder with a volume greater than the average daily hot water use in worksheet (43)
  - c. There must be no solar water heating system present
  - d. There must be no battery storage system present

If any of these conditions are not met, the presence of the PV diverter should still be recorded by the SAP assessor, but it should be disregarded by software for the purposes of the calculation.

2. Calculate the output of the PV system according to Appendix M2

3. Calculate the PV generation beta factor according to Appendix M2
4. Multiply the PV generation by (0.8 - beta) to calculate the excess available to the PV diverter and apply a correction factor of 0.9 to take account of increased cylinder losses:

$$S_{PV,diverter} = E_{PV} \times (0.8 - \text{beta}) \times 0.9$$

If this is a negative number, reset to zero

5. Include  $S_{PV,diverter}$  (as a negative value) in the calculation of worksheet (64)<sub>m</sub>

## **G5 Combination of FGHRs, WWHRs, PV diverter and solar water heating**

When there is both FGHRs and instantaneous WWHRs the savings from the FGHRs, WWHRs, PV diverter and solar water heating interact. When two or more of these items are present the calculations must be done in the following order:

1. WWHRs;
2. PV diverter;
3. Solar water heating, allowing for the WWHRs and PV diverter in worksheet (H17) in Appendix H;
4. FGHRs, allowing for the WWHRs saving and the solar input in equations (G1), (G2) and (G6) and (if applicable) worksheet (G6).

## **Appendix H: Solar thermal systems**

[Proposed new method based on EN15316-4-3 is currently undergoing further testing.]

**Appendix I: (not used)**

## Appendix J: Hot water

The following steps are used to estimate the hot water demand associated with showers, baths and other uses.

### 1 Hot water used for mixer showers for worksheet (42a)<sub>m</sub>

- a. Establish how many shower outlets are present in the dwelling,  $N_{\text{outlets}}$  (including any instantaneous electric showers), and their flow rates in litres per minute using Table J4. Provision for up to five shower outlets should be made. If there are more than five, the five with the highest flow rates should be used and the rest ignored.
- b. Establish whether any baths are present in the dwelling.
- c. Calculate the number of showers taken per day

$$\begin{aligned} N_{\text{shower}} &= 0.45 N + 0.65 \text{ (if any baths also present)} \\ &= 0.58 N + 0.83 \text{ (if no baths are present)} \\ &= 0 \text{ (if no shower outlets in the dwelling)} \end{aligned} \quad \left. \vphantom{\begin{aligned} N_{\text{shower}} &= 0.45 N + 0.65 \text{ (if any baths also present)} \\ &= 0.58 N + 0.83 \text{ (if no baths are present)} \\ &= 0 \text{ (if no shower outlets in the dwelling)} \end{aligned}} \right\} \text{ (J1)}$$

where  $N$  is the assumed number of occupants from Table 1b

- d. Multiply the flow rate of each shower outlet by 6 minutes to calculate the average volume of warm water use per shower event for each outlet in litres.
- e. For each mixer outlet,  $i$ , multiply the volume per shower event by the behavioural variation factor for the month,  $f_{\text{beh}}$ , given in Table J5 to calculate the warm water use per shower event for each month  $V_{\text{warm},i}$ .
- f. For each mixer outlet calculate the monthly warm water consumption in litres/day

$$V_{d,\text{warm},i} = V_{\text{warm},i} \times N_{\text{shower}} / N_{\text{outlets}} \quad \text{(J2)}$$

- g. For each mixer outlet calculate the monthly hot water consumption (litre/day), by multiplying the figure for warm water consumption by the fraction of hot required,  $f_{\text{hot,shower}}$ ,

$$\begin{aligned} V_{\text{hot},i} &= V_{d,\text{warm},i} \times f_{\text{hot,shower}} \\ \text{where } f_{\text{hot,shower}} &= (41.0 - T_{\text{cold},m}) / (52.0 - T_{\text{cold},m}) \end{aligned} \quad \text{(J3)}$$

Values of  $T_{\text{cold},m}$  are given in Table J1.

- h. Sum the figures for each mixer shower outlet to give the total hot water required in each month,  $V_{d,\text{shower}}$  (l/day). This gives the values for worksheet (42a)<sub>m</sub>.
- i. From the monthly values, calculate the annual average daily hot water use for mixer showers,  $V_{d,\text{shower,ave}}$  (l/day), weighted by the number of days in each month for use in step (d)

$$V_{d,\text{shower,ave}} = \sum V_{d,\text{shower}} \times n_m \div 365 \quad \text{(J4)}$$

- j. Multiply the daily volume calculated in step (f) by the number of days in the month to get the monthly volume of warm water associated with each shower mixer outlet,  $V_{\text{shower},i,m}$  (litres/month)<sup>18</sup>

$$V_{\text{shower},i,m} = V_{d,\text{warm},i} \times n_m \quad \text{(J5)}$$

### 2 Hot water used for baths for worksheet (42b)<sub>m</sub>

- a. Calculate the average number of baths per day for the household

$$\begin{aligned} N_{\text{bath}} &= 0 \text{ (if no bath present, but there is a shower)} \\ &= 0.13 N + 0.19 \text{ (if shower also present)} \\ &= 0.35 N + 0.50 \text{ (if no shower present, or no bath and no shower)} \end{aligned} \quad \left. \vphantom{\begin{aligned} N_{\text{bath}} &= 0 \text{ (if no bath present, but there is a shower)} \\ &= 0.13 N + 0.19 \text{ (if shower also present)} \\ &= 0.35 N + 0.50 \text{ (if no shower present, or no bath and no shower)} \end{aligned}} \right\} \text{ (J6)}$$

- b. To calculate the daily warm water consumption for baths for each month,  $V_{\text{warm,bath}}$  (l/day), multiply the number of baths per day by a bath volume of 73 litres and the behavioural variation factor for the month,  $f_{\text{beh}}$ , given in Table J5

$$V_{\text{warm,bath}} = N_{\text{bath}} \times 73 \times f_{\text{beh}} \quad \text{(J7)}$$

- c. Calculate the hot water consumption for each month for baths,  $V_{d,\text{bath}}$  (l/day), by multiplying the warm water consumption by the fraction of hot water required,  $f_{\text{hot,bath}}$ :

$$f_{\text{hot,bath}} = (42.0 - T_{\text{cold},m}) / (52.0 - T_{\text{cold},m}) \quad \text{(J8)}$$

Values of  $T_{\text{cold},m}$  are given in Table J1. This gives the values for worksheet (42b)<sub>m</sub>.

- d. Calculate the daily hot water consumption for each month,  $V_{d,\text{bath}}$  (l/day), by multiplying the warm water consumption by the fraction of hot water required,

$$V_{d,\text{bath}} = V_{\text{warm,bath}} \times f_{\text{hot,bath}} \quad \text{(J9)}$$

<sup>18</sup> For use in Appendix G

- e. From the monthly values, calculate the annual average daily hot water use for baths,  $V_{d,bath,ave}$  (l/day), weighted by the number of days in each month for use in step (d)

$$V_{d,bath,ave} = \sum V_{d,bath} \times n_m / 365 \quad (J10)$$

- f. Multiply the daily volume by the number of days in the month to get the monthly volume of warm water used for baths,  $V_{bath,m}$  (litres/month)<sup>18</sup>

$$V_{bath,m} = V_{d,warm,bath} \times n_m \quad (J11)$$

3 Hot water used for other purposes for worksheet (42c)<sub>m</sub>

- a. Average daily hot water use for other hot water uses,  $V_{d,other,ave}$  (litres/day), is calculated based on the number of occupants

$$V_{d,other,ave} = (9.8 \times N) + 14 \quad (J12)$$

- b. Calculate the daily consumption for each month for other uses of hot water,  $V_{d,other}$  (l/day), by multiplying  $V_{d,other,ave}$  by the monthly variation factor given in Table J2. This gives the values for worksheet (42c)<sub>m</sub>.

4 The annual average hot water usage for worksheet (43) is the sum of the annual averages for showers, baths and other uses calculated in steps (a), (b) and (c)

- a.  $V_{d,average} = V_{d,shower,ave} + V_{d,bath,ave} + V_{d,other,ave}$

- b. Reduce  $V_{d,average}$  by 5% if the dwelling is designed to achieve a water use target of not more than 125 litres per person per day (all water use, hot and cold) (J13)

5 Hot water usage in litres per day for each month, worksheet (44)<sub>m</sub>, is the sum of the monthly figures for showers, baths and other uses

- a.  $V_{d,m} = V_{d,shower} + V_{d,bath} + V_{d,other}$

- b. Reduce  $V_{d,m}$  by 5% if the dwelling is designed to achieve a water use target of not more than 125 litres per person per day (all water use, hot and cold) (J14)

6 The energy content of water used for worksheet (45)<sub>m</sub> is

$$4.18 \times V_{d,m} \times n_m \times \Delta T_m / 3600 \quad (\text{kWh/month}) \quad (J15)$$

where  $\Delta T_m$  is the temperature rise for month m from Table J3.

- 7 If hot water is generated at the point of use (hot water code 907 or 909 from Table 4a), the distribution loss for worksheet (46)<sub>m</sub> is zero. For all other hot water systems, the distribution loss is 0.15 times the energy content calculated in step 6, including for heat networks (whether or not a hot water cylinder is present).

8 Electricity used for instantaneous electric showers for worksheet (64a)

- a. Calculate the number of showers per day taken using each electric shower using  $N_{shower}$  and  $N_{outlets}$  in 1c and 1a respectively.

$$NES = N_{shower} / N_{outlets} \quad (J16)$$

- b. Calculate the monthly electricity consumption associated with the use of each electric shower,  $EES_{j,m}$  (kWh/month), by multiplying the number of uses per day by the behavioural factor,  $f_{beh}$ , the rated power of the unit,  $PES_j$ , from Table J4, a shower duration of 0.1 hours (i.e. 6 minutes) and the number of days in the month,  $n_m$ .

$$EES_{j,m} = NES \times f_{beh} \times PES_j \times 0.1 \times n_m \quad (J17)$$

(where j is an index number for each electric shower present)

- c. Sum the energy consumption of all electric showers present in the dwelling to give the total energy consumption for electric showers for use in worksheet (64a)<sub>m</sub>.

$$EES_m = \sum EES_{j,m} \quad (J18)$$

- d. Calculate the volume of warm water provided by each IES,  $V_{IES,j,m}$  (litres/month)<sup>19</sup>, assuming water is provided at 41°C

$$V_{IES,j,m} = EES_{j,m} / [(41.0 - T_{cold,m}) \times 4.18 / 3600] \quad (J19)$$

Where  $T_{cold,m}$  is the cold water temperature taken from Table J1.

<sup>19</sup> Used in appendix G



**Table J1: Cold water temperatures (°C)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
From header tank	9.5	10.4	11.5	12.9	15.3	18.4	19.6	18.5	17.2	14.9	12.1	8.9
From mains	7.1	8.2	9.4	13.4	15.3	17.6	18.2	17.3	16.1	13.5	10.3	6.8

[This table is due to be reviewed again for the next SAP update.]

**Table J2: Monthly factors for hot water use**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1.10	1.06	1.02	0.98	0.94	0.90	0.90	0.94	0.98	1.02	1.06	1.10	1.00

**Table J3: Temperature rise of hot water drawn off ( $\Delta T_m$ , in K)**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
41.2	41.4	40.1	37.6	36.4	33.9	30.4	33.4	33.5	36.3	39.4	39.9	37.0

**Table J4: Shower flow rates and rated power**

The actual flow rate of any shower outlets fed by the dwelling's main hot water system, or the rated power in kW in the case of any instantaneous electric showers present, should be obtained where possible. In the case of a new dwelling in England or Wales the flow rate should be consistent with the value used for the purposes of compliance with Approved Document Part G of the Building Regulations<sup>20</sup>. The flow rate of shower outlets should take account of any flow restrictors present, subject to a minimum flow of 6 l/min. If a lower flow rate has been recorded use 6 l/min. The rated power of instantaneous electric showers is subject to a minimum of 9kW. If a lower figure has been recorded use 9kW. If the actual flow rate or power rating is unknown the following defaults should be used.

Hot water type	Default flow rate (l/min)	Default rated power (kW)
Vented hot water system	7	-
Vented hot water system + pump	12	-
Combi boiler or unvented hot water system	11	-
Part G fittings approach - maximum consumption <sup>20</sup>	10 (England) or 9 (Wales)	-
Instantaneous electric shower	-	9.3

**Table J5: Behavioural factor for showers and baths, fb<sub>eh</sub>**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.035	1.021	1.007	0.993	0.979	0.965	0.965	0.979	0.993	1.007	1.021	1.035

<sup>20</sup> Flow rates of showers do not form part of the Building Regulations in Scotland or Northern Ireland.

## Appendix K: Thermal bridging

Thermal bridges that occur at junctions between building elements are included in the calculation of transmission heat losses.

The quantity which describes the heat loss associated with a thermal bridge is its linear thermal transmittance,  $\Psi$ . This is a property of a thermal bridge and is the rate of heat flow per degree per unit length of the bridge, that is not accounted for in the U-values of the plane building elements containing the thermal bridge<sup>21</sup>.

The transmission heat transfer coefficient associated with non-repeating thermal bridges is calculated as:

$$H_{TB} = \sum(L \times \Psi) \quad (K1)$$

where L is the length of the thermal bridge, in metres, over which  $\Psi$  applies

$\Psi$  is the linear thermal transmittance (W/m·K)

Some SAP calculations might be done where the y-value is pre-calculated for a particular house (see below) or the details of the thermal bridges are not known (existing dwellings) In such cases use.

$$H_{TB} = y \sum A_{exp} \quad (K2)$$

where  $A_{exp}$  is the total area of external elements calculated at worksheet (31), m<sup>2</sup>, and  $y = 0.20$  W/m<sup>2</sup>K or is calculated from individual  $\Psi$ -values (see below).

There are several possibilities for specifying the thermal bridging:

- 1) Details from a government-approved source involving independent assessment of the construction method of junctions and provision of  $\Psi$ -values for that junction. An example of a government-approved source is: Accredited Construction Details Scotland (2015)  
www.gov.scot/Topics/Built-Environment/Building/Building-standards/techbooks/techhandbooks
- 2) Details from reputable non-government database containing independently assessed thermal junction details;
- 3)  $\Psi$  values have been calculated by a person with suitable expertise and experience using the guidance set out in BR 497, *Conventions for calculating linear thermal transmittance and temperature factors* and BRE IP 1/06, *Assessing the effects of thermal bridging at junctions and around openings*. In this case use those calculated  $\Psi$ -values in equation (K1) along with the length of each junction.
- 4) If none of the above applies (e.g. for existing dwellings) use equation (K2) with  $y = 0.20$ .

SAP software should allow entry of  $\Psi$ -values for each junction and its length, as well as entry of a y-value calculated from individual  $\Psi$ -values for the particular dwelling design.

It is possible to use both 1), 2) and 3) together for different junctions within a given calculation.

Where data via 1), 2) or 3) are available for some junctions but not for all junctions, the values in the 'default' column of Table K1 should be used for those for which a linear thermal transmittance is not available.

It is also permissible to use a y-value that has been calculated for a particular house design from individual  $\Psi$  values<sup>22</sup>, where each  $\Psi$ -value has been obtained via 1), 2) or 3) above. Use this y-value in equation (K2). Documentary evidence as to the calculation of the y-value must be available. Such a y-value is applicable only to a dwelling of the size, configuration and construction for which it was calculated.

Table K1 lists the junctions which, if present, should be used in a SAP assessment.

Note: All the  $\Psi$ -values given in the Table K1 are for the whole junction exposed to the external environment; if a junction is shared by a two or more dwellings, divide the  $\Psi$ -value by the number of dwellings involved and apply the proportion to each dwelling.

<sup>21</sup> Repeating thermal bridges that occur throughout a building element, for example timber studs or joists, are taken into account in the U-value of the element and so are not included here.

<sup>22</sup> A y-value is calculated as the sum of  $(L \times \Psi)$  for all junctions divided by the total area of external elements (which includes exposed elements but not party wall).

**Table K1 : Values of  $\Psi$  for different types of junctions**

	<b>Ref</b>	<b>Junction detail applicable to the whole junction</b>	<b>Default <math>\Psi</math> (W/m<math>\cdot</math>K)</b>
<b>Junctions with an external wall</b>	E1	Steel lintel with perforated steel base plate	1.00
	E2	Other lintels (including other steel lintels)	1.00
	E3	Sill	0.10
	E4	Jamb	0.10
	E5	Ground floor (normal)	0.32
	E19	Ground floor (inverted)	0.10
	E20	Exposed floor (normal)	0.32
	E21	Exposed floor (inverted)	0.32
	E22	Basement floor	0.22
	E6	Intermediate floor within a dwelling	0.14
	E7	Party floor between dwellings (in blocks of flats)	0.28
	E8	Balcony within a dwelling, wall insulation continuous *	0.10
	E9	Balcony between dwellings, wall insulation continuous *	0.15
	E23	Balcony within or between dwellings, balcony support penetrates wall insulation	1.00
	E10	Eaves (insulation at ceiling level)	0.12
	E24	Eaves (insulation at ceiling level - inverted)	0.15
	E11	Eaves (insulation at rafter level)	0.15
	E12	Gable (insulation at ceiling level)	0.25
	E13	Gable (insulation at rafter level)	0.25
	E14	Flat roof	0.16
	E15	Flat roof with parapet	0.30
	E16	Corner (normal)	0.18
	E17	Corner (inverted – internal area greater than external area)	0.00
	E18	Party wall between dwellings	0.24
	E25	Staggered party wall between dwellings	0.24
<b>Junctions with a party wall</b>	P1	Ground floor	0.32
	P6	Ground floor (inverted)	0.32
	P2	Intermediate floor within a dwelling	0
	P3	Intermediate floor between dwellings (in blocks of flats)	0
	P7	Exposed floor (normal)	0.48
	P8	Exposed floor (inverted)	0.48
	P4	Roof (insulation at ceiling level)	0.48
	P5	Roof (insulation at rafter level)	0.48
<b>Junctions within a roof or with a room-in-roof</b>	R1	Roof window	0.24
	R2	Sill of roof window	0.24
	R3	Jamb of roof window	0.24
	R4	Ridge (vaulted ceiling)	0.12
	R5	Ridge (inverted)	0.12
	R6	Flat ceiling	0.12
	R7	Flat ceiling (inverted)	0.12
	R8	Roof to wall (rafter)	0.12
	R9	Roof to wall (flat ceiling)	0.32
	R10	All other roof or room-in-roof junctions	0.32

\* This is an externally supported balcony (the balcony slab is not a continuation of the floor slab) where the wall insulation is continuous and not bridged by the balcony slab or its supports

## Appendix L: Energy for lighting and electrical appliances

### L1 Lighting

The calculation of lighting energy use is based on the quantity and efficacy of the fixed lighting provided<sup>23</sup>, and on the contribution of daylight. Where it is not possible to obtain the efficacy of fixed lighting from manufacturer's data, values from Table L1 should be used.

The basis of the procedure described below is to compare the provided capacity of fixed lighting with a reference capacity range based on the dwelling's floor area. A range is used to allow some flexibility for different lighting designs and dwelling layouts. If the lighting capacity provided is less than the bottom of the reference range, additional top-up lighting (of poor efficacy) is assumed to be used to meet the shortfall. If more is provided than the top of the reference range, the surplus is assumed to be used (using the actual efficacy). In both cases this is likely to lead to an increase in predicted lighting energy. Lighting energy is therefore minimised where the provided lighting capacity is within the reference range and supplied by lamps of a high efficacy.

#### Calculation steps

1. Calculate annual base lighting requirement,  $\Lambda_B$  (klm·h/yr)<sup>24</sup>

$$\Lambda_B = 11.2 \times 59.73 \times (\text{TFA} \times N)^{0.4714} \quad (\text{L1})$$

where TFA is the total floor area in m<sup>2</sup> and N is the assumed number of occupants (see Table 1b).

2. Calculate the daylighting correction factor,  $C_{\text{daylight}}$

- a. 
$$G_L = \frac{\sum 0.9 \times A_w \times g_L \times \text{FF} \times Z_L}{\text{TFA}} \quad (\text{L2a})$$

where

FF is the frame factor (fraction of window that is glazed) for the actual window or from Table 6c

$A_w$  is the area of a window, m<sup>2</sup>

TFA is the total floor area of the dwelling, m<sup>2</sup>

$g_L$  is the light transmittance factor from Table 6b

$Z_L$  is the light access factor from Table 6d

- b. if  $G_L \leq 0.095$ ,

$$C_{\text{daylight}} = 52.2 G_L^2 - 9.94 G_L + 1.433 \quad (\text{L2b})$$

if  $G_L > 0.095$

$$C_{\text{daylight}} = 0.96$$

3. Calculate the fixed lighting requirement  $\Lambda_{\text{req}}$  (klm·h/yr)

$$\Lambda_{\text{req}} = 2/3 \times \Lambda_B \times C_{\text{daylight}} \quad (\text{L3})$$

4. Calculate the reference fixed lighting capacity upper limit,  $C_{L,\text{ref}}$  (lm)

$$C_{L,\text{ref}} = 330 \times \text{TFA} \quad (\text{L4})$$

5. For assessments of new dwellings calculate the capacity of the fixed lighting provided,  $C_{L,\text{fixed}}$  (lm). This is the sum over all fixed lighting outlets of the product of the power (Watts) and efficacy (lm/W) of each outlet (or each group of similar outlets). For existing dwellings (where it may not be practical to establish the details of all lamps) and for any dwelling with no fixed lighting, use the following equation to estimate the capacity of fixed lighting:

$$C_{L,\text{fixed}} = 185 \times \text{TFA} \quad (\text{L5})$$

6. Calculate the fixed lighting provision  $\Lambda_{\text{prov}}$  (klm·h/yr)

$$\Lambda_{\text{prov}} = \Lambda_{\text{req}} \times C_{L,\text{fixed}} / C_{L,\text{ref}} \quad (\text{L6})$$

7. Calculate top-up lighting requirement,  $\Lambda_{\text{topup}}$  (klm·h/yr)

If  $\Lambda_{\text{prov}} < \Lambda_{\text{req}} / 3$

$$\Lambda_{\text{topup}} = \Lambda_{\text{req}} / 3 - \Lambda_{\text{prov}} \quad (\text{L7})$$

If  $\Lambda_{\text{req}} / 3 \geq \Lambda_{\text{prov}}$

$$\Lambda_{\text{topup}} = 0$$

8. Calculate the average efficacy of the fixed lighting provided,  $\epsilon_{\text{fixed}}$  (lm/W)

- a. For new dwellings

<sup>23</sup> Subject, in the case of DER calculations for a new dwelling, to any requirements of Building Regulations that apply in the administration where the dwelling will be constructed.

<sup>24</sup> lm denotes lumens; so the unit in this case is 'kilo-lumen-hours per year'.

$$\epsilon_{\text{fixed}} = C_{L,\text{fixed}} / \Sigma \text{power of fixed lighting outlets} \quad (\text{L8})$$

- b. For existing dwellings this is a straight average of the efficacies of all fixed lighting outlets based on their actual efficacies, where known, or defaults based on lamp technology type from Table L1.

9. Calculate the energy required for lighting

- a. Calculate the energy required for fixed lighting,  $E_{L,\text{fixed}}$  (kWh/yr)

$$\text{If } \Lambda_{\text{req}} \geq \Lambda_{\text{prov}}$$

$$E_{L,\text{fixed}} = \Lambda_{\text{req}} / \epsilon_{\text{fixed}}$$

$$\text{If } \Lambda_{\text{req}} < \Lambda_{\text{prov}}$$

$$E_{L,\text{fixed}} = \Lambda_{\text{prov}} / \epsilon_{\text{fixed}}$$

- b. Calculate the energy required for top-up lighting,  $E_{L,\text{topup}}$  (kWh/yr)

$$E_{L,\text{topup}} = \Lambda_{\text{topup}} / 21.3 \quad (\text{L9b})$$

- c. Calculate the energy required for portable lighting,  $E_{L,\text{portable}}$  (kWh/yr)

$$E_{L,\text{portable}} = 1/3 \times \Lambda_B \times C_{\text{daylight}} / 21.3 \quad (\text{L9c})$$

- d. Calculate the total energy required for lighting,  $E_L$  (kWh/yr)

$$E_L = E_{L,\text{fixed}} + E_{L,\text{topup}} + E_{L,\text{portable}} \quad (\text{L9d})$$

10. Calculate the lighting energy required in each month  $m$  (Jan=1, Dec=12),  $E_{L,m}$  (kWh/month)

$$E_{L,m} = E_L \times [1 + 0.5 \times \cos(2\pi (m - 0.2) / 12)] \times n_m / 365 \quad (\text{L10})$$

where  $n_m$  is the number of days in month and  $m$  is the month number (Jan=1, Feb=2, etc.)

11. Recalculate the annual total as the sum of the monthly values

$$E_L' = \sum_{m=1}^{12} E_{L,m} \quad (\text{L11})$$

12. The associated internal heat gain for each month,  $G_{L,m}$  (Watts), is calculated as follows, assuming 15% of lighting energy is used for external lighting

- a. For standard gains,  $G_{L,m} = E_{L,m} \times 0.85 \times 1000 / (24 \times n_m)$  (L12)

- b. For reduced gains,  $G_{L,m} = \Lambda_B \times C_{\text{daylight}} / 80 \times 0.85 \times 1000 / (24 \times n_m)$  (L12a)

Equation (L11) gives the annual energy use for lighting required for worksheet (232). Equation (L12) gives the heat gain from lighting in each month required for worksheet (67)<sub>m</sub>.

**Table L1 : Default luminous efficacy for lamp types**

Lamp type	Lumens/Watt
Linear fluorescent	80.5
LEDs, CFLs	66.9
Halogen LV	26.1
Halogen lamps	15.7
Incandescent	11.2

## L2 Electrical appliances

The initial value of the annual energy use in kWh for electrical appliances is:

$$E_A = 207.8 \times (\text{TFA} \times N)^{0.4714} \quad (\text{L13})$$

where TFA is the total floor area in m<sup>2</sup> and N is the assumed number of occupants (see Table 1b).

The appliances energy use in kWh in month  $m$  (January = 1 to December = 12) is

$$E_{A,m} = E_A \times [1 + 0.157 \times \cos(2\pi (m - 1.78) / 12)] \times n_m / 365 \quad \text{kWh} \quad (\text{L14})$$

Then re-calculate the annual total as the sum of the monthly values:

$$E_A = \sum_{m=1}^{12} E_{A,m} \quad (\text{L15})$$

The associated internal heat gain for each month in watts is

$$G_{A,m} = E_{A,m} \times 1000 / (24 \times n_m) \quad (\text{L16a})$$

where  $n_m$  is the number of days in month  $m$ . When reduced internal heat gains are assumed for the calculation the appliance gains are based on efficient cold and wet appliances and below average use of other appliances:

$$G_{A,m} = 0.67 \times E_{A,m} \times 1000 / (24 \times n_m) \quad (\text{L16})$$

The annual CO<sub>2</sub> emissions in kg/m<sup>2</sup>/year associated with electrical appliances is

$$E_A \times EF_{\text{electricity}} / \text{TFA} \quad (\text{L17})$$

where  $EF_{\text{electricity}}$  is the emission factor for electricity (Table 12).

Equation (L16) or (L16a) is used for the heat gain from appliances in each month in Section 5 of the calculation. Equation (L17) is used where an estimate is required of the annual CO<sub>2</sub> emissions for appliances. For example, this was formerly used in the Code for Sustainable Homes Level 6 assessment.

### L3 Cooking

Internal heat gains in watts from cooking:

$$G_C = 35 + 7 N \quad (\text{L18})$$

When lower internal heat gains are assumed for the calculation,

$$G_C = 23 + 5 N \quad (\text{L18a})$$

CO<sub>2</sub> emissions in kg/m<sup>2</sup>/year associated with cooking:

$$(119 + 24 N) / \text{TFA} \quad (\text{L19})$$

where TFA is the total floor area in m<sup>2</sup> and N is the assumed number of occupants (see Table 1b).

Equation (L18) or (L18a) is used for the heat gain from cooking in Section 5 of the calculation. Equation (L19) is used where an estimate is required of the annual CO<sub>2</sub> emissions for cooking. For example, this was formerly used in relation to Level 6 of the Code for Sustainable Homes and Stamp Duty Land Tax.

Cooking electricity consumption:

$$E_{\text{Cook}} = 138 + 28 \times N \quad (\text{L20})$$

$$E_{\text{cook,m}} = E_{\text{Cook}} \times n_m / 365 \quad (\text{L21})$$

## Appendix M: Energy from Photovoltaic (PV) technology, small and micro wind turbines and small-scale hydro-electric generators

The procedures in this appendix give annual electricity generation, which is added in at the end of the calculation.

This appendix may be extended in future to cover other technologies.

### M1 Photovoltaics

Photovoltaic (PV) technology converts daylight directly into electricity. It works during daylight hours but more electricity is produced when the sunshine is more intense (a sunny day) and is striking the PV modules directly. Unlike solar systems for heating water, PV technology does not produce heat. Instead, PV produces electricity as a result of interaction of sunlight with semi-conductor materials in the PV cells.

For SAP calculations, the energy produced per year depends on the installed peak power (kWp) of the PV module (the peak power corresponds to the rate of electricity generation in bright sunlight, formally defined as the output of the module under radiation of 1 kW/m<sup>2</sup> at 25°C). PV modules are available in a range of types and some produce more electricity per square metre than others, and the peak power depends on the type of module as well as its effective area. In the UK climate, an installation with 1 kWp typically produces about 720 to 940 kWh of electricity per year (at favourable orientation and not overshadowed, depending on latitude).

At times of high solar radiation the PV array may generate more electricity than the instantaneous electricity demand within the dwelling. An estimate is made in SAP of this surplus which is assumed to be exported to the grid.

The procedure for PV may use data made available by the Microgeneration Certification Scheme (MCS) and is as follows.

- 1) Establish the installed peak power of the PV unit (kWp).
- 2) The electricity produced by the PV module,  $E_{PV}$  (kWh/year), is as follows:

$$E_{PV} = 0.8 \times \text{kWp} \times S \times Z_{PV} \quad (\text{M1})$$

where  $S$  is the annual solar radiation (kWh/m<sup>2</sup>) from U3.3 in Appendix U for the applicable climate, orientation and tilt of the PV

and  $Z_{PV}$  is the overshadowing factor. If available, this should be the figure determined by the Microgeneration Certification Scheme (MCS) assessor, otherwise use a figure from Table M1.

Apportion the annual output to each month of the year in proportion to the monthly solar radiation incident on the array (from U3.2) to give  $E_{PV,m}$ .

If there is more than one PV array, e.g. at different tilt or orientation, apply this process to each and sum the monthly electricity generation figures.

**Table M1 : Overshading factor (if MCS figure unavailable)**

Overshading description	% of southern <sup>25</sup> sky blocked by obstructions	$Z_{PV}$
Heavy	> 80%	0.2
Significant	> 60% - 80%	0.35
Modest	20% - 60%	0.5
None or very little	< 20%	1

- 3) The cost saving associated with the generated electricity depends on whether it is used directly within the dwelling or whether it is exported. Electricity used directly within the dwelling is valued at the unit cost for purchased electricity (standard tariff, or the high/low rate proportions given in Table 12a in the case of an off-peak tariff). Electricity exported is valued at the price for electricity exported to the grid, also from Table

<sup>25</sup> I.e. from East to West, through South



12a. The cost saving therefore depends on a factor  $\beta$ , which is in the range 0.0 to 1.0 and is defined as the proportion of the generated electricity that is used directly within the dwelling. The value of  $\beta$  for PV is higher if there is a battery storage system present because this allows electricity generated to be used within the dwelling later if it cannot be used immediately.

$\beta$  is calculated for each month of the year as follows:

- a. Calculate the applicable<sup>26</sup> electrical consumption to which PV can contribute ( $D_{PV}$ , kWh):
 
$$D_{PV} = E_{L,m} + E_{A,m} + E_{cook,m} + (231) \times n_m / 365 + E_{space,m} + E_{water,m}$$

$$E_{space} = (211)_m + (213)_m + (215)_m$$
, where (211), (213) and/or (215) should be included only where the fuel code applied to them in Section 10a of the SAP worksheet is 30, 32, 34, 35 or 40. If there is no space heating using these fuels  $E_{space} = 0$ .  
 $E_{water} = (219)_m \times (243)$  if electric immersion with off-peak tariff  
 $E_{water} = (219)_m$  if water heating fuel code applied in Section 10a of the SAP worksheet is 30  
 Otherwise  $E_{water} = 0$ .
- b. Calculate the PV supply/demand ratio  $R_{PV}$ 

$$R_{PV} = E_{PV}/D_{PV}$$
- c. Calculate the beta factor coefficients
 
$$C_{PV1} = 1.610 - 0.0987 \times C_{bat}$$

$$C_{PV2} = 0.415 - 0.00776 \times C_{bat}$$

$$C_{PV3} = 0.511 + 0.0866 \times C_{bat}$$
 where  $C_{bat}$  is the usable capacity of the battery in kWh, limited to a maximum value of 15kWh.  
 $C_{bat} = 0$  if no battery present.
- d. Calculate the  $\beta$ -factor
 
$$\beta = \text{Exp}(-C_{PV1} \times (R_{PV} \times C_{PV2})^{C_{PV3}})$$
- e. For each month calculate how much of the PV energy generation is used within the dwelling ( $E_{PV,dw}$ ) and exported ( $E_{PV,ex}$ ).
 
$$E_{PV,dw} = E_{PV} \times \beta$$

$$E_{PV,ex} = E_{PV} \times (1 - \beta)$$
- f. Sum the monthly figures to give the annual totals used within the dwelling and exported.
- g. When calculating the fuel cost benefits, apply the normal electricity price to PV energy used within the dwelling and the exported electricity price from Table 12a to PV energy exported to the grid. In the case of the former, use a weighted average of high and low rates (Table 12a) if an off-peak tariff is used.

The above procedure may be refined in future as more data becomes available on battery and other storage systems.

- 4) For calculation of CO<sub>2</sub> emissions, the emissions factor is that for grid-displaced electricity from Table 12. The same factor applies to all electricity generated, whether used within the dwelling or exported.
- 5) Where the PV array is mounted on the building concerned or wholly within its curtilage, and its output is directly connected to the building's electricity supply, the output calculated by (M1) is included in the worksheet at (233) or (333).

In the case of a building containing more than one dwelling, e.g. a block of flats, there are two cases.

- a) If the PV output goes to particular individual dwellings, the annual output is credited to the dwellings concerned. This applies to calculation of CO<sub>2</sub> emissions and costs.
- b) Otherwise the electricity generated is applied to the landlord's supply and is not counted as part of the dwelling assessment.

## M2 Micro wind turbines on the building or within its curtilage

The procedure given below applies to small wind turbines mounted either on the roof of the dwelling or on a nearby mast within its curtilage. For a wind turbine that serves more than one dwelling see M3.

<sup>26</sup> Includes 'non-regulated' uses from Appendix L (appliances and cooking), but excludes electricity used for off-peak space and water heating.

The performance of wind turbines is very sensitive to the local wind conditions. The procedure given here is based on typical conditions using a formula given by GreenSpec<sup>27</sup> and the wind speed correction factors given in MIS 3003<sup>28</sup>.

At times of higher wind speeds the wind turbine may generate more electricity than the instantaneous electricity demand within the dwelling. Arrangements must be made for the surplus electricity to be exported to the grid via a dual or two-way electricity meter.

It should be noted that the procedure given in this Appendix is an approximate one and in particular that the correction factors in MIS 3003, while representing the best currently available estimates, are known to be imprecise. Also, it is based on generic turbine technology. It will be revised as better information becomes available.

Meanwhile the procedure is considered as valid for the purposes of calculations by SAP when:

- no part of the turbine blade dips below the level of the ridge of the roof;
- there are no obstructions significantly larger than the building within a radius of 10 times the building height.

It should not be applied if those conditions are not met.

1) The output power  $P_{\text{wind}}$  of one turbine in watts at a wind speed of  $s$  m/s is:

$$P_{\text{wind}} = CP \times A \times PA \times G \times IE \quad (\text{M2})$$

where

CP is the aerodynamic power coefficient (efficiency of the rotor to convert energy)

A is the swept area of the blade

PA is the power density of the wind =  $0.6125 s^3$

G is the efficiency of the generator

IE is efficiency of the inverter (allowing for power drawn by the inverter)<sup>29</sup>.

2) The annual energy in kWh/year is related to the output at average wind speed by

$$E_{\text{wind}} = N_{\text{turbines}} \times P_{\text{wind}} \times 1.9 \times 8766 \times 0.001 \quad (\text{M3})$$

where  $N_{\text{turbines}}$  is the number of wind turbines, 1.9 is a parameter representing the wind speed variation function and 8766 is the number of hours per year.

If there is more than one turbine of differing hub height or blade diameter, apply equation (M3) to each and sum the annual electricity generation.

- 3) The product of CP, G and IE is taken as 0.24.
- 4) The area A is  $0.25 \times \pi \times (\text{rotor diameter})^2$ .
- 5) The average wind speed is taken as 5.0 m/s multiplied by the appropriate correction factor from Table M3<sup>30</sup>.
- 6) The total electricity produced as calculated in step 2) above is entered in worksheet (234).
- 7) For calculation of the cost savings the factor  $\beta$  (see Section M1) is 0.7. At present the effect of battery storage on the value of  $\beta$  with wind turbines is ignored. We hope to update this in future when further data is available.

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<sup>27</sup> [www.greenspec.co.uk/html/energy/windturbines.html](http://www.greenspec.co.uk/html/energy/windturbines.html) (accessed 20 September 2007)

<sup>28</sup> Microgeneration Installation Standard MIS 3003, *Requirements for contractors undertaking the supply, design, installation, set to work commissioning and handover of micro and small wind turbine systems*  
<https://www.microgenerationcertification.org>

<sup>29</sup> Equation (M2) differs from that on the GreenSpec website by including IE. The latter is included so as to provide the system output rather than the turbine output.

<sup>30</sup> Factors in Table M3 are derived from data in *The Designer's Guide to Wind Loading of Structures*, N.J. Cook, Butterworths, 1986.

- 8) For calculation of CO<sub>2</sub> emissions, the emissions factor for grid-displaced electricity from Table 12 applies to all electricity generated, whether used within the dwelling or exported.

**Table M3 : Wind speed correction factors**

<b>Terrain type</b>	<b>Height of turbine hub above ridge of roof (m)*</b>	<b>Correction factor</b>
Dense urban (city centres with mostly closely spaced buildings of four storeys or higher)	10	0.56
	5	0.51
	2	0.40
	0	0.28
Low rise urban / suburban (town or village situations with other buildings well spaced)	6	0.67
	4	0.61
	2	0.53
	0	0.39
Rural (open country with occasional houses and trees)	12	1.00
	7	0.94
	2	0.86
	0	0.82

\* must be at least half the rotor diameter

Use linear interpolation for intermediate values. For hub height higher than the maximum given for the terrain type use the highest for that terrain type (i.e. 0.56, 0.67 or 1.00). This is because of limitations of current knowledge; the table will be revised in future.

As an alternative to the above procedure the total annual output of wind turbines may be estimated using the procedure given in Microgeneration Installation Standard MIS 3003. It is recommended that the wind speed at the intended location is monitored for at least a year in order to ascertain the local wind conditions but if that data is not available the wind speed can be estimated from the NOABL database as described in MIS 3003 (this is subject to the limitation in MIS 3003 of a maximum 50 kW rated output at a wind speed of 11 m/s).

### **M3 Wind turbines associated with more than one dwelling**

This refers to wind turbines such as might be installed as part of a housing development. They are not included for the assessment of ratings but can be included in the assessment of an overall CO<sub>2</sub> emission figure inclusive of all energy uses (including appliances and cooking), for example the former Code for Sustainable Homes level 6 assessment. If not actually on the site they can be included provided that they are connected directly to the site. Electricity surplus to the instantaneous electricity demand of the dwellings is fed into the electricity grid.

The total annual output of wind turbines should be estimated using the procedure given in Microgeneration Installation Standard MIS 3003. It is recommended that the wind speed at the intended location is monitored for at least a year in order to ascertain the local wind conditions but if those data are not available the wind speed can be estimated from the NOABL database as described in MIS 3003 (this is subject to the limitation in MIS 3003 of a maximum 50 kW rated output at a wind speed of 11 m/s).

The total output from the wind turbines should be apportioned between the dwellings concerned on the basis of their floor area, by multiplying the total annual output by the floor area of the dwelling divided by the total floor area of buildings on the development.

### **M4 Small-scale hydro-electric generators**

Hydro-electric generation is possible only in a small number of situations. Each case is different and detailed calculations of the electricity generated are outside the scope of SAP 2012.

Where small-scale hydro-electric generation is applicable, it may be allowed for in SAP calculations as follows.

- 1) The total electricity generated per year is calculated and signed off by a suitably qualified engineer having adequate competence in the assessment of the technology. In case of doubt guidance should be sought from BRE.
- 2) Where more than one dwelling benefits from the hydro-electric generation, the kWh per year attributable to each dwelling is obtained from the total in step 1) by multiplying the total annual output by the floor area of the dwelling divided by the total floor area of buildings on the development.
- 3) For calculation of the cost savings the factor  $\beta$  (see Section M1) is 0.4. The effect of battery storage on the value of  $\beta$  with hydro-electric generation is ignored.
- 4) For calculation of CO<sub>2</sub> emissions, the emissions factor for grid-displaced electricity from Table 12 applies to all electricity generated, whether used within the dwelling or exported.
- 5) Where the electricity generator is within the curtilage of the building, and its output is directly connected to the building's electricity supply, the output is entered in worksheet (236a).
- 6) In other cases the electricity generated divided by the sum of the floor areas of the buildings concerned may be used in assessments where the total net CO<sub>2</sub> emissions are being calculated (e.g. formerly for Code for Sustainable Homes level 6 assessments).

## Appendix N: Micro-cogeneration (or micro-CHP) and heat pumps

### N1 Overview

This appendix deals with heating products whose energy performance is supported by test data in the Product Characteristics Database (PCDB) and depends critically on the plant size ratio<sup>31</sup>. Micro-cogeneration (also known as micro-CHP) and heat pumps are two such products. Products can provide a) heating and hot water throughout the year, b) heating and hot water during the heating season only, c) heating only, or d) hot water only. For heat pumps that are not supported by test data see section 9.2.7.

#### N1.1 Micro-cogeneration

Micro-cogeneration provides both heat and electricity. It is assumed to be heat-led, meaning that it is allowed to operate only when there is a demand for space heating or hot water. The domestic application of micro-cogeneration is treated as an alternative to a conventional domestic boiler, using mains gas, LPG, oil or solid fuel. It is also assumed that it is connected to the public electricity supply in such a way that all surplus generated electricity is exported. This appendix is not applicable unless these assumptions have been confirmed.

The characteristics of micro-cogeneration are described by data derived from laboratory tests. The test data are used to calculate parameters related to the annual energy performance of the micro-cogeneration “package”. The term “package” refers to a micro-cogeneration unit (such as an engine and generator) in conjunction with a defined set of optional other components (e.g. a boiler or thermal store). The laboratory test data are analysed by an annual performance method to produce results (known as “intermediate results”) that are used for SAP as described in section N2. This method is held on the website: [www.ncm-pcdb.org.uk](http://www.ncm-pcdb.org.uk).

Any space heating requirements not met by the micro-cogeneration package is to be provided by secondary heating. If a secondary heating system is not specified assume direct electric heaters. If the package provides domestic hot water it is assumed to provide all water heating needs for the applicable period.

The heat produced by the package and the electrical energy consumed/generated are based on operation during an average year, taking account of its output rating and the design heat loss for the dwelling in which it is installed. The amount of auxiliary heating is determined by the plant size ratio (full output power of the micro-cogeneration package divided by the design heat loss). If the plant size ratio is less than 0.2 then the package cannot be regarded as a main heating system, and the performance data are invalid for SAP.

The electricity consumed/generated will normally be negative, and then represents the net electricity produced by the micro-cogeneration package that is available to offset electricity that would otherwise be taken from the public electricity supply grid or, to the extent that instantaneous generation exceeds instantaneous electricity demand, is exported to the grid.

The thermal efficiency of the micro-cogeneration package is used in the normal way for the calculation of energy requirements for space heating and/or water heating (depending on the services provided by the package). The electricity consumed (or the net electricity generation) is scaled according to the net energy use as obtained in the SAP calculation.

#### N1.2 Heat pumps

Heat pumps provide space and/or water heating with efficiencies in excess of 100% as they transfer heat from outside the heated envelope of the dwelling, usually from (a) the ground, (b) ground or surface water, (c) outside air, (d) exhaust air from mechanical extract ventilation (MEV), (d) exhaust air from balanced mechanical ventilation without or with heat recovery (MVHR) or (e) a mixture of exhaust air from an MEV or MVHR and outside air.

A heat pump “package” refers to a heat pump unit in conjunction with a defined set of optional components (e.g. a hot water cylinder and auxiliary electric heater). Heat pump packages have been categorised by hot water provision, which can be:

- integral hot water store; or
- separate cylinder with characteristics specified as part of the package; or
- separate cylinder with characteristics not specified as part of the package; or
- not provided by heat pump package.

In the latter case a water heating system is specified separately for the SAP calculation.

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<sup>31</sup> Plant size ratio is the full output power of the heating appliance divided by the design heat loss of the dwelling

The characteristics of heat pump packages are described by data derived from laboratory tests. The laboratory test data are analysed by an annual performance method to produce results that are used for SAP as described in N2. An exhaust air heat pump is tested with a given mechanical ventilation system, and so the exhaust air heat pump system is defined as the mechanical ventilation system *and* the heat pump.

The performance of the heat pump package depends on temperature conditions and running hours, which are affected by output rating and the design heat loss of the dwelling. Space heating requirements not met by the heat pump package are assumed to be provided by secondary heating<sup>32</sup>, which is explicitly accounted for in the space heating efficiency in the database record for the heat pump and plant size ratio. If the package provides domestic hot water it is assumed to provide all water heating needs for the applicable period. Any water heating requirement not provided by the heat pump is assumed to be met by an electric immersion heater within the package and is also explicitly accounted for in the water heating efficiency in the database record for the heat pump. The exception is combined heat pump and boiler system packages, where performance is determined and held in the PCDB for each heat generator.

The thermal efficiency of the heat pump package is used in the normal way for the calculation of energy requirements for space heating and/or water heating (depending on the services provided by the package).

This appendix covers heat pumps powered solely from electricity (referred to as electric heat pumps) or from fuels including but not limited to mains gas, LPG or oil.

### **N1.2.1 Calculation assumptions**

For micro-cogeneration and heat pumps (all types), SAP assumes that a single water circulation pump serving the heat emitters is sufficient. If additional pumps are required then electricity use will be higher than that estimated.

Heat pumps that provide domestic hot water may have synchronised control for water heating. Synchronised control means that the primary operation of the auxiliary water heater (electric immersion) is controlled by the heat pump, so as to ensure that the timing of auxiliary heating is coordinated with the heat pump to prevent unnecessary operation of the auxiliary heater (i.e. the heat pump does as much of the water heating as possible). Local occupant control to provide boost may be present, but this automatically resets once the required hot water temperature is achieved in the cylinder so that further manual intervention is required for any subsequent boost; no allowance is made in this Appendix for boost operation. If a heat pump providing domestic hot water does not have synchronised control, it is assumed that the heat pump operates as an electric immersion, with an annual hot water heating efficiency of 100% recorded in the database.

The calculation of heat pump space and water heating efficiency is affected by hot water consumption assumptions and the worst-case hot water cylinder characteristics defined by the manufacturer during application to the PCDB - see N3.7.2. The efficiency calculations assume that the vessel is located within the dwelling heated envelope, if it is not the fuel requirement is liable to be higher than that indicated by this appendix and associated annual performance method.

The heat pump may be able to provide all the heat needed for space heating if the plant size ratio is large enough. Where that is not the case, the procedure calculates the additional (auxiliary) heat needed on the basis that it is also synchronised and under control of the heat pump, for example via an integral direct-acting electric heater. If such synchronisation is not present or not closely controlled, the fuel requirement is liable to be higher than that indicated by this appendix and associated annual performance method.

The effect of weather compensation control (Ecodesign temperature control classes II, III, VI or VII) upon the annual space heating performance of heat pumps is very significant, see Section 9.4 for definition. Note: For the avoidance of doubt, the definition's requirement to limit temperature means that controls altering heat output with reference only to return (heat pump inlet) temperature will not satisfy the definition; flow (heat pump outlet) temperature would not be limited in this case. All heat pumps entered in the PCDB are analysed with and without weather compensation enabled. Where applicable, the SAP assessor must receive documentary evidence confirming that weather compensation is permanently enabled in order select that data record. If the presence of weather compensation is unknown or cannot be confirmed by documentary evidence, the default option (data record calculated with no weather compensation) must be selected.

For all heat pump installations, whether utilising weather compensation or not, the annual performance method assumes that where a heat load exists, causing operation of the heat pump, the heat emitter system is capable of emitting that heat. In certain circumstances "short cycling" may occur, where heat pump run times are shortened to very small time periods, reducing annual performance and typically caused by poor control arrangements. This

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<sup>32</sup> This would be direct-electric heating in the case of electric heat pumps unless expressed otherwise

phenomenon is not accounted for within this method and may result in poorer annual performance and therefore higher fuel consumption than predicted.

The presence of heat pump buffer vessels is ignored for the purposes of SAP, even if installed outside the heated envelope. It is assumed that the specification of a buffer vessel, in order to reduce on/off cycling and improve annual efficiency, will only occur if vessel heat losses do not negate this improvement.

## N2 Datasets

The data to be used for SAP calculations are provided by way of the PCDB. Each database record consists of the data in Table N1 and a number of sets of intermediate test results (Table N2). The intermediate results from the annual energy performance methods for micro-cogeneration and heat pumps are produced in sets, of which a sub-set of parameters depends on the plant size ratio (PSR). Each sub-set is calculated for a different PSR (up to 9 in total), for example 0.2, 0.5, 1.0, 1.2, 1.5, 2.0, 3.0, 4.0 and 10.0.

The plant size ratio (PSR) is calculated as the maximum nominal output of the package divided by the design heat loss of the dwelling, or part of the dwelling, which is served by the package. The dwelling's heat loss coefficient, worksheet (39), is multiplied by a temperature difference of 24.2 K to provide the dwelling design heat loss. Where the package only serves part of the dwelling space heating service, it must be set as main system 1, with the fraction (0 to 1) of the heat loss satisfied by the package determined by a suitable method<sup>33</sup> and entered in SAP software (in practice the fraction from main system 2 is actually entered in SAP worksheet at (203)). In such circumstances, the package may still provide a water heating service. In the case of a range-rated package, the PSR for the dwelling is calculated assuming that it is set to the top of the range as this is how it was tested.

The PSR-dependent results applicable to the dwelling are then obtained by linear interpolation<sup>34</sup> between the two datasets whose PSRs enclose that of the dwelling. The dwelling-specific values are used in equations (N1) to (N14) to calculate the parameters used in the SAP calculation.

If the PSR for the dwelling is greater than the largest value in the database record or less than the smallest value in the database record the data are invalid for the dwelling concerned. However, in the case of a heat pump (ground, water or air source), where the PSR is greater than the largest value in the data record<sup>35</sup>, an efficiency may be obtained from linear interpolation<sup>34</sup> between that at the largest PSR in the data record and efficiency 100% at PSR two times the largest PSR in the data record<sup>36</sup>. This extension to higher PSRs is not valid for exhaust air heat pumps.

### N2.1 Heat pumps

For heat pumps a set of PSR-dependent results (latter entries of Table N2) is provided for each of up to six heat distribution system types and, in the case of an exhaust air heat pump, for two or three air flow rates at which the combined system was tested. The latter requires an additional linear interpolation of the data based on the air flow rate through the ventilation system in litres per second calculated by equation (N1).

$$\text{throughput (l/s)} = (5) \text{ volume (m}^3\text{)} \times (23a) \text{ system throughput (ach/hour)} \div 3.6 \quad (\text{N1})$$

- a) If the throughput for the dwelling is greater than the highest value in the database record for the heat pump use the efficiency values at the highest air flow rate in the database record.
- b) If the throughput lies within the range of values in the database record use the efficiency values for the applicable throughput by linear interpolation.
- c) If the throughput is less than the lowest value in the database record calculate a heat pump over-ventilation ratio ( $R_{hp}$ ) as the lowest rate in the database record in the database record (l/s) divided by the required dwelling rate (l/s); otherwise set the ratio to 1. When the ratio exceeds 2 the data are invalid for the dwelling and when it is above 1 but less than or equal to 2 use the efficiency values for the lowest value in the database record. Further calculations are required using the over-ventilation ratio as set out in N3.2.

<sup>33</sup> Such as EN 12831 or design guidance satisfying the requirements outlined in Section 9.3; also see Appendix A1. Note: Dwellings with combined heat pump and boiler system packages are assumed to heat the entire dwelling (main system 1 = heat pump, main system 2 = boiler; only two space heating systems are permitted for SAP calculations).

<sup>34</sup> For the efficiency values, the interpolated efficiency is the reciprocal of linear interpolation between the reciprocals of the efficiencies.

<sup>35</sup> The largest permitted PSR for heat pumps in the PCDB is generally 3.0.

<sup>36</sup> For a non-electric heat pump use the specific electricity value for the largest PSR in the data record.

The interpolation for PSR should be done first, followed by the interpolation for air flow rate.

**Table N1: Package general information**

Data item	Unit
Package main fuel (see Table 12)	-
For heat pumps, the heat pump source, one of: - ground - ground water - surface water - air - exhaust air MEV - exhaust air MVHR - exhaust air mixed - combined heat pump and boiler - solar-assisted – Type A <sup>37</sup> - solar-assisted – Type B <sup>37</sup>	-
Service provision, one of - space and hot water all year - space and hot water in heating season only - space heating only - water heating only	-
For heat pumps, the product index number for MEV/MVHR (for exhaust air MEV, exhaust air MVHR or exhaust air mixed)	-
Hot water vessel, one of - integral to package - separate, specified cylinder - separate but unspecified cylinder - none (DHW not provided by package)	-
Hot water vessel volume (where relevant)	litres
Hot water vessel loss (where relevant)	kWh/day
Heat transfer area of heat exchanger within hot water vessel (where relevant)	m <sup>2</sup>

<sup>37</sup> A solar-assisted heat pump uses solar energy to improve annual performance. For solar-assisted - Type A heat sources, the utilisation of Appendix Q data is necessary to enable the recognition of additional variables not defined in this Appendix. For solar-assisted - Type B heat sources, the PCDB data record includes all necessary data.



Table N2: Annual performance results held in PCDB

Data item (applicable to both heat pumps and micro-cogeneration unless indicated otherwise)	Symbol	Unit
Daily heating duration (24, 16 or 11 <sup>38</sup> or variable) <u>Note:</u> This is always Variable		hours/day
Effect of weather compensation included in test data (yes/no) (heat pumps only)		-
Central heating circulator power included in calculated performance data (yes/no) <u>Note:</u> This is always 'yes' for electric heat pumps and 'no' for micro-cogeneration		-
Water heating thermal efficiency from Load Profile M test <sup>39</sup> (for hot water only heat pump packages or micro-CHP)	$\eta_{\text{water},1}$	%
Electricity consumed or, if negative, net electricity generated, either calculated or during Load Profile M test, per unit of heat generated for water heating	$e_{\text{water},1}$	kWh of electricity per kWh of heat
Water heating thermal efficiency for optional Load Profile L test <sup>40</sup> For combined heat pump and boiler packages, this will be the calculated boiler hot water heating efficiency.	$\eta_{\text{water},2}$	%
Electricity consumed or, if negative, net electricity generated, during optional Load Profile L test, per unit of heat generated for water heating	$e_{\text{water},2}$	kWh of electricity per kWh of heat
For heat pumps, type of heat distribution system*, one of: - wet system, flow temperature 65°C <sup>41</sup> - wet system, flow temperature 58°C - wet system, flow temperature 55°C - wet system, flow temperature 45°C - wet system, flow temperature 35°C - Warm air system		-
For exhaust air heat pumps, the air flow rate for which the PSR dependent results apply		l/s
<b>PSR dependent results</b>		
Plant size ratio for which the data below apply	PSR	-
For combined heat pump and boiler packages only: Heat pump space heating fraction. Calculated fraction (0 to 1) represents the proportion of space heating energy demand satisfied by the heat pump	$e_{\text{space},F}$	-
For combined heat pump and boiler packages only: Heat pump hot water heating fraction. Calculated fraction (0 to 1) represents the proportion of water heating energy demand satisfied by the heat pump	$e_{\text{water},F}$	-
Space heating thermal efficiency	$\eta_{\text{space},1}$	%
Boiler space heating thermal efficiency (if applicable)	$\eta_{\text{space},2}$	%
Calculated water heating thermal efficiency (for heat pump packages providing space and hot water heating)	$\eta_{\text{water},3}$	%
For non-electric heat generators: Electricity consumed for space heating or, if negative, net electricity generated, per unit of heat generated for space heating	$e_{\text{space}}$	kWh of electricity per kWh of heat
For exhaust air or mixed air heat pumps - running hours	$H_{\text{hp}}$	hours per year

\* 58°C applies in all cases (except high temperature heat pumps or warm air systems), irrespective of actual dwelling heat emitter type, unless the heating system has been designed and installed as described in 9.3.

### N2.1.1 Mechanical ventilation for exhaust air heat pump

An exhaust air heat pump package includes a mechanical ventilation system which is characterised by the heat exchanger efficiency, if any, and the specific fan power (in W per l/s) which depends on the number of wet rooms and the duct type (rigid or flexible). For an exhaust air heat pump, set the ventilation system to MEV or MVHR as applicable. The PCDB contains information on the performance of the mechanical ventilation system, which is used to calculate the fan consumption and dwelling air infiltration rate (see section N3.2).

## N3 Calculation of space and water heating

### N3.1 Circulation pump and fan

For non-electric heat pumps and micro-cogeneration: The heat gain for a water circulation pump or fan is taken from Table 5a and is included in worksheet (70). The electricity use from Table 4f is included in worksheet (230c).

For electric heat pumps: The electricity used by the water circulation pump or fan is included within the calculated annual space and hot water heating efficiency and is not included in worksheet (230c). The default heat gain from Table 5a is included via worksheet (70).

The electricity used by any fans within the package (apart from mechanical ventilation fans, which are dealt with separately in N3.2) is included in data items  $e_{\text{space}}$  and  $e_{\text{water},1}$  for micro-generation and non-electric heat pump packages (see N4.2). For electric heat pumps, the electricity used is included directly in  $\eta_{\text{space}}$  and  $\eta_{\text{water}}$  (see N4.1).

### N3.2 Exhaust air heat pump, MEV and MVHR

Exhaust air heat pumps (MEV or MVHR) may require a higher air flow rate through the ventilation system when operating than would apply without the heat pump. To allow for this there is a separate calculation, equation (N4), that replaces data from Table 4f.

For exhaust air heat pumps the running hours are included in a set of calculation results dependent on the plant size ratio. With exhaust air heat pumps the heat pump and the mechanical ventilation systems are tested together and so the energy consumption of the central ventilation fan while the heat pump is operating is included in the thermal efficiency, but not when it is not.

Heat pumps with mechanical ventilation are tested at two or three different air flow rates as explained in section N2.1. If the required rate for the dwelling, equation (N1), is less than the lowest air flow rate for which data are provided in the PCDB record for the heat pump, the mechanical ventilation is assumed to operate at the required rate during the non-heat pump operation and at the lowest rate in the database record for the heat pump during heat pump operation hours and hence will change the building infiltration rate calculation (step e) below).

- Obtain from the heat pump record the run hours ( $h_{\text{hp}}$ ) applicable to the system exhaust air throughput for the dwelling, after applying linear interpolation based on the plant size ratio and system air throughput, rounding  $h_{\text{hp}}$  to the nearest integer value. Run hours are the total number of hours per year that the heat pump operates to achieve that heat output required by the building.
- Obtain from the MEV/MVHR PCDB record the specific fan power (SFP) for the duct type and number of wet rooms. If data are not listed for the duct type or number of wet rooms use the default values in Table 4g.
- Calculate the heat pump over-ventilation ratio  $R_{\text{hp}}$  using equation (N2). This is the ratio of the air flow through the ventilation system allowing for the operational requirement of the heat pump, to that which would apply for an equivalent ventilation system without a heat pump.

<sup>38</sup> 11 hours/day is 9 hours on weekdays and 16 at weekends (standard SAP heating schedule), giving a weekly average of 11 hours/day

<sup>39</sup> If the heat pump service provision is both space and hot water, this value is calculated using the annual performance method and is therefore PSR dependent. Otherwise, for hot water only heat pumps and micro-cogeneration, this is from a hot water test using load profile M (defined in EN 16147 for heat pumps)

<sup>40</sup> This is from an additional hot water test using load profile L (defined in EN 16147)

<sup>41</sup> High temperature heat pumps only

If the lowest air flow rate in the heat pump PCDB record (in l/s) is less than the throughput for the dwelling from equation (N1),  $R_{hp} = 1$ ; otherwise:

$$R_{hp} = \text{lowest air flow rate (l/s)} \times 3.6 \div [(23a) \times (5)] \quad (N2)$$

d) Calculate the annual fan consumption according to equation (N3) in kWh per year:

$$(230a) = (5) \times \text{SFP} \times \text{Fan in-use factor} \times (23a) \times R_{hp} \times (8760 - h_{hp}) \div 3600 \quad (N3)$$

e) Obtain the mechanical ventilation throughput factor,  $F_{mv}$ , from equation (N4) for calculation of worksheet (23b):

$$F_{mv} = [(8760 - h_{hp}) + (R_{hp} \times h_{hp})] \div 8760 \quad (N4)$$

Note. The above is not implemented as an iterative procedure. Instead:

- set  $F_{mv} = 1$  and calculate the ventilation loss rate and PSR
- obtain  $F_{mv}$  from equation (N4)
- re-calculate the ventilation loss rate and PSR, and apply this Appendix without further change to  $F_{mv}$  or  $R_{hp}$ .

### N3.3 Exhaust air heat pump, mixed

An exhaust air heat pump (mixed) uses a mixture of the exhaust air from an MEV or MVHR system and external air as its heat source. The heat pump and the mechanical ventilation systems are tested together and the product index number for MEV/MVHR system is included in the PCDB record for the heat pump. It is assumed that the mechanical ventilation system provides a fixed air change rate of 0.5 air changes per hour to the dwelling and the heat pump automatically mixes these two heat sources so as to satisfy the instantaneous heat requirement. If required the external airflow rate supplied to the heat pump will be increased. This mode of operation is reflected in the efficiency values provided in the PCDB record for each PSR. The SAP calculation uses the data for the specified mechanical ventilation system and assigns efficiency values to the heat pump as described in this appendix for an air source heat pump.

### N3.4 Exhaust air heat pump, hot water only

An exhaust air heat pump for hot water only (MEV, MVHR or mixed) is assumed to operate as a mechanical ventilation system. A fixed air change rate of 0.5 air changes per hour to the dwelling is assumed, even if additional single room ventilation systems are installed. The water heating efficiency given in the PCDB data record applies in all months.

Heat pump hot water performance testing is conducted at an airflow rate that represents the minimum number of wet rooms supported by the unit, as specified by the manufacturer. The airflow during the test, and during commissioned operation, is continuous, not intermittent, even if the heat pump compressor operates intermittently. The performance test of the heat pump ventilation components (with the heat pump compressor off) is conducted at an airflow rate range that represents the declared minimum and maximum rates achievable (corresponding to the number of wet rooms supported). SAP assessments for dwellings outside this range are not permitted.

### N3.5 Mean internal temperature

The package, when undersized in relation to the design heat loss of the dwelling, can provide space heating needs on more days of the heating season if it operates for 16 hours per day or continuously. Table N4 shows the days of operation indicated by the parameters  $N_{24,16}$ ,  $N_{24,9}$  and  $N_{16,9}$  depending on the heating duration defined in the PCDB record and, if duration is variable, on the plant size ratio. For the normal SAP heating schedule, the heating season would comprise 68 weekend days with 16 hours of heating and 170 weekdays with 9 hours of heating (2 hours in the morning and 7 hours in the evening). Summer months are included here only for consideration of cooling (see Table 10b).

Obtain the total number of days per year for each mode of operation from Tables N4 and N5. Allocate these to months in the following order: Jan, Dec, Feb, Mar, Nov, Apr, Oct, May (coldest to the warmest), until all the days  $N_{24,16}$ ,  $N_{24,9}$  and  $N_{16,9}$  have been allocated. All the days  $N_{24,9}$  are allocated first, and then  $N_{16,9}$ .

Example: Variable heating duration with PSR = 0.2 (first row of Table N5 applies:  $N_{24,9} = 143$ ,  $N_{16,9} = 8$  and  $N_{24,16} = 57$ ).

January:  $N_{24,16,m=1} = 9$  and  $N_{24,9,m=1} = 22$ . All weekdays in January have been allocated so  $N_{16,9,m=1} = 0$ . The number of days remaining to be allocated is now  $N_{24,16} = 48$ ,  $N_{24,9} = 121$  and  $N_{16,9} = 8$ .

This is continued for Dec, Feb, Mar, Nov, Apr after which the number of days remaining to be allocated is  $N_{24,16} = 6$ ,  $N_{24,9} = 13$  and  $N_{16,9} = 8$ .  
 For October,  $N_{24,16,m=10} = 6$ ,  $N_{24,9,m=10} = 13$  and  $N_{16,9,m=10} = 8$ .  
 All days are now allocated so there are none for May.

[Table N3 is no longer used so has been deleted.]

**Table N4: Additional days at longer heating duration**

Heating duration (from PCDB record)	Number of days operating at the number of hours indicated by the first subscript instead of the SAP standard hours indicated by the second subscript		
	$N_{24,16}$	$N_{24,9}$	$N_{16,9}$
24	104	261	0
16	0	0	261
11	0	0	0
Variable	see Table N5	see Table N5	see Table N5

**Table N5: Additional days at longer heating duration for variable heating**

Plant size ratio	Number of days operating at the hours shown by the first subscript instead of that of the second		
	$N_{24,16}$	$N_{24,9}$	$N_{16,9}$
0.1	67	166	1
0.2	62	156	4
0.3	55	137	12
0.4	48	120	12
0.5	37	91	31
0.6	27	68	35
0.7	14	36	47
0.8	7	19	50
0.9	4	10	35
1	2	6	24
1.1	1	3	16
1.2 or more	1	2	9

Use linear interpolation for intermediate values of plant size ratio, rounding the result to the nearest whole number of days.

**Table N6: Weekend days and weekdays each month**

Month:	Jan	Dec	Feb	Mar	Nov	Apr	Oct	May	Jun	Jul	Aug	Sep
Number of weekend days, $WE_m$	9	9	8	9	8	8	9	9	9	9	9	8
Number of weekdays, $WD_m$	22	22	20	22	22	22	22	22	21	22	22	22

Replace step 7 in Table 9c, which is  $T = (5 \times T_{\text{weekday}} + 2 \times T_{\text{weekend}}) \div 7$ , with:

Mean temperature (living area or elsewhere)

$$T = \frac{[(N_{24,16,m} + N_{24,9,m}) \times T_h + (WE_m - N_{24,16,m} + N_{16,9,m}) \times T_{\text{weekend}} + (WD_m - N_{16,9,m} - N_{24,9,m}) \times T_{\text{weekday}}]}{(WE_m + WD_m)} \quad (N5)$$

Where  $T_h$  is heating temperature for continuous heating for the living area or elsewhere in Table N7.

**Table N7: Heating temperatures with continuous heating**

Living area	Elsewhere	
Temperature $T_h$ (°C)	Heating control (Table 4e)	Temperature $T_h$ °C
21	1	21 – 0.5 HLP
	2	21 – HLP + HLP <sup>2</sup> / 12
	3	21 – HLP + HLP <sup>2</sup> / 12

### N3.6 Thermal efficiency for space heating

For heat pumps the space heating thermal efficiency, worksheet (206), is  $\eta_{\text{space},1}$  multiplied by 0.95 (0.95 is an in-use factor).

*Note. In reality the space heating efficiency varies through the year according to the source temperature. The value used in this procedure is adjusted to the total annual space heating requirement so as to give the correct total fuel use but the monthly values of fuel use will not be correctly indicated.*

For combined heat pump and boiler packages,  $\eta_{\text{space},2}$  is used in (207) and represents the boiler space heating efficiency; no in-use factor is applied (worksheet (206) is  $\eta_{\text{space},1}$  multiplied by 0.95). The factor  $e_{\text{space},F}$  (less than 1) is used in (203) to apportion the annual heat energy requirement (98) satisfied by the boiler. No boiler efficiency correction is applied via Table 4c.

For micro-cogeneration packages the in-use factor is 1 because they are based on 24-hour tests, so worksheet (206) is equal to  $\eta_{\text{space},1}$ .

### N3.7 Thermal efficiency for water heating

If the package provides water heating then:

- Heat pumps: If service provision provides space and hot water heating, then obtain the thermal efficiency for water heating ( $\eta_{\text{water}}$ ) (216) from the PCDB (defined as  $\eta_{\text{water},3}$ ).
- For micro-cogeneration with hot water service provision or heat pumps providing a hot water only service provision, obtain the thermal efficiency for water heating ( $\eta_{\text{water}}$ ) (216) from the PCDB (defined as  $\eta_{\text{water},1}$ ), unless two efficiency values are recorded in PCDB – in this case use c).
- If two thermal efficiency values for water heating are recorded in the PCDB then:
  - obtain  $\eta_{\text{water}}$  (216) from b) above if  $V_{d,\text{average}} \leq 100.2$  litres/day, or
  - set  $\eta_{\text{water}}$  equal to  $\eta_{\text{water},2}$  if  $V_{d,\text{average}} \geq 199.8$ , or
  - obtain  $\eta_{\text{water}}$  from equation (N7) if  $100.2 < V_{d,\text{average}} < 199.8$ $V_{d,\text{average}}$  is as defined in Appendix J, step J4 a).

$$\eta_{\text{water}} = \eta_{\text{water},1} + \frac{\eta_{\text{water},2} - \eta_{\text{water},1}}{99.6} \times (V_{d,\text{average}} - 100.2) \quad (\text{N7})$$

- If a combined heat pump and boiler package is used, then  $\eta_{\text{water},2}$  is the boiler hot water generation efficiency. The factor  $e_{\text{water},F}$  (value from 0 to 1) is used to apportion the (annual) hot water energy requirement (64) satisfied by the electric heat pump, the remainder ( $1 - e_{\text{water},F}$ ) is satisfied by the boiler.

#### N3.7.1 Thermal efficiency for water heating – micro-cogeneration

If the micro-cogeneration package provides both space and hot water heating, calculate the monthly water heating efficiency,  $\eta_{\text{water},\text{monthly}}$ , for worksheet (217)<sub>m</sub> according to equation (N8).

$$\eta_{\text{water,monthly}} = \frac{Q_{\text{space}} + Q_{\text{water}}}{\frac{Q_{\text{space}}}{\eta_{\text{space}}} + \frac{Q_{\text{water}}}{\eta_{\text{water}}}} \quad (\text{N8})$$

where

$Q_{\text{space}}$  (kWh/month) is the quantity calculated at (98)<sub>m</sub> multiplied by (204);

$Q_{\text{water}}$  (kWh/month) is the quantity calculated at (64)<sub>m</sub>;

For months in which worksheet (98)<sub>m</sub> is zero, or both worksheet (98)<sub>m</sub> and worksheet (64)<sub>m</sub> are zero, worksheet (217)<sub>m</sub> is  $\eta_{\text{water,monthly}}$ .

For micro-cogeneration packages that provide hot water only,  $\eta_{\text{water,monthly}}$  is  $\eta_{\text{water}}$  for all months.

For micro-cogeneration packages that do not provide hot water in the summer, an alternative water heating system must be specified for months in which worksheet (98)<sub>m</sub> is zero.

### N3.7.2 Thermal efficiency for water heating – heat pumps

If the heat pump provides water heating in (217)<sub>m</sub>, multiply the thermal efficiency ( $\eta_{\text{water}}$ ) for water heating by the in-use factor in Table N8; subject to a minimum efficiency of 100%.

**Table N8: In-use factor for water heating efficiency for heat pumps**

Description of hot water provision	In-use factor
Integral hot water store	0.95
Separate but specified cylinder	0.95
Separate but specified cylinder but cylinder does not meet the performance criteria specified below this table	0.60
Separate and unspecified cylinder	0.60
Hot water not provided by package	n/a

With a separate but specified cylinder the in-use factor of 0.95 applies when the actual cylinder has performance parameters at least equal to those in the PCDB record, namely:

- cylinder volume not less than that in the PCDB record, and
- heat transfer area not less than that in the PCDB record<sup>42</sup>, and
- heat loss (kWh/day) [either (48) or (47) × (51) × (52)] not greater than that in the PCDB record.

If any of these conditions are not fulfilled, or are unknown, the in-use factor is 0.60.

## N3.8 Hot water storage losses

### N3.8.1 Micro-cogeneration

If the micro-cogeneration package supplies hot water via an integral store, the heat loss associated with hot water storage is included in the intermediate results and zero is entered for the cylinder loss (55) and the primary loss (59).

Otherwise a cylinder is specified separately and the cylinder loss and primary loss are included in the SAP calculation.

### N3.8.2 Heat pumps

If the heat pump package supplies hot water via an integral store enter the daily cylinder loss from the heat pump PCDB record in (48) and the temperature factor (Table 2b) for an indirect cylinder with cylinder thermostat and separate time control in (49); the primary loss (59) is zero.

<sup>42</sup> With some heat pumps the heat exchanger is inside the heat pump. In those cases the heat exchange area in the database record is zero and this test does not apply.

If the heat pump provides hot water via a separate cylinder the primary loss (59) is from Table 3 and characteristics of the cylinder are to be supplied separately: if the declared heat loss is available enter this in (48); otherwise enter the volume in (47) and use the insulation type and thickness in Table 2 to calculate (52).

If the heat pump package provides only space heating, the details of the hot water system are to be provided separately.

### **N3.9 Secondary fraction (for Micro-cogeneration only)**

Obtain the fraction of the total space heating requirement not provided by the main heating from Table N9. Usually this is assigned to a secondary heating system (room heaters) but can be a second main system if contained within or linked to the package.

**Table N9: Secondary fraction**

Plant size ratio	Secondary fraction for each daily heating duration			
	24	16	11	Variable
0.10	0.75	0.81	0.86	0.75
0.15	0.63	0.72	0.79	0.64
0.20	0.52	0.63	0.72	0.53
0.25	0.42	0.55	0.66	0.43
0.30	0.33	0.47	0.59	0.33
0.35	0.24	0.40	0.53	0.25
0.40	0.17	0.33	0.48	0.18
0.45	0.12	0.26	0.42	0.12
0.50	0.07	0.21	0.37	0.08
0.55	0.05	0.16	0.32	0.05
0.60	0.03	0.12	0.28	0.03
0.65	0.02	0.09	0.23	0.02
0.70	0.01	0.06	0.20	0.01
0.75	0	0.05	0.16	0
0.80	0	0.03	0.13	0
0.85	0	0.02	0.11	0
0.90	0	0.02	0.09	0
0.95	0	0.01	0.07	0
1.00	0	0	0.05	0
1.05	0	0	0.04	0
1.10	0	0	0.03	0
1.15	0	0	0.03	0
1.20	0	0	0.02	0
1.25	0	0	0.02	0
1.30	0	0	0.01	0
1.35	0	0	0.01	0
1.4 or more	0	0	0	0

Use linear interpolation for intermediate values of plant size ratio, rounding the result to the nearest 0.001.

*Note. In reality the secondary fraction varies through the year according to space heating requirement. The value used in this procedure is adjusted to the total annual space heating requirement so as to give the correct total main and secondary fuel use but the monthly values of fuel use may not be correctly indicated.*

## **N4 Electricity produced/consumed**

### **N4.1 Electric heat pumps**

For heat pumps powered solely by electricity, any ancillary electricity consumed, such as circulation pumps, is included in the space and hot water thermal efficiencies and worksheet (235) is zero.

### **N4.2 Micro-cogeneration and non-electric heat pumps**

This section calculates the total electricity generated or consumed by micro-cogeneration appliances and non-electric heat pumps based on tested data.



If the package provides water heating calculate the electricity produced or consumed daily per heat generated during hot water production,  $e_{\text{water}}$ , using equation (N9) or equation (N10). If it does not provide water heating set  $e_{\text{water}} = 0$ .

If the water heating test data are provided in the PCDB record for load profile M only:

$$e_{\text{water}} = e_{\text{water},1} \quad (\text{N9})$$

If the water heating test data are provided in the PCDB record for both profile M and profile L then:

obtain  $e_{\text{water}}$  from equation (N9) if  $V_{d,\text{average}} \leq 100.2$  litres/day, or

set  $e_{\text{water}}$  to  $e_{\text{water},2}$  if  $V_{d,\text{average}} \geq 199.8$ , or

obtain  $e_{\text{summer}}$  from equation (N10) if  $100.2 < V_{d,\text{average}} < 199.8$ .

$$e_{\text{summer}} = e_{\text{water},1} + \frac{e_{\text{water},2} - e_{\text{water},1}}{99.6} \times (V_{d,\text{average}} - 100.2) \quad (\text{N10})$$

Calculate the electricity produced or consumed during the year using equation (N11), (N12), (N13) or (N14) according to the services provided by the package.

- a) Package provides space and hot water heating all year round. The electricity consumed or generated is scaled to the actual annual heat requirement of the dwelling for both heating and hot water according to equation (N11).

$$E^* = (98) \times (204) \times e_{\text{space}} + (64) \times e_{\text{water}} \quad (\text{N11})$$

- b) Package provides space heating and hot water heating during the heating season only. The electricity consumed or generated is scaled to the actual annual heat requirement of the dwelling for both heating and hot water according to equation (N12).

$$E^* = (98) \times (204) \times e_{\text{space}} + e_{\text{water}} \times \sum_{(98)_m > 0} (64)_m \quad (\text{N12})$$

in which the summation only applies to the months when the space heating requirement, worksheet (98)<sub>m</sub>, is greater than zero.

- c) Package provides space heating only. The electricity consumed or generated is scaled to the actual annual space heating requirement of the dwelling according to equation (N13).

$$E^* = (98) \times (204) \times e_{\text{space}} \quad (\text{N13})$$

- d) Package provides water heating only. The electricity consumed or generated is scaled to the actual annual water heating requirement of the dwelling according to equation (N14).

$$E^* = (64) \times e_{\text{water}} \quad (\text{N14})$$

If  $E^*$  is positive, enter  $E^*$  in worksheet (235) and use the unit price for standard tariff electricity, or in the case of an off-peak tariff the high and low rate prices in the proportions defined in Table 12a, in the calculation of worksheet (252).

If  $E^*$  is negative, enter  $E^*$  in worksheet (235) as a negative value. The cost saving associated with the net generated electricity depends on whether it is used directly within the dwelling or whether it is exported. Electricity used directly within the dwelling is valued at the unit cost for purchased electricity (usually the standard tariff, or the high and low rates in the proportions defined in Table 12a, in the case of an off-peak tariff). Electricity exported is valued at the price in Table 12 for electricity sold to the grid.

The effective price depends on a factor  $\beta$ , which is in the range 0.0 to 1.0 and is defined as the proportion of the generated electricity that is used directly within the dwelling. The value of  $\beta$  depends on the coincidence of electricity generation and electricity demand within the dwelling. At present the value of  $\beta = 0.40$  should be used for SAP calculations: this will be reviewed in future if relevant data become available. The fuel price used in the

calculation of worksheet (252) is then:  $\beta \times \text{normal electricity price} + (1 - \beta) \times \text{exported electricity price}$ , using in the case of an off-peak tariff the high-rate fraction for locally generated electricity in Table 12a.

**Appendix O (not used)**

## Appendix P: Summer heat-gain check

This appendix provides a basic method for assessing the propensity of a house to have high internal temperature in hot weather due to heat gains. It does not provide an estimate of cooling needs. The procedure is not integral to SAP and does not affect the calculated SAP rating or other metrics. It should not be depended on by designers to ensure a given design will provide thermal comfort.

The calculation is related to the factors that contribute to internal temperature: solar gain (taking account of orientation, shading and glazing transmission); ventilation (taking account of window opening in hot weather), thermal capacity and mean summer temperature for the location of the dwelling.

Further information about techniques to avoid overheating can be found in ‘Overheating in new homes: A review of the evidence’, NF46, NHBC Foundation, November 2012.

### P1 Assessment procedure

The procedure is undertaken for the months of June, July and August. The weather data is that of the actual region in which the dwelling is located from Appendix U.

1. Determine the effective air change rate during hot weather. If a mechanical ventilation system provides summer ventilation, use the specified air change rate for the system. If this is a higher rate than is used during the heating season, the assessor should obtain evidence showing that this higher rate can be maintained continuously. If natural ventilation is used the answers to the following questions are used by SAP software to select the appropriate entry from table P1: This contains indicative values based on the procedure in BS 5925<sup>43</sup>.
  - a. Is there a local source of noise likely to prevent windows being left open for long periods? (Y/N)  
If the dwelling is in close proximity (<20m) and line of sight to a main road, railway, industrial site, is under a major airport approach (within 6km from airport), or subject to any other obvious source of noise, this should be assumed to prevent occupants from opening windows for long periods .
  - b. Is there a security risk if windows are left open unattended? (Y/N)  
Assume any window or door classed as ‘easily accessible’ according to Approved Document Q could not be left open unattended, unless appropriately certified secure night time ventilation (e.g. by means of grilles, shutters with vents or purpose-made ventilators) is fitted. Note that this classification will include some upper floor windows.
  - c. To what extent can windows be left open for extended periods? Choose from:
    - Can’t be left open (trickle vents only)  
- If the answer to a. or b. is ‘yes’, assume trickle vents only (and the following options should be suppressed).
    - Slightly open (50mm)  
- Slightly open refers to windows that can be securely locked with a gap of about 50 mm.
    - Fully open
  - d. Is cross-ventilation possible?  
Cross ventilation can be assumed only if at least half of the storeys in the dwelling have windows on opposite sides and there is a route for the ventilation air. Normally bungalows and two storey houses can be cross ventilated because internal doors can be left open. Three storey houses and other situations with two connected storeys of which one is more than 4.5 m above ground level often have floors which have fire doors onto stairs that prevent cross ventilation.
  - e. Number of storeys: this is determined from the dwelling dimensions data.

**Table P1: Effective air change rate**

Window Opening	Effective air change rate in ach		
	Trickle vents only	Windows slightly open (50 mm)	Fully open
Single storey dwelling (bungalow, flat) Cross ventilation possible	0.1	0.8	3

<sup>43</sup> BS 5925:1991, Code of practice for ventilation principles and design for natural ventilation

Single storey dwelling (bungalow, flat) Cross ventilation not possible	0.1	0.5	2
Dwelling of two or more storeys Windows open upstairs and downstairs Cross ventilation possible	0.2	1	4
Dwelling of two or more storeys Windows open upstairs and downstairs Cross ventilation not possible	0.1	0.6	2.5

2. Calculate the ventilation heat loss,  $H_v^{\text{summer}}$ , using the formula:

$$H_v^{\text{summer}} = 0.33 \times n \times V \quad (\text{P1})$$

where:

$n$  = air change rate during hot weather, ach

$V$  = volume of the heated space of the dwelling,  $\text{m}^3$

3. Calculate the heat loss coefficient under summer conditions:

$$H = \text{total fabric heat loss} + H_v^{\text{summer}} \quad (\text{P2})$$

The total fabric heat loss is the same as for the heating season (worksheet (37)).

4. Calculate the solar gains for the summer month,  $G_{\text{solar}}^{\text{summer}}$ , using the solar flux for the appropriate month and climate region from Table U3.

$$G_{\text{solar}}^{\text{summer}} = \sum(0.9 \times A_w \times S \times g_{\perp} \times \text{FF} \times Z_{\text{summer}}) \quad (\text{P3})$$

where:

0.9 is a factor representing the ratio of typical average transmittance to that at normal incidence

$A_w$  is the area of an opening (a window, roof window or fully glazed door),  $\text{m}^2$

$S$  is the solar flux on a surface during the summer period from Appendix U3.2,  $\text{W}/\text{m}^2$

$g_{\perp}$  is the total solar energy transmittance factor of the glazing at normal incidence from Table 6b

FF is the frame factor for windows and doors (fraction of opening that is glazed) from Table 6c

$Z_{\text{summer}}$  is the overheating summer solar access factor (calculated as in section P3)

In the case of a window certified by a rating scheme, the quoted solar factor is  $g_{\text{window}}$ , which is equal to  $0.9 \times g_{\perp} \times \text{FF}$ . The solar gain for such windows is calculated as

$$G_{\text{solar}}^{\text{summer}} = \sum(A_w \times S \times g_{\text{window}} \times Z_{\text{summer}}) \quad (\text{P4})$$

Solar gains should be calculated separately for each orientation, and totalled according to equation (P3).

Assume that the summer internal gains ( $G_i$ ) are equal to the winter internal gains (these are calculated in section 5 of the SAP worksheet), except that

- where water heating in summer is by a summer-only electric immersion primary loss is not included in the summer gains, and

- gains associated with heating systems (Table 5a) are not included in the summer gains,

so that the total gains are:

$$G = G_{\text{solar}}^{\text{summer}} + G_i \quad (\text{P5})$$

5. Calculate the summer Gain/Loss ratio:

$$\text{Summer Gain/Loss ratio} = \frac{G}{H} \quad (\text{P6})$$

6. Obtain the mean external temperature for the month and climate region,  $T_e^{\text{summer}}$ , from Table U1.

7. Obtain the threshold internal temperature which is used to estimate likelihood of high internal temperature. This is the mean internal temperature during the summer period plus an increment related to the thermal mass.

$$T_{\text{threshold}} = T_e^{\text{summer}} + \frac{G}{H} + \Delta T_{\text{mass}} \quad (\text{P7})$$

where

$$\begin{aligned} \Delta T_{\text{mass}} &= 2.0 - 0.007 \times \text{TMP} && \text{if TMP} < 285 \\ \Delta T_{\text{mass}} &= 0 && \text{if TMP} \geq 285 \end{aligned}$$

where TMP is the thermal mass parameter (for further details see Table 1i).

Where night cooling can be employed (window opening at night)  $\Delta T_{\text{mass}}$  is further modified if  $\text{TMP} > 285$  by a term  $-0.002 \times (\text{TMP} - 285)$ .

8. Use Table P2 to estimate tendency to high internal temperature in hot weather.

**Table P2: Levels of threshold temperature corresponding to likelihood of high internal temperature during hot weather**

$T_{\text{threshold}}$	Likelihood of high internal temperature during hot weather
$< 20.5^\circ\text{C}$	Not significant
$\geq 20.5^\circ\text{C}$ and $< 22.0^\circ\text{C}$	Slight
$\geq 22.0^\circ\text{C}$ and $< 23.5^\circ\text{C}$	Medium
$\geq 23.5^\circ\text{C}$	High

## P2 Reporting of results

Results should include:

- details of the house design including its thermal mass parameter and specification of any overhangs, together with its orientation and the climatic region assumed;
- for one or more scenarios, the category from Table P2 for the months of June, July and August for stated assumptions on occupant-determined factors (usage of blinds/curtains and window opening).

### P3 Solar shading

$Z_{\text{summer}}$  is given by

$$Z_{\text{summer}} = Z_{\text{blinds}} (Z + Z_{\text{overhangs}} - 1) \quad (\text{P8})$$

subject to

$$Z_{\text{summer}} \geq 0.1 Z_{\text{blinds}} \quad (\text{P9})$$

where

$Z_{\text{blinds}}$  is a shading factor for blinds or curtains

$Z$  is the solar access factor from Table 6d

$Z_{\text{overhangs}}$  is a shading factor for overhangs

Table P3 gives values for  $Z_{\text{blinds}}$ , and Tables P4 and P5 give values for  $Z_{\text{overhangs}}$ . If there are no overhangs,  $Z_{\text{overhangs}} = 1$ .

#### P3.1 Curtains and blinds

Unless specifically included in the design specification a default of dark coloured curtains should be assumed. Blinds or curtains shall be assumed closed 75% of the time during daylight hours ( $f = 0.75$ ). Shutters with window closed is compatible with windows open half the time in Table P1 as the latter refers to night-time and Table P3 refers to daytime.

**Table P3 : Shading factors for blinds, curtains or external shutters**

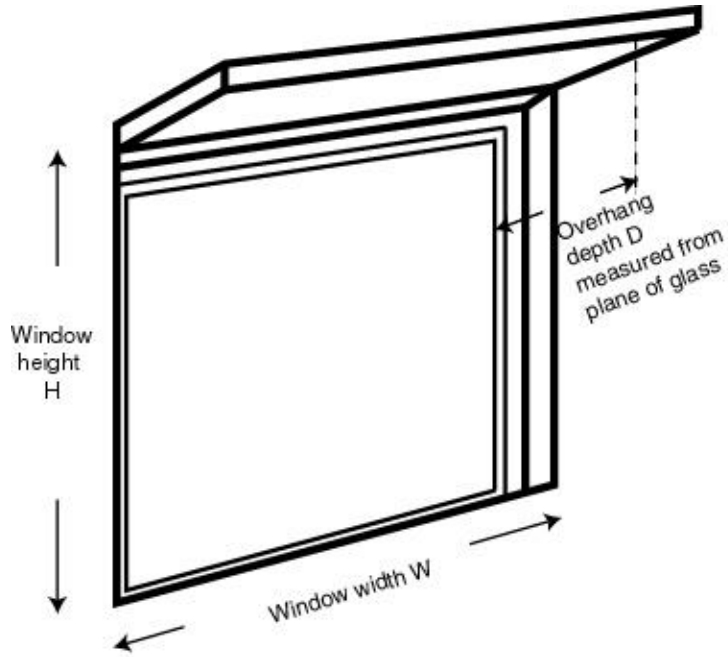
Blind or curtain type	$Z_{\text{blind}}$
Net curtain (covering whole window)	0.87
Net curtain (covering half window)	0.94
Dark-coloured curtain or roller blind	0.90
Light-coloured curtain or roller blind	0.74
Dark-coloured venetian blind	0.92
Light-coloured venetian blind	0.81
Dark-coloured external shutter*, window closed	0.53
White external shutter*, window closed	0.51
Dark-coloured external shutter*, window fully open	0.90
White external shutter*, window fully open	0.77

\* External shutters are not applicable to roof windows

Notes to Table P3

- Factor applies when fully closed. If closed only for a fraction  $f$  of the daylight hours or applicable only to a fraction  $f$  of the windows use  $f \times Z_{\text{blind}} + (1 - f)$ .
- Factor applies for venetian blind with slats at  $45^\circ$  against the sun. The same factor can be used if the blind is fully closed. If closed only for a fraction  $f$  of the daylight hours or applicable only to a fraction  $f$  of the windows use  $f \times Z_{\text{blind}} + (1 - f)$ .
- External shutters are not applicable to roof windows.

**P3.2 Overhangs**



Where the overhang is at least twice as wide as the window (e.g. balconies on blocks of flats) use Table P4. In other cases use Table P5. Interpolation may be used between rows of these tables. Use the average overhang depth if it varies. Usually the same value of  $Z_{overhangs}$  can be applied to all the windows on a given façade on the basis of an average depth-to-height ratio. This can be applied only to windows whose orientation is known.

**Table P4:  $Z_{overhangs}$  for wide overhangs**

Depth/H	Orientation of window				
	N	NE/NW	E/W	SE/SW	S
0.0	1.00	1.00	1.00	1.00	1.00
0.2	0.92	0.89	0.88	0.83	0.77
0.4	0.85	0.80	0.76	0.67	0.55
0.6	0.79	0.72	0.66	0.54	0.38
0.8	0.73	0.65	0.58	0.43	0.32
1	0.69	0.59	0.51	0.36	0.30
1.2 or more	0.66	0.55	0.46	0.31	0.29

This table is to be used where the overhang is at least twice as wide as the window

**Table P5:  $Z_{overhangs}$  for normal overhangs**

Depth/H	Orientation of window				
	N	NE/NW	E/W	SE/SW	S
0.0	1.00	1.00	1.00	1.00	1.00
0.2	0.94	0.91	0.89	0.84	0.79
0.4	0.90	0.85	0.79	0.72	0.64
0.6	0.88	0.81	0.72	0.62	0.53
0.8	0.86	0.79	0.66	0.55	0.50
1	0.85	0.77	0.61	0.52	0.49
1.2 or more	0.84	0.76	0.57	0.50	0.48

This table is to be used where the overhang is less than twice as wide as the window



## Appendix Q: Special features and specific data

### Q1 Special features

This appendix provides a method to enable the SAP calculation to make use of the characteristics of technologies that are not included in the published SAP specification.

This procedure may only be used for technologies whose characteristics have been independently assessed and which are described on the web page [www.ncm-pcdb.org.uk](http://www.ncm-pcdb.org.uk) or a web page linked to it. For such systems, this web page will contain details for calculating the data to be used in the SAP calculation.

In general the technology might use additional energy from one fuel while saving energy from another fuel.

Where more than one technology is applicable the procedure is applied for each.

Where the Appendix Q data are provided on an annual basis:

SAP rating:

1. include the amount of energy saved by the technology (kWh/year) in worksheet (236n) or (336n);
2. multiply the amount of saved energy by the unit price of the fuel concerned to obtain worksheet (270) or (380);
3. include the amount of energy used by the technology in worksheet (237n);
4. multiply the energy used by the unit price of the fuel concerned and to obtain worksheet (271) or (371);
5. include both these items in the calculation of the total energy cost.

In the case of electricity using an off-peak tariff the fractions of electricity at the high and low rates are needed to determine the appropriate price (Table 12a).

CO<sub>2</sub> emissions: the amount of energy saved or used by the technology (kWh/year) is multiplied by the appropriate emission factor and included in the total CO<sub>2</sub> emissions.

In some cases the data may be provided on a monthly basis, in which case they are included at the appropriate point in the worksheet.

Where the feature is concerned only with CO<sub>2</sub> emissions rather than energy, enter the applicable emissions figures directly into worksheet (270) and (271). For heat networks, specific data may be given in the Products Characteristics Database.

### Q2 Specific data

A similar mechanism will be used to enable the use of data specific to a technology. For applicable data types, the web page mentioned above will give details of the conditions for accepting the data and their applicability within the SAP calculation.

## Appendix R: Reference values

**This appendix will be updated in future to take account of any changes to Building Regulations.**

**The current wording is taken from SAP 2012 and is not necessarily applicable to SAP 10.0.**

This appendix provides reference values for the parameters of a SAP calculation, which are used in connection with establishing a target fabric energy efficiency and/or a target CO<sub>2</sub> emissions rate for the purposes of demonstrating compliance with regulations for new dwellings. The reference values are used to define a notional dwelling of the same size and shape as the actual dwelling.

Note: Building Regulations can vary between England, Wales, Scotland and Northern Ireland. The data in this Appendix apply only to the jurisdiction(s) stated.

### R1 England (Approved Document L1A, 2013 Edition)

1. To calculate the Target Emissions Rate (TER):
  - a. create a notional dwelling defined by Table R1.
  - b. calculate the CO<sub>2</sub> emissions for the notional dwelling so defined.
  - c. calculate the TER using those emissions as described in the Approved Document paragraphs 2.4 and 2.5 taking account of the applicable fuel factor.
2. To calculate the Target Fabric Energy Efficiency (TFEE) (Approved Document paragraph 2.6):
  - a. create a notional dwelling defined by Table R1.
  - b. apply the conditions for fabric energy efficiency (as listed in section 11).
  - c. calculate FEE for the notional dwelling so defined.
  - d.  $TFEE = 1.15 \times FEE$ .

### R2 Wales (Approved Document L1A, 2014 Edition)

To calculate the Target Emissions Rate (TER):

- a. create a notional dwelling defined by Table R1.
- b. calculate the CO<sub>2</sub> emissions for the notional dwelling so defined.
- c. calculate the TER using those emissions as described in the Approved Document paragraphs 8.1.2 and 8.1.3 taking account of the applicable fuel factor.

**Table R1 : Reference values for England and for Wales**

Element or system	Value
<b>Climate data</b>	<b>UK average</b>
Size and shape	Same as actual dwelling
Opening areas (windows, roof windows and doors)	Same as actual dwelling up to a maximum for total area of openings of 25% of total floor area. If the total area of openings in the actual dwelling exceeds 25% of the total floor area, reduce to 25% as follows: 1) Include all opaque and semi-glazed doors with the same areas as the actual dwelling (excluding any doors not in exposed elements, e.g. entrance door to a flat from a heated corridor). 2) Reduce area of all windows and roof windows by a factor equal to [25% of total floor area less area of doors included in 1)] divided by [total area of windows and roof windows in actual dwelling].
External walls including semi-exposed walls	$U = 0.18 \text{ W/m}^2\text{K}$
Party walls	$U = 0$
Floors	$U = 0.13 \text{ W/m}^2\text{K}$
Roofs	$U = 0.13 \text{ W/m}^2\text{K}$

Element or system	Value
Opaque door (<30% glazed area)	$U = 1.0 \text{ W/m}^2\text{K}$
Semi-glazed door (30%-60% glazed area)	$U = 1.2 \text{ W/m}^2\text{K}$
Windows and glazed doors with >60% glazed area	$U = 1.4 \text{ W/m}^2\text{K}$ Frame factor = 0.7 Solar energy transmittance = 0.63 Light transmittance = 0.80 Orientation same as actual dwelling Overshading same as for DER calculation (average if actual dwelling has very little or average overshading; same as actual dwelling if greater overshading)
Roof windows	$U = 1.4 \text{ W/m}^2\text{K}$ (Adjustment factor of $+0.3 \text{ W/m}^2\text{K}$ applied to roof window as described below Table 6e; resultant $U$ value = $1.7 \text{ W/m}^2\text{K}$ ) Overshading factor 1.0 Other parameters as for windows
Curtain wall	Curtain walling to be treated as standard glazing and opaque wall with the same areas as the actual dwelling. When the total opening area exceeds 25% of floor area the glazed area to be reduced to 25% as for opening areas above. $U$ -value of opaque wall = $0.18 \text{ W/m}^2\text{K}$ $U$ -value of glazing = $1.5 \text{ W/m}^2\text{K}$ (which includes an allowance of 0.1 for thermal bridging within the curtain wall)
Thermal mass	Medium ( $250 \text{ kJ/m}^2\text{K}$ )
Living area	Same as actual dwelling
Number of sheltered sides	Same as actual dwelling
Allowance for thermal bridging	<ol style="list-style-type: none"> <li>If the thermal bridging in the actual dwelling has been specified by using the default <math>y</math>-value of <math>0.15 \text{ W/m}^2\text{K}</math>, the thermal bridging is defined by <math>y = 0.05 \text{ W/m}^2\text{K}</math>.</li> <li>Otherwise the thermal bridging allowance is calculated using the lengths of junctions in the actual dwelling and the <math>\psi</math> values in Table R2.</li> </ol> Note. Where the area of openings in the actual dwelling is > 25% of the total floor area the lengths of junctions in the notional dwelling remain the same as the lengths in the actual dwelling, even though window area is reduced as described for 'Opening areas' above.
Ventilation system	Natural ventilation with intermittent extract fans
Air permeability	$5 \text{ m}^3/\text{h}\cdot\text{m}^2$ at 50 Pa
Chimneys and open flues	None of any type - i.e. worksheet (6a) to (6f) are zero
Extract fans / passive vents	2 extract fans for total floor area up to $70 \text{ m}^2$ , 3 for total floor area > $70 \text{ m}^2$ and up to $100 \text{ m}^2$ , 4 for total floor area > $100 \text{ m}^2$
Main heating fuel (space and water)	Mains gas
Heating system	Boiler and radiators Central heating pump 2013 or later, in heated space Design flow temperature = $55^\circ\text{C}$
Boiler	If gas or oil combi boiler in actual dwelling, instantaneous combi boiler; otherwise regular boiler Efficiency, SEDBUK(2009) = 89.5% Room-sealed, fan-assisted flue Modulating burner control No hot water test for combi boiler

Element or system	Value
Heating system controls	1. For a single storey dwelling in which the living area is greater than 70% of total floor area, programmer and room thermostat; 2. For any other dwelling, time and temperature zone control. And in all cases: Boiler interlock ErP Class V
Hot water system	Heated by boiler (regular or combi as above) Separate time control for space and water heating
Showers and baths	1 shower with a flow rate of 7l/min. Bath also present. Shower is fed by main water heating system (not instantaneous electric shower).
Hot water cylinder	If cylinder specified in actual dwelling: volume of cylinder in actual dwelling If combi boiler: no cylinder Otherwise: 150 litres If cylinder, declared loss factor = $0.85 \times (0.2 + 0.051 V^{2/3})$ kWh/day, where V is the volume of the cylinder in litres
Primary water heating losses	Fully insulated primary pipework Cylinder temperature controlled by thermostat Cylinder in heated space
Water use limited to 125 litres per person per day	Yes
Secondary space heating	None
Lighting	Fixed lighting capacity (lm) = 185 x TFA Efficacy of all fixed lighting = 66.9 lm/W
Air conditioning	None

Table R2 : Reference values of psi for junctions (England)

	Ref	Junction detail	$\Psi$ (W/m <sup>2</sup> ·K)
<b>Junctions with an external wall</b>	E1	Steel lintel with perforated steel base plate	0.05
	E2	Other lintels (including other steel lintels)	0.05
	E3	Sill	0.05
	E4	Jamb	0.05
	E5	Ground floor (normal)	0.16
	E19	Ground floor (inverted)	0.07
	E20	Exposed floor (normal)	0.32
	E21	Exposed floor (inverted)	0.32
	E22	Basement floor	0.07
	E6	Intermediate floor within a dwelling	0.0
	E7	Party floor between dwellings (in blocks of flats) <sup>a)</sup>	0.07
	E8	Balcony within a dwelling, wall insulation continuous <sup>b)</sup>	0.0
	E9	Balcony between dwellings, wall insulation continuous <sup>b) c)</sup>	0.02
	E23	Balcony within or between dwellings, balcony support penetrates wall insulation	0.02
	E10	Eaves (insulation at ceiling level)	0.06
	E24	Eaves (insulation at ceiling level - inverted)	0.24
	E11	Eaves (insulation at rafter level)	0.04
	E12	Gable (insulation at ceiling level)	0.06
	E13	Gable (insulation at rafter level)	0.08
	E14	Flat roof	0.08
	E15	Flat roof with parapet	0.56
	E16	Corner (normal)	0.09
	E17	Corner (inverted – internal area greater than external area)	-0.09
	E18	Party wall between dwellings <sup>c)</sup>	0.06
	E25	Staggered party wall between dwellings <sup>c)</sup>	0.06
<b>Junctions with a party wall</b> <sup>c)</sup>	P1	Ground floor	0.08
	P6	Ground floor (inverted)	0.07
	P2	Intermediate floor within a dwelling	0.0
	P3	Intermediate floor between dwellings (in blocks of flats)	0.0
	P7	Exposed floor (normal)	0.16
	P8	Exposed floor (inverted)	0.24
	P4	Roof (insulation at ceiling level)	0.12
	P5	Roof (insulation at rafter level)	0.08

<sup>a)</sup> Value of  $\Psi$  is applied to both sides of the party floor

<sup>b)</sup> This is an externally supported balcony (the balcony slab is not a continuation of the floor slab) where the wall insulation is continuous and not bridged by the balcony slab or its supports

<sup>c)</sup> Value of  $\Psi$  is applied to each dwelling

Table R2 (continued) : Values of psi for junctions in notional dwelling (England)

	Ref	Junction detail	$\Psi$ (W/m·K)
<b>Junctions within a roof or with a room-in-roof</b>	R1	Head of roof window	0.08
	R2	Sill of roof window	0.06
	R3	Jamb of roof window	0.08
	R4	Ridge (vaulted ceiling)	0.08
	R5	Ridge (inverted)	0.04
	R6	Flat ceiling	0.06
	R7	Flat ceiling(inverted)	0.04
	R8	Roof to wall (rafter)	0.06
	R9	Roof to wall (flat ceiling)	0.04

**Appendix S: Reduced Data SAP for existing dwellings**

RdSAP procedures for use with SAP 10.0 will be added later.

## **Appendix T: Improvement measures for Energy Performance Certificates**

To be added when RdSAP 10.0 is prepared.



## Appendix U: Climate data

The climate data needed are external temperature, wind speed and solar radiation.

Calculations for fabric energy efficiency (FEE), regulation compliance (TER and DER) and for ratings (SAP rating and environmental impact rating) are done with UK average weather. Other calculations (such as for energy use and costs on EPCs) are done using local weather. Weather data for each postcode district are published separately and are used when the postcode district is known; in other cases the data from Tables U1 to U4 are used.

See map on section U4. Regions are assigned by postcode in Table U6.

### U1 External temperature

**Table U1: Mean external temperature (°C)**

These data are for typical height above sea level representative of the region (see Table U4).

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 UK average	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
1 Thames	5.1	5.6	7.4	9.9	13.0	16.0	17.9	17.8	15.2	11.6	8.0	5.1
2 South East England	5.0	5.4	7.1	9.5	12.6	15.4	17.4	17.5	15.0	11.7	8.1	5.2
3 Southern England	5.4	5.7	7.3	9.6	12.6	15.4	17.3	17.3	15.0	11.8	8.4	5.5
4 South West England	6.1	6.4	7.5	9.3	11.9	14.5	16.2	16.3	14.6	11.8	9.0	6.4
5 Severn Wales / Severn England	4.9	5.3	7.0	9.3	12.2	15.0	16.7	16.7	14.4	11.1	7.8	4.9
6 Midlands	4.3	4.8	6.6	9.0	11.8	14.8	16.6	16.5	14.0	10.5	7.1	4.2
7 West Pennines Wales / West Pennines England	4.7	5.2	6.7	9.1	12.0	14.7	16.4	16.3	14.1	10.7	7.5	4.6
8 North West England / South West Scotland	3.9	4.3	5.6	7.9	10.7	13.2	14.9	14.8	12.8	9.7	6.6	3.7
9 Borders Scotland / Borders England	4.0	4.5	5.8	7.9	10.4	13.3	15.2	15.1	13.1	9.7	6.6	3.7
10 North East England	4.0	4.6	6.1	8.3	10.9	13.8	15.8	15.6	13.5	10.1	6.7	3.8
11 East Pennines	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
12 East Anglia	4.7	5.2	7.0	9.5	12.5	15.4	17.6	17.6	15.0	11.4	7.7	4.7
13 Wales	5.0	5.3	6.5	8.5	11.2	13.7	15.3	15.3	13.5	10.7	7.8	5.2
14 West Scotland	4.0	4.4	5.6	7.9	10.4	13.0	14.5	14.4	12.5	9.3	6.5	3.8
15 East Scotland	3.6	4.0	5.4	7.7	10.1	12.9	14.6	14.5	12.5	9.2	6.1	3.2
16 North East Scotland	3.3	3.6	5.0	7.1	9.3	12.2	14.0	13.9	12.0	8.8	5.7	2.9
17 Highland	3.1	3.2	4.4	6.6	8.9	11.4	13.2	13.1	11.3	8.2	5.4	2.7
18 Western Isles	5.2	5.0	5.8	7.6	9.7	11.8	13.4	13.6	12.1	9.6	7.3	5.2
19 Orkney	4.4	4.2	5.0	7.0	8.9	11.2	13.1	13.2	11.7	9.1	6.6	4.3
20 Shetland	4.6	4.1	4.7	6.5	8.3	10.5	12.4	12.8	11.4	8.8	6.5	4.6
21 Northern Ireland	4.8	5.2	6.4	8.4	10.9	13.5	15.0	14.9	13.1	10.0	7.2	4.7

**U2 Wind speed****Table U2: Wind speed (m/s) for calculation of infiltration rate**

<b>Region</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>
<b>0 UK average</b>	<b>5.1</b>	<b>5.0</b>	<b>4.9</b>	<b>4.4</b>	<b>4.3</b>	<b>3.8</b>	<b>3.8</b>	<b>3.7</b>	<b>4.0</b>	<b>4.3</b>	<b>4.5</b>	<b>4.7</b>
1 Thames	4.2	4.0	4.0	3.7	3.7	3.3	3.4	3.2	3.3	3.5	3.5	3.8
2 South East England	4.8	4.5	4.4	3.9	3.9	3.6	3.7	3.5	3.7	4.0	4.1	4.4
3 Southern England	5.1	4.7	4.6	4.3	4.3	4.0	4.0	3.9	4.0	4.5	4.4	4.7
4 South West England	6.0	5.6	5.6	5.0	5.0	4.4	4.4	4.3	4.7	5.4	5.5	5.9
5 Severn Wales / Severn England	4.9	4.6	4.7	4.3	4.3	3.8	3.8	3.7	3.8	4.3	4.3	4.6
6 Midlands	4.5	4.5	4.4	3.9	3.8	3.4	3.3	3.3	3.5	3.8	3.9	4.1
7 West Pennines Wales / West Pennines England	4.8	4.7	4.6	4.2	4.1	3.7	3.7	3.7	3.7	4.2	4.3	4.5
8 North West England / South West Scotland	5.2	5.2	5.0	4.4	4.3	3.9	3.7	3.7	4.1	4.6	4.8	4.7
9 Borders Scotland / Borders England	5.2	5.2	5.0	4.4	4.1	3.8	3.5	3.5	3.9	4.2	4.6	4.7
10 North East England	5.3	5.2	5.0	4.3	4.2	3.9	3.6	3.6	4.1	4.3	4.6	4.8
11 East Pennines	5.1	5.0	4.9	4.4	4.3	3.8	3.8	3.7	4.0	4.3	4.5	4.7
12 East Anglia	4.9	4.8	4.7	4.2	4.2	3.7	3.8	3.8	4.0	4.2	4.3	4.5
13 Wales	6.5	6.2	5.9	5.2	5.1	4.7	4.5	4.5	5.0	5.7	6.0	6.0
14 West Scotland	6.2	6.2	5.9	5.2	4.9	4.7	4.3	4.3	4.9	5.4	5.7	5.4
15 East Scotland	5.7	5.8	5.7	5.0	4.8	4.6	4.1	4.1	4.7	5.0	5.2	5.0
16 North East Scotland	5.7	5.8	5.7	5.0	4.6	4.4	4.0	4.1	4.6	5.2	5.3	5.1
17 Highland	6.5	6.8	6.4	5.7	5.1	5.1	4.6	4.5	5.3	5.8	6.1	5.7
18 Western Isles	8.3	8.4	7.9	6.6	6.1	6.1	5.6	5.6	6.3	7.3	7.7	7.5
19 Orkney	7.9	8.3	7.9	7.1	6.2	6.1	5.5	5.6	6.4	7.3	7.8	7.3
20 Shetland	9.5	9.4	8.7	7.5	6.6	6.4	5.7	6.0	7.2	8.5	8.9	8.5
21 Northern Ireland	5.4	5.3	5.0	4.7	4.5	4.1	3.9	3.7	4.2	4.6	5.0	5.0

### U3 Solar radiation

#### U3.1 Solar radiation on a horizontal plane

**Table U3: Mean global solar irradiance (W/m<sup>2</sup>) on a horizontal plane, and solar declination**

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 UK average	26	54	96	150	192	200	189	157	115	66	33	21
1 Thames	30	56	98	157	195	217	203	173	127	73	39	24
2 South East England	32	59	104	170	208	231	216	182	133	77	41	25
3 Southern England	35	62	109	172	209	235	217	185	138	80	44	27
4 South West England	36	63	111	174	210	233	204	182	136	78	44	28
5 Severn Wales / Severn England	32	59	105	167	201	226	206	175	130	74	40	25
6 Midlands	28	55	97	153	191	208	194	163	121	69	35	23
7 West Pennines Wales / West Pennines England	24	51	95	152	191	203	186	152	115	65	31	20
8 North West England / South West Scotland	23	51	95	157	200	203	194	156	113	62	30	19
9 Borders Scotland / Borders England	23	50	92	151	200	196	187	153	111	61	30	18
10 North East England	25	51	95	152	196	198	190	156	115	64	32	20
11 East Pennines	26	54	96	150	192	200	189	157	115	66	33	21
12 East Anglia	30	58	101	165	203	220	206	173	128	74	39	24
13 Wales	29	57	104	164	205	220	199	167	120	68	35	22
14 West Scotland	19	46	88	148	196	193	185	150	101	55	25	15
15 East Scotland	21	46	89	146	198	191	183	150	106	57	27	15
16 North East Scotland	19	45	89	143	194	188	177	144	101	54	25	14
17 Highland	17	43	85	145	189	185	170	139	98	51	22	12
18 Western Isles	16	41	87	155	205	206	185	148	101	51	21	11
19 Orkney	14	39	84	143	205	201	178	145	100	50	19	9
20 Shetland	12	34	79	135	196	190	168	144	90	46	16	7
21 Northern Ireland	24	52	96	155	201	198	183	150	107	61	30	18
<b>Solar declination (°)</b>												
All regions	-20.7	-12.8	-1.8	9.8	18.8	23.1	21.2	13.7	2.9	-8.7	-18.4	-23.0

**Table U4: Representative latitude and height above mean sea level**

<b>Region</b>	<b>Representative Latitude (°N)</b>	<b>Representative height above sea level (m)</b>
<b>0 UK average</b>	<b>53.5</b>	<b>79</b>
1 Thames	51.6	53
2 South East England	51.1	55
3 Southern England	50.9	50
4 South West England	50.5	85
5 Severn Wales / Severn England	51.5	99
6 Midlands	52.6	116
7 West Pennines Wales / West Pennines England	53.5	71
8 North West England / South West Scotland	54.6	119
9 Borders Scotland / Borders England	55.2	101
10 North East England	54.4	78
11 East Pennines	53.5	79
12 East Anglia	52.1	29
13 Wales	52.6	138
14 West Scotland	55.9	113
15 East Scotland	56.2	117
16 North East Scotland	57.3	123
17 Highland	57.5	218
18 Western Isles	57.7	59
19 Orkney	59.0	53
20 Shetland	60.1	50
21 Northern Ireland	54.6	72

### U3.2 Solar radiation on vertical and inclined surfaces

Solar radiation for any orientation and tilt,  $S(\text{orient}, p, m)$  in  $\text{W}/\text{m}^2$ , is obtained from the data in Table U3 as follows.

$$S(\text{orient}, p, m) = S_{h,m} \times R_{h\text{-inc}}(\text{orient}, p, m) \quad (\text{U1})$$

$$R_{h\text{-inc}}(\text{orient}, p, m) = A \times \cos^2(\phi - \delta) + B \times \cos(\phi - \delta) + C \quad (\text{U2})$$

where:

orient is the orientation of the surface (N, NE, E, SE, S, SW, W or NW)

p is the tilt (inclination) of the surface in degrees from horizontal (e.g.  $0^\circ$  is horizontal,  $90^\circ$  is vertical)

$S_{h,m}$  is the horizontal solar flux ( $\text{W}/\text{m}^2$ ) from Table U3

$R_{h\text{-inc}}(\text{orient}, p, m)$  is the factor for converting from horizontal to vertical or inclined solar flux in month m for a given orientation and tilt

$\phi$  is the latitude in degrees from Table U4

$\delta$  is the solar declination for the applicable month in degrees from Table U3  
A, B and C depend on orientation and tilt according to equation (U3)

$$\left. \begin{aligned} A &= k_1 \times \sin^3(p/2) + k_2 \times \sin^2(p/2) + k_3 \times \sin(p/2) \\ B &= k_4 \times \sin^3(p/2) + k_5 \times \sin^2(p/2) + k_6 \times \sin(p/2) \\ C &= k_7 \times \sin^3(p/2) + k_8 \times \sin^2(p/2) + k_9 \times \sin(p/2) + 1 \end{aligned} \right\} \quad (U3)$$

The constants  $k_1$  to  $k_9$  depend on orientation as given in Table U5.

For orientations other than those in Table U5, interpolate between two of the columns in the table for each of  $k_1$  to  $k_9$ . For example for orientation  $165^\circ$  from North, interpolate between South-East ( $135^\circ$ ) and South ( $180^\circ$ ).

**Table U5: Constants for calculation of solar flux on vertical and inclined surfaces**

	Orientation				
	North	NE/NW	East/West	SE/SW	South
$k_1$	26.3	0.165	1.44	-2.95	-0.66
$k_2$	-38.5	-3.68	-2.36	2.89	-0.106
$k_3$	14.8	3.0	1.07	1.17	2.93
$k_4$	-16.5	6.38	-0.514	5.67	3.63
$k_5$	27.3	-4.53	1.89	-3.54	-0.374
$k_6$	-11.9	-0.405	-1.64	-4.28	-7.4
$k_7$	-1.06	-4.38	-0.542	-2.72	-2.71
$k_8$	0.0872	4.89	-0.757	-0.25	-0.991
$k_9$	-0.191	-1.99	0.604	3.07	4.59

Angles may need to be converted to radians depending on the software implementation of the sine and cosine functions.

For a roof window in a pitched roof with a pitch of less than  $70^\circ$ , calculate the solar flux for its orientation and pitch. If the pitch is  $70^\circ$  or greater, treat as a vertical window.

### U3.3 Annual solar radiation on a surface

The annual solar radiation in kWh/m<sup>2</sup> on a surface of any orientation and tilt is:

$$S = 0.024 \sum_{m=1}^{12} n_m \times S(\text{orient}, p, m) \quad (U4)$$

where  $n_m$  is the number of days in month  $m$  and  $S(\text{orient}, p, m)$  is calculated for each month as set out in U3.2.

## U4 Region from postcodes

The region indicated in Table U6 applies to all postcodes in the postcode area except those for which specific postcode districts are given. For example BD16 is in region 11 and BD23 is in region 10.

**Table U6: Postcodes**

Postcode	Region	Postcode	Region	Postcode	Region	Postcode	Region
AB	16	G	14	N	1	SL	1
AL	1	GL	5E	NE	9E	SM	1
B	6	GU	1	NG	11	SN	5E
BA	5E	GU11-12	3	NN	6	SN7	1
BB	7E	GU14	3	NP	5W	SO	3
BD	11	GU28-29	2	NP8	13	SP	5E
BD23-24	10	GU30-35	3	NR	12	SP6-11	3
BH	3	GU46	3	NW	1	SR	9E
BL	7E	GU51-52	3	OL	7E	SR7-8	10
BN	2	HA	1	OX	1	SS	12
BR	2	HD	11	PA	14	ST	6
BS	5E	HG	10	PE	12	SW	1
BT	21	HP	1	PE9-12	11	SY	6
CA	8E	HR	6	PE20-25	11	SY14	7E
CB	12	HS	18	PH	15	SY15-25	13
CF	5W	HU	11	PH19-25	17	TA	5E
CH	7E	HX	11	PH26	16	TD	9S
CH5-8	7W	IG	12	PH30-44	17	TD12	9E
CM	12	IP	12	PH49	14	TD15	9E
CM21-23	1	IV	17	PH50	14	TF	6
CO	12	IV30-32	16	PL	4	TN	2
CR	1	IV36	16	PO	3	TQ	4
CT	2	KA	14	PO18-22	2	TR	4
CV	6	KT	1	PR	7E	TS	10
CW	7E	KW	17	RG	1	TW	1
DA	2	KW15-17	19	RG21-29	3	UB	1
DD	15	KY	15	RH	1	W	1
DE	6	L	7E	RH10-20	2	WA	7E
DG	8S	LA	7E	RM	12	WC	1
DH	10	LA7-23	8E	S	11	WD	1
DH4-5	9E	LD	13	S18	6	WF	11
DL	10	LE	6	S32-33	6	WN	7E
DN	11	LL	7W	S40-45	6	WR	6
DT	3	LL23-27	13	SA	5W	WS	6
DY	6	LL30-78	13	SA14-20	13	WV	6
E	1	LN	11	SA31-48	13	YO	10
EC	1	LS	11	SA61-73	13	YO15-16	11
EH	15	LS24	10	SE	1	YO25	11
EH43-46	9S	LU	1	SG	1	ZE	20
EN	1	M	7E	SK	7E		
EN9	12	ME	2	SK13	6		
EX	4	MK	1	SK17	6		
FK	14	ML	14	SK22-23	6		
FY	7E						



## SAP WORKSHEET (Version 10.0)

### 1. Overall dwelling dimensions

	Area (m <sup>2</sup> )		Average storey height (m)		Volume (m <sup>3</sup> )
Basement	<input type="text"/> (1a)	×	<input type="text"/> (2a)	=	<input type="text"/> (3a)
Ground floor	<input type="text"/> (1b)	×	<input type="text"/> (2b)	=	<input type="text"/> (3b)
First floor	<input type="text"/> (1c)	×	<input type="text"/> (2c)	=	<input type="text"/> (3c)
Second floor	<input type="text"/> (1d)	×	<input type="text"/> (2d)	=	<input type="text"/> (3d)
Third floor	<input type="text"/> (1e)	×	<input type="text"/> (2e)	=	<input type="text"/> (3e)
Other floors ( <i>repeat as necessary</i> )	<input type="text"/> (1n)	×	<input type="text"/> (2n)	=	<input type="text"/> (3n)
Total floor area TFA = (1a)+(1b)+(1c)+(1d)+(1e)...(1n) =	<input type="text"/> (4)				
Dwelling volume					(3a)+(3b)+(3c)+(3d)+(3e)...(3n) = <input type="text"/> (5)

### 2. Ventilation rate

	main heating	secondary heating	other	total	m <sup>3</sup> per hour
Number of chimneys / flues:					
- open chimneys	<input type="text"/>	+ <input type="text"/>	+ <input type="text"/>	= <input type="text"/>	× 80 = <input type="text"/> (6a)
- open flues	<input type="text"/>	+ <input type="text"/>	+ <input type="text"/>	= <input type="text"/>	× 35 = <input type="text"/> (6b)
- chimneys / flues attached to closed fire	<input type="text"/>	+ <input type="text"/>	+ <input type="text"/>	= <input type="text"/>	× 10 = <input type="text"/> (6c)
- flues attached to solid fuel boiler	<input type="text"/>	+ <input type="text"/>	+ <input type="text"/>	= <input type="text"/>	× 20 = <input type="text"/> (6d)
- flues attached to other heater	<input type="text"/>	+ <input type="text"/>	+ <input type="text"/>	= <input type="text"/>	× 35 = <input type="text"/> (6e)
Number of blocked chimneys				<input type="text"/>	× 20 = <input type="text"/> (6f)
Number of intermittent extract fans				<input type="text"/>	× 10 = <input type="text"/> (7a)
Number of passive vents				<input type="text"/>	× 10 = <input type="text"/> (7b)
Number of flueless gas fires				<input type="text"/>	× 40 = <input type="text"/> (7c)
					Air changes per hour
Infiltration due to chimneys, flues, fans, PSVs, etc.					$[(6a)+(6b)+(6c)+(6d)+(6f)+(7a)+(7b)+(7c)] \div (5) =$ <input type="text"/> (8)
<i>If a pressurisation test has been carried out or is intended, proceed to (17), otherwise continue from (9) to (16)</i>					
Number of storeys in the dwelling (n <sub>s</sub> )				<input type="text"/>	(9)
Additional infiltration				$[(9) - 1] \times 0.1 =$	<input type="text"/> (10)
Structural infiltration: 0.25 for steel or timber frame or 0.35 for masonry construction <i>if both types of wall are present, use the value corresponding to the greater wall area (after deducting areas of openings); if equal use 0.35</i>					<input type="text"/> (11)
If suspended wooden ground floor, enter 0.2 (unsealed) or 0.1 (sealed), else enter 0					<input type="text"/> (12)
If no draught lobby, enter 0.05, else enter 0					<input type="text"/> (13)
Percentage of windows and doors draught proofed				<input type="text"/>	(14)
Window infiltration				$0.25 - [0.2 \times (14) \div 100] =$	<input type="text"/> (15)
Infiltration rate				$(8) + (10) + (11) + (12) + (13) + (15) =$	<input type="text"/> (16)
Air permeability value, q <sub>50</sub> , expressed in cubic metres per hour per square metre of envelope area					<input type="text"/> (17)



If based on air permeability value, then (18) = [(17) ÷ 20] + (8), otherwise (18) = (16) (18)

*Air permeability value applies if a pressurisation test has been done, or a design or specified air permeability is being used*

Number of sides on which dwelling is sheltered (19)

Shelter factor  $(20) = 1 - [0.075 \times (19)] =$  (20)

Infiltration rate incorporating shelter factor  $(21) = (18) \times (20) =$  (21)

Infiltration rate modified for monthly wind speed:

Monthly average wind speed from Table U2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(22) <sub>m</sub> =	(22) <sub>1</sub>	(22) <sub>2</sub>	(22) <sub>3</sub>	(22) <sub>4</sub>	(22) <sub>5</sub>	(22) <sub>6</sub>	(22) <sub>7</sub>	(22) <sub>8</sub>	(22) <sub>9</sub>	(22) <sub>10</sub>	(22) <sub>11</sub>	(22) <sub>12</sub>

Wind Factor  $(22a)_m = (22)_m \div 4$

(22a) <sub>m</sub> =	(22a) <sub>1</sub>	(22a) <sub>2</sub>	(22a) <sub>3</sub>	(22a) <sub>4</sub>	(22a) <sub>5</sub>	(22a) <sub>6</sub>	(22a) <sub>7</sub>	(22a) <sub>8</sub>	(22a) <sub>9</sub>	(22a) <sub>10</sub>	(22a) <sub>11</sub>	(22a) <sub>12</sub>
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Adjusted infiltration rate (allowing for shelter and wind speed) = (21) × (22a)<sub>m</sub>

(22b) <sub>m</sub> =	(22b) <sub>1</sub>	(22b) <sub>2</sub>	(22b) <sub>3</sub>	(22b) <sub>4</sub>	(22b) <sub>5</sub>	(22b) <sub>6</sub>	(22b) <sub>7</sub>	(22b) <sub>8</sub>	(22b) <sub>9</sub>	(22b) <sub>10</sub>	(22b) <sub>11</sub>	(22b) <sub>12</sub>
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Calculate effective air change rate for the applicable case:

*If mechanical ventilation: air change rate through system* 0.5 (23a)

*If exhaust air heat pump using Appendix N, (23b) = (23a) × F<sub>mv</sub> (equation (N4)), otherwise (23b) = (23a)* (23b)

*If balanced with heat recovery: efficiency in % allowing for in-use factor (from PCDB) =* (23c)

a) If balanced mechanical ventilation with heat recovery (MVHR)  $(24a)_m = (22b)_m + (23b) \times [1 - (23c) \div 100]$   
 (24a)<sub>m</sub> = 

(24a) <sub>1</sub>	(24a) <sub>2</sub>	(24a) <sub>3</sub>	(24a) <sub>4</sub>	(24a) <sub>5</sub>	(24a) <sub>6</sub>	(24a) <sub>7</sub>	(24a) <sub>8</sub>	(24a) <sub>9</sub>	(24a) <sub>10</sub>	(24a) <sub>11</sub>	(24a) <sub>12</sub>
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(24a)

b) If balanced mechanical ventilation without heat recovery (MV)  $(24b)_m = (22b)_m + (23b)$   
 (24b)<sub>m</sub> = 

(24b) <sub>1</sub>	(24b) <sub>2</sub>	(24b) <sub>3</sub>	(24b) <sub>4</sub>	(24b) <sub>5</sub>	(24b) <sub>6</sub>	(24b) <sub>7</sub>	(24b) <sub>8</sub>	(24b) <sub>9</sub>	(24b) <sub>10</sub>	(24b) <sub>11</sub>	(24b) <sub>12</sub>
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(24b)

c) If whole house extract ventilation or positive input ventilation from outside  
 if  $(22b)_m < 0.5 \times (23b)$ , then  $(24c) = (23b)$ ; otherwise  $(24c) = (22b)_m + 0.5 \times (23b)$   
 (24c)<sub>m</sub> = 

(24c) <sub>1</sub>	(24c) <sub>2</sub>	(24c) <sub>3</sub>	(24c) <sub>4</sub>	(24c) <sub>5</sub>	(24c) <sub>6</sub>	(24c) <sub>7</sub>	(24c) <sub>8</sub>	(24c) <sub>9</sub>	(24c) <sub>10</sub>	(24c) <sub>11</sub>	(24c) <sub>12</sub>
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(24c)

d) If natural ventilation or whole house positive input ventilation from loft  
 if  $(22b)_m \geq 1$ , then  $(24d)_m = (22b)_m$  otherwise  $(24d)_m = 0.5 + [(22b)_m^2 \times 0.5]$   
 (24d)<sub>m</sub> = 

(24d) <sub>1</sub>	(24d) <sub>2</sub>	(24d) <sub>3</sub>	(24d) <sub>4</sub>	(24d) <sub>5</sub>	(24d) <sub>6</sub>	(24d) <sub>7</sub>	(24d) <sub>8</sub>	(24d) <sub>9</sub>	(24d) <sub>10</sub>	(24d) <sub>11</sub>	(24d) <sub>12</sub>
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(24d)

Effective air change rate - enter (24a) or (24b) or (24c) or (24d) in (25)

(25) <sub>m</sub> =	(25) <sub>1</sub>	(25) <sub>2</sub>	(25) <sub>3</sub>	(25) <sub>4</sub>	(25) <sub>5</sub>	(25) <sub>6</sub>	(25) <sub>7</sub>	(25) <sub>8</sub>	(25) <sub>9</sub>	(25) <sub>10</sub>	(25) <sub>11</sub>	(25) <sub>12</sub>	(25)
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If Appendix Q applies in relation to air change rate, the effective air change rate is calculated via Appendix Q and use the following instead:

Effective air change rate from Appendix Q calculation sheet:

(25) <sub>m</sub> =	(25) <sub>1</sub>	(25) <sub>2</sub>	(25) <sub>3</sub>	(25) <sub>4</sub>	(25) <sub>5</sub>	(25) <sub>6</sub>	(25) <sub>7</sub>	(25) <sub>8</sub>	(25) <sub>9</sub>	(25) <sub>10</sub>	(25) <sub>11</sub>	(25) <sub>12</sub>	(25)
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### 3. Heat losses and heat loss parameter

Items in the table below are to be expanded as necessary to allow for all different types of element e.g. 4 wall types. The  $\kappa$ -value is the heat capacity per unit area, see Table 1h

Element	Gross area, m <sup>2</sup>	Opening s m <sup>2</sup>	Net area A, m <sup>2</sup>	U-value W/m <sup>2</sup> K	= A × U W/K	$\kappa$ -value kJ/m <sup>2</sup> ·K	A × $\kappa$ kJ/K
Solid door			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>		<input type="text"/> (26)
Semi-glazed door			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>		<input type="text"/> (26a)
Window			<input type="text"/> × * below	<input type="text"/>	<input type="text"/>		<input type="text"/> (27)
Roof window			<input type="text"/> × * below	<input type="text"/>	<input type="text"/>		<input type="text"/> (27a)
Basement floor			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (28)
Ground floor			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (28a)
Exposed floor			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (28b)
Basement wall	<input type="text"/> - <input type="text"/>	=	<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (29)
External wall	<input type="text"/> - <input type="text"/>	=	<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (29a)
Roof	<input type="text"/> - <input type="text"/>	=	<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (30)
<b>Total area of external elements ΣA, m<sup>2</sup></b>			<input type="text"/> (31)				
Party wall			<input type="text"/> × <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/> (32)
<i>(party wall U-value from Table 3.6, <math>\kappa</math> according to its construction)</i>							
Party floor			<input type="text"/>			<input type="text"/>	<input type="text"/> (32a)
Party ceiling			<input type="text"/>			<input type="text"/>	<input type="text"/> (32b)
Internal wall **			<input type="text"/>			<input type="text"/>	<input type="text"/> (32c)
Internal floor			<input type="text"/>			<input type="text"/>	<input type="text"/> (32d)
Internal ceiling			<input type="text"/>			<input type="text"/>	<input type="text"/> (32e)

\* for windows and roof windows, use effective window U-value calculated using formula  $1/[(1/U\text{-value})+0.04]$  as in paragraph 3.2

\*\* include the areas on both sides of internal walls and partitions

Fabric heat loss, W/K =  $\Sigma(A \times U)$  (26)...(30) + (32) =  (33)

Heat capacity  $C_m = \Sigma(A \times \kappa)$  (28)...(30) + (32) + (32a)...(32e) =  (34)

Thermal mass parameter (TMP =  $C_m \div TFA$ ) in kJ/m<sup>2</sup>K = (34)  $\div$  (4) =  (35)

For design assessments where the details of the construction are not known precisely the indicative values of TMP in Table 1j can be used instead of a detailed calculation. Also TMP calculated separately can be used in (35).

Thermal bridges :  $\Sigma(L \times \Psi)$  calculated using Appendix K  (36)

if details of thermal bridging are not known (36) =  $0.15 \times (31)$

Total fabric heat loss (33) + (36) =  (37)

Ventilation heat loss calculated monthly (38)<sub>m</sub> =  $0.33 \times (25)_m \times (5)$

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
(38) <sub>m</sub> =	(38) <sub>1</sub>	(38) <sub>2</sub>	(38) <sub>3</sub>	(38) <sub>4</sub>	(38) <sub>5</sub>	(38) <sub>6</sub>	(38) <sub>7</sub>	(38) <sub>8</sub>	(38) <sub>9</sub>	(38) <sub>10</sub>	(38) <sub>11</sub>	(38) <sub>12</sub>	(38)

Heat transfer coefficient, W/K (39)<sub>m</sub> = (37) + (38)<sub>m</sub>

(39)<sub>m</sub> = 

(39) <sub>1</sub>	(39) <sub>2</sub>	(39) <sub>3</sub>	(39) <sub>4</sub>	(39) <sub>5</sub>	(39) <sub>6</sub>	(39) <sub>7</sub>	(39) <sub>8</sub>	(39) <sub>9</sub>	(39) <sub>10</sub>	(39) <sub>11</sub>	(39) <sub>12</sub>
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Average =  $\Sigma(39)_{1...12} / 12 =$   (39)

Heat loss parameter (HLP), W/m<sup>2</sup>K  $(40)_m = (39)_m \div (4)$

$(40)_m =$ 

(40) <sub>1</sub>	(40) <sub>2</sub>	(40) <sub>3</sub>	(40) <sub>4</sub>	(40) <sub>5</sub>	(40) <sub>6</sub>	(40) <sub>7</sub>	(40) <sub>8</sub>	(40) <sub>9</sub>	(40) <sub>10</sub>	(40) <sub>11</sub>	(40) <sub>12</sub>
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Average =  $\Sigma(40)_{1...12} / 12 =$   (40)

**Number of days in month** (Table 1a)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
(41) <sub>m</sub> =	(41) <sub>1</sub>	(41) <sub>2</sub>	(41) <sub>3</sub>	(41) <sub>4</sub>	(41) <sub>5</sub>	(41) <sub>6</sub>	(41) <sub>7</sub>	(41) <sub>8</sub>	(41) <sub>9</sub>	(41) <sub>10</sub>	(41) <sub>11</sub>	(41) <sub>12</sub>	(41)

**4. Water heating energy requirement**

kWh/year

Assumed occupancy, N  (42)

if TFA > 13.9,  $N = 1 + 1.76 \times [1 - \exp(-0.000349 \times (TFA - 13.9)^2)] + 0.0013 \times (TFA - 13.9)$

if TFA ≤ 13.9, N = 1

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Hot water usage in litres per day for mixer showers, V<sub>d,shower</sub> (from Appendix J)

$(42a)_m =$ 

(42a) <sub>1</sub>	(42a) <sub>2</sub>	(42a) <sub>3</sub>	(42a) <sub>4</sub>	(42a) <sub>5</sub>	(42a) <sub>6</sub>	(42a) <sub>7</sub>	(42a) <sub>8</sub>	(42a) <sub>9</sub>	(42a) <sub>10</sub>	(42a) <sub>11</sub>	(42a) <sub>12</sub>
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 (42a)

Hot water usage in litres per day for baths, V<sub>d,bath</sub> (from Appendix J)

$(42b)_m =$ 

(42b) <sub>1</sub>	(42b) <sub>2</sub>	(42b) <sub>3</sub>	(42b) <sub>4</sub>	(42b) <sub>5</sub>	(42b) <sub>6</sub>	(42b) <sub>7</sub>	(42b) <sub>8</sub>	(42b) <sub>9</sub>	(42b) <sub>10</sub>	(42b) <sub>11</sub>	(42b) <sub>12</sub>
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 (42b)

Hot water usage in litres per day for other uses, V<sub>d,other</sub> (from Appendix J)

$(42c)_m =$ 

(42c) <sub>1</sub>	(42c) <sub>2</sub>	(42c) <sub>3</sub>	(42c) <sub>4</sub>	(42c) <sub>5</sub>	(42c) <sub>6</sub>	(42c) <sub>7</sub>	(42c) <sub>8</sub>	(42c) <sub>9</sub>	(42c) <sub>10</sub>	(42c) <sub>11</sub>	(42c) <sub>12</sub>
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 (42c)

Annual average hot water usage in litres per day V<sub>d,average</sub> (from Appendix J)  (43)

Hot water usage in litres per day for each month V<sub>d,m</sub> = (42a) + (42b) + (42c)

$(44)_m =$ 

(44) <sub>1</sub>	(44) <sub>2</sub>	(44) <sub>3</sub>	(44) <sub>4</sub>	(44) <sub>5</sub>	(44) <sub>6</sub>	(44) <sub>7</sub>	(44) <sub>8</sub>	(44) <sub>9</sub>	(44) <sub>10</sub>	(44) <sub>11</sub>	(44) <sub>12</sub>
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Total =  $\Sigma(44)_{1...12} =$   (44)

Energy content of hot water used =  $4.18 \times V_{d,m} \times n_m \times \Delta T_m / 3600$  kWh/month (see Tables 1b, 1c, 1d)

$(45)_m =$ 

(45) <sub>1</sub>	(45) <sub>2</sub>	(45) <sub>3</sub>	(45) <sub>4</sub>	(45) <sub>5</sub>	(45) <sub>6</sub>	(45) <sub>7</sub>	(45) <sub>8</sub>	(45) <sub>9</sub>	(45) <sub>10</sub>	(45) <sub>11</sub>	(45) <sub>12</sub>
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Total =  $\Sigma(45)_{1...12} =$   (45)

*If instantaneous water heating at point of use (no hot water storage), enter "0" in (46) to (61)*

*For heat networks include distribution loss whether or not hot water tank is present*

Distribution loss  $(46)_m = 0.15 \times (45)_m$

$(46)_m =$ 

(46) <sub>1</sub>	(46) <sub>2</sub>	(46) <sub>3</sub>	(46) <sub>4</sub>	(46) <sub>5</sub>	(46) <sub>6</sub>	(46) <sub>7</sub>	(46) <sub>8</sub>	(46) <sub>9</sub>	(46) <sub>10</sub>	(46) <sub>11</sub>	(46) <sub>12</sub>
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 (46)

Storage volume (litres) including any solar or WWHRS storage within same vessel  (47)

*If heat network and no tank in dwelling, enter 110 litres in (47)*

*Otherwise if no stored hot water (this includes instantaneous combi boilers) enter '0' in (47)*

Water storage loss:

a) If manufacturer's declared loss factor is known (kWh/day):  (48)

Temperature factor from Table 2b  (49)

Energy lost from water storage, kWh/day  $(48) \times (49) =$   (50)

b) If manufacturer's declared loss factor is not known :

Hot water storage loss factor from Table 2 (kWh/litre/day)  (51)

*If heat network see section 4.3*

Volume factor from Table 2a  (52)

Temperature factor from Table 2b  (53)

Energy lost from water storage, kWh/day  $(47) \times (51) \times (52) \times (53) =$   (54)

Enter (50) or (54) in (55)   (55)

Water storage loss calculated for each month  $(56)_m = (55) \times (41)_m$

(56)<sub>m</sub> = 

(56) <sub>1</sub>	(56) <sub>2</sub>	(56) <sub>3</sub>	(56) <sub>4</sub>	(56) <sub>5</sub>	(56) <sub>6</sub>	(56) <sub>7</sub>	(56) <sub>8</sub>	(56) <sub>9</sub>	(56) <sub>10</sub>	(56) <sub>11</sub>	(56) <sub>12</sub>
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 (56)

If the vessel contains dedicated solar storage or dedicated WWHRS storage,  $(57)_m = (56)_m \times [(47) - V_s] \div (47)$ , else  $(57)_m = (56)_m$  where  $V_s$  is  $V_{ww}$  from Appendix G3 or (H12) from Appendix H (as applicable).

(57)<sub>m</sub> = 

(57) <sub>1</sub>	(57) <sub>2</sub>	(57) <sub>3</sub>	(57) <sub>4</sub>	(57) <sub>5</sub>	(57) <sub>6</sub>	(57) <sub>7</sub>	(57) <sub>8</sub>	(57) <sub>9</sub>	(57) <sub>10</sub>	(57) <sub>11</sub>	(57) <sub>12</sub>
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 (57)

Primary circuit loss for each month from Table 3

*(modified by factor from Table H4 if there is solar water heating and a cylinder thermostat, although not for DHW-only heat networks)*

(59)<sub>m</sub> = 

(59) <sub>1</sub>	(59) <sub>2</sub>	(59) <sub>3</sub>	(59) <sub>4</sub>	(59) <sub>5</sub>	(59) <sub>6</sub>	(59) <sub>7</sub>	(59) <sub>8</sub>	(59) <sub>9</sub>	(59) <sub>10</sub>	(59) <sub>11</sub>	(59) <sub>12</sub>
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 (59)

Combi loss for each month from Table 3a, 3b or 3c (enter "0" if not a combi boiler)

(61)<sub>m</sub> = 

(61) <sub>1</sub>	(61) <sub>2</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>3</sub>	(61) <sub>12</sub>
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 (61)

Total heat required for water heating calculated for each month  $(62)_m = 0.85 \times (45)_m + (46)_m + (57)_m + (59)_m + (61)_m$

(62)<sub>m</sub> = 

(62) <sub>1</sub>	(62) <sub>2</sub>	(62) <sub>3</sub>	(62) <sub>4</sub>	(62) <sub>5</sub>	(62) <sub>6</sub>	(62) <sub>7</sub>	(62) <sub>8</sub>	(62) <sub>9</sub>	(62) <sub>10</sub>	(62) <sub>11</sub>	(62) <sub>12</sub>
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 (62)

Solar DHW input calculated using Appendix G or Appendix H (negative quantity) (enter "0" if no solar contribution to water heating) (add additional lines if FGHRs, WWHRS and/or PV diverter applies, see Appendix G)

(63)<sub>m</sub> = 

(63) <sub>1</sub>	(63) <sub>2</sub>	(63) <sub>3</sub>	(63) <sub>4</sub>	(63) <sub>5</sub>	(63) <sub>6</sub>	(63) <sub>7</sub>	(63) <sub>8</sub>	(63) <sub>9</sub>	(63) <sub>10</sub>	(63) <sub>11</sub>	(63) <sub>12</sub>
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 (63)

Output from water heater for each month, kWh/month  $(64)_m = (62)_m + (63)_m$

(64)<sub>m</sub> = 

(64) <sub>1</sub>	(64) <sub>2</sub>	(64) <sub>3</sub>	(64) <sub>4</sub>	(64) <sub>5</sub>	(64) <sub>6</sub>	(64) <sub>7</sub>	(64) <sub>8</sub>	(64) <sub>9</sub>	(64) <sub>10</sub>	(64) <sub>11</sub>	(64) <sub>12</sub>
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Total per year (kWh/year) =  $\Sigma(64)_{1...12} =$    (64)

*if (64)<sub>m</sub> < 0 then set to 0*

Energy used by instantaneous electric shower(s), kWh/month (from Appendix J)

(64a)<sub>m</sub> = 

(64a) <sub>1</sub>	(64a) <sub>2</sub>	(64a) <sub>3</sub>	(64a) <sub>4</sub>	(64a) <sub>5</sub>	(64a) <sub>6</sub>	(64a) <sub>7</sub>	(64a) <sub>8</sub>	(64a) <sub>9</sub>	(64a) <sub>10</sub>	(64a) <sub>11</sub>	(64a) <sub>12</sub>
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Total per year (kWh/year) =  $\Sigma(64a)_{1...12} =$    (64a)

Heat gains from water heating, kWh/month  $0.25 \times [0.85 \times (45)_m + (61)_m + (64a)_m] + 0.8 \times [(46)_m + (57)_m + (59)_m]$

(65)<sub>m</sub> = 

(65) <sub>1</sub>	(65) <sub>2</sub>	(65) <sub>3</sub>	(65) <sub>4</sub>	(65) <sub>5</sub>	(65) <sub>6</sub>	(65) <sub>7</sub>	(65) <sub>8</sub>	(65) <sub>9</sub>	(65) <sub>10</sub>	(65) <sub>11</sub>	(65) <sub>12</sub>
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 (65)  
*include (57)<sub>m</sub> in calculation of (65)<sub>m</sub> only if hot water store is in the dwelling or hot water is from heat network*

### 5. Internal gains (see Tables 5 and 5a)

Metabolic gains (Table 5), watts

(66)<sub>m</sub> = 

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(66) <sub>1</sub>	(66) <sub>2</sub>	(66) <sub>3</sub>	(66) <sub>4</sub>	(66) <sub>5</sub>	(66) <sub>6</sub>	(66) <sub>7</sub>	(66) <sub>8</sub>	(66) <sub>9</sub>	(66) <sub>10</sub>	(66) <sub>11</sub>	(66a) <sub>12</sub>

 (66)

Lighting gains (calculated in Appendix L, equation L12 or L12a), also see Table 5

(67)<sub>m</sub> = 

(67) <sub>1</sub>	(67) <sub>2</sub>	(67) <sub>3</sub>	(67) <sub>4</sub>	(67) <sub>5</sub>	(67) <sub>6</sub>	(67) <sub>7</sub>	(67) <sub>8</sub>	(67) <sub>9</sub>	(67) <sub>10</sub>	(67) <sub>11</sub>	(67) <sub>12</sub>
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 (67)

Appliances gains (calculated in Appendix L, equation L16 or L16a), also see Table 5

(68)<sub>m</sub> = 

(68) <sub>1</sub>	(68) <sub>2</sub>	(68) <sub>3</sub>	(68) <sub>4</sub>	(68) <sub>5</sub>	(68) <sub>6</sub>	(68) <sub>7</sub>	(68) <sub>8</sub>	(68) <sub>9</sub>	(68) <sub>10</sub>	(68) <sub>11</sub>	(68) <sub>12</sub>
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 (68)

Cooking gains (calculated in Appendix L, equation L18 or L18a), also see Table 5

(69)<sub>m</sub> = 

(69) <sub>1</sub>	(69) <sub>2</sub>	(69) <sub>3</sub>	(69) <sub>4</sub>	(69) <sub>5</sub>	(69) <sub>6</sub>	(69) <sub>7</sub>	(69) <sub>8</sub>	(69) <sub>9</sub>	(69) <sub>10</sub>	(69) <sub>11</sub>	(69) <sub>12</sub>
-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	--------------------	--------------------	--------------------

 (69)

Pumps and fans gains (Table 5a)

(70)<sub>m</sub> = 

(70) <sub>1</sub>	(70) <sub>2</sub>	(70) <sub>3</sub>	(70) <sub>4</sub>	(70) <sub>5</sub>	(70) <sub>6</sub>	(70) <sub>7</sub>	(70) <sub>8</sub>	(70) <sub>9</sub>	(70) <sub>10</sub>	(70) <sub>11</sub>	(70) <sub>12</sub>
-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	--------------------	--------------------	--------------------

 (70)

Losses e.g. evaporation (negative values) (Table 5)

(71)<sub>m</sub> = 

(71) <sub>1</sub>	(71) <sub>2</sub>	(71) <sub>3</sub>	(71) <sub>4</sub>	(71) <sub>5</sub>	(71) <sub>6</sub>	(71) <sub>7</sub>	(71) <sub>8</sub>	(71) <sub>9</sub>	(71) <sub>10</sub>	(71) <sub>11</sub>	(71) <sub>12</sub>
-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	--------------------	--------------------	--------------------

 (71)

Water heating gains (Table 5)

(72)<sub>m</sub> = 

(72) <sub>1</sub>	(72) <sub>2</sub>	(72) <sub>3</sub>	(72) <sub>4</sub>	(72) <sub>5</sub>	(72) <sub>6</sub>	(72) <sub>7</sub>	(72) <sub>8</sub>	(72) <sub>9</sub>	(72) <sub>10</sub>	(72) <sub>11</sub>	(72) <sub>12</sub>
-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	-------------------	--------------------	--------------------	--------------------

 (72)

**Total internal gains** =  $(66)_m + (67)_m + (68)_m + (69)_m + (70)_m + (71)_m + (72)_m$

(73)<sub>m</sub> = 

(73) <sub>1</sub>	(73) <sub>2</sub>	(73) <sub>3</sub>	(73) <sub>4</sub>	(73) <sub>5</sub>	(73) <sub>6</sub>	(73) <sub>7</sub>	(73) <sub>8</sub>	(73) <sub>9</sub>	(73) <sub>10</sub>	(73) <sub>11</sub>	(73) <sub>12</sub>
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 (73)

### 6. Solar gains

Solar gains are calculated using solar flux from U3 in Appendix U and associated equations to convert to the applicable orientation. Rows (74) to (82) are used 12 times, one for each month, repeating as needed if there is more than one window type,

	Access factor Table 6d	Area m <sup>2</sup>	Solar flux W/m <sup>2</sup>	$g_{\perp}$ Specific data or Table 6b	FF Specific data or Table 6c	Gains (W)
North	×	×	×	×	×	(74)
Northeast	×	×	×	×	×	(75)
East	×	×	×	×	×	(76)
Southeast	×	×	×	×	×	(77)
South	×	×	×	×	×	(78)
Southwest	×	×	×	×	×	(79)
West	×	×	×	×	×	(80)
Northwest	×	×	×	×	×	(81)
Roof windows	1.0	×	×	×	×	(82)

Solar gains in watts, calculated for each month  $(83)_m = \Sigma(74)_m \dots (82)_m$

$$(83)_m = (83)_1 \quad (83)_2 \quad (83)_3 \quad (83)_4 \quad (83)_5 \quad (83)_6 \quad (83)_7 \quad (83)_8 \quad (83)_9 \quad (83)_{10} \quad (83)_{11} \quad (83)_{12} \quad (83) \quad (83)$$

**Total gains – internal and solar**  $(84)_m = (73)_m + (83)_m$ , watts

$$(84)_m = (84)_1 \quad (84)_2 \quad (84)_3 \quad (84)_4 \quad (84)_5 \quad (84)_6 \quad (84)_7 \quad (84)_8 \quad (84)_9 \quad (84)_{10} \quad (84)_{11} \quad (84)_{12} \quad (84) \quad (84)$$

### 7. Mean internal temperature (heating season)

Temperature during heating periods in the living area from Table 9,  $T_{h1}$  (°C) 21 (85)

Utilisation factor for gains for living area,  $\eta_{1,m}$  (see Table 9a)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
$(86)_m =$	$(86)_1$	$(86)_2$	$(86)_3$	$(86)_4$	$(86)_5$	$(86)_6$	$(86)_7$	$(86)_8$	$(86)_9$	$(86)_{10}$	$(86)_{11}$	$(86)_{12}$	(86)

Mean internal temperature in living area  $T_1$  (follow steps 3 to 7 in Table 9c)

$$(87)_m = (87)_1 \quad (87)_2 \quad (87)_3 \quad (87)_4 \quad (87)_5 \quad (87)_6 \quad (87)_7 \quad (87)_8 \quad (87)_9 \quad (87)_{10} \quad (87)_{11} \quad (87)_{12} \quad (87) \quad (87)$$

Temperature during heating periods in rest of dwelling from Table 9,  $T_{h2}$  (°C)

$$(88)_m = (88)_1 \quad (88)_2 \quad (88)_3 \quad (88)_4 \quad (88)_5 \quad (88)_6 \quad (88)_7 \quad (88)_8 \quad (88)_9 \quad (88)_{10} \quad (88)_{11} \quad (88)_{12} \quad (88) \quad (88)$$

Utilisation factor for gains for rest of dwelling,  $\eta_{2,m}$  (see Table 9a)

$$(89)_m = (89)_1 \quad (89)_2 \quad (89)_3 \quad (89)_4 \quad (89)_5 \quad (89)_6 \quad (89)_7 \quad (89)_8 \quad (89)_9 \quad (89)_{10} \quad (89)_{11} \quad (89)_{12} \quad (89) \quad (89)$$

Mean internal temperature in the rest of dwelling  $T_2$

(follow steps 8 to 9 in Table 9c, if two main heating systems see further notes in Table 9c)

$$(90)_m = (90)_1 \quad (90)_2 \quad (90)_3 \quad (90)_4 \quad (90)_5 \quad (90)_6 \quad (90)_7 \quad (90)_8 \quad (90)_9 \quad (90)_{10} \quad (90)_{11} \quad (90)_{12} \quad (90) \quad (90)$$

Living area fraction  $f_{LA} = \text{Living area} \div (4) =$  (91)

Mean internal temperature (for the whole dwelling) =  $f_{LA} \times T_1 + (1 - f_{LA}) \times T_2$

$$(92)_m = (92)_1 \quad (92)_2 \quad (92)_3 \quad (92)_4 \quad (92)_5 \quad (92)_6 \quad (92)_7 \quad (92)_8 \quad (92)_9 \quad (92)_{10} \quad (92)_{11} \quad (92)_{12} \quad (92) \quad (92)$$

Apply adjustment to the mean internal temperature from Table 4e, where appropriate

$$(93)_m = (93)_1 \quad (93)_2 \quad (93)_3 \quad (93)_4 \quad (93)_5 \quad (93)_6 \quad (93)_7 \quad (93)_8 \quad (93)_9 \quad (93)_{10} \quad (93)_{11} \quad (93)_{12} \quad (93) \quad (93)$$

### 8. Space heating requirement

Set  $T_i$  to the mean internal temperature obtained at step 11 of Table 9b, so that  $T_{i,m} = (93)_m$  and re-calculate the utilisation factor for gains using Table 9a

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Utilisation factor for gains,  $\eta_m$ :

$$(94)_m = (94)_1 \quad (94)_2 \quad (94)_3 \quad (94)_4 \quad (94)_5 \quad (94)_6 \quad (94)_7 \quad (94)_8 \quad (94)_9 \quad (94)_{10} \quad (94)_{11} \quad (94)_{12} \quad (94) \quad (94)$$

Useful gains,  $\eta_m G_m$ , W =  $(94)_m \times (84)_m$

$$(95)_m = (95)_1 \quad (95)_2 \quad (95)_3 \quad (95)_4 \quad (95)_5 \quad (95)_6 \quad (95)_7 \quad (95)_8 \quad (95)_9 \quad (95)_{10} \quad (95)_{11} \quad (95)_{12} \quad (95) \quad (95)$$

Monthly average external temperature from Table U1

$$(96)_m = (96)_1 \quad (96)_2 \quad (96)_3 \quad (96)_4 \quad (96)_5 \quad (96)_6 \quad (96)_7 \quad (96)_8 \quad (96)_9 \quad (96)_{10} \quad (96)_{11} \quad (96)_{12} \quad (96) \quad (96)$$

Heat loss rate for mean internal temperature,  $L_m, W = (39)_m \times [(93)_m - (96)_m]$   
 $(97)_m =$ 

$(97)_1$	$(97)_2$	$(97)_3$	$(97)_4$	$(97)_5$	$(97)_6$	$(97)_7$	$(97)_8$	$(97)_9$	$(97)_{10}$	$(97)_{11}$	$(97)_{12}$
----------	----------	----------	----------	----------	----------	----------	----------	----------	-------------	-------------	-------------

 (97)

Space heating requirement for each month, kWh/month =  $0.024 \times [(97)_m - (95)_m] \times (41)_m$   
 $(97a)_m =$ 

$(97a)_1$	$(97a)_2$	$(97a)_3$	$(97a)_4$	$(97a)_5$	-	-	-	-	$(97a)_{10}$	$(97a)_{11}$	$(97a)_{12}$
-----------	-----------	-----------	-----------	-----------	---	---	---	---	--------------	--------------	--------------

  
 Total per year (kWh/year) =  $\Sigma(98)_{1...5,10..12} =$ 

--

 (97a)

Solar space heating calculated using Appendix H (negative quantity) (enter "0" if no solar contribution to space heating)  
 $(97b)_m =$ 

$(97b)_1$	$(97b)_2$	$(97b)_3$	$(97b)_4$	$(97b)_5$	-	-	-	-	$(97b)_{10}$	$(97b)_{11}$	$(97b)_{12}$
-----------	-----------	-----------	-----------	-----------	---	---	---	---	--------------	--------------	--------------

  
 Total per year (kWh/year) =  $\Sigma(97b)_{1...5,10..12} =$ 

--

 (97b)

Space heating requirement for each month after solar contribution, kWh/month  $(98)_m = (97a)_m + (97b)_m$   
 $(98)_m =$ 

$(98)_1$	$(98)_2$	$(98)_3$	$(98)_4$	$(98)_5$	-	-	-	-	$(98)_{10}$	$(98)_{11}$	$(98)_{12}$
----------	----------	----------	----------	----------	---	---	---	---	-------------	-------------	-------------

  
 Total per year (kWh/year) =  $\Sigma(98)_{1...5,10..12} =$ 

--

 (98)

Space heating requirement in kWh/m<sup>2</sup>/year  $(97a) \div (4) =$ 

--

 (99)

*For range cooker boilers where efficiency is obtained from the Product Characteristics Database, multiply the results in  $(98)_m$  by  $(1 - \Phi_{case}/\Phi_{water})$  where  $\Phi_{case}$  is the heat emission from the case of the range cooker at full load (in kW); and  $\Phi_{water}$  is the heat transferred to water at full load (in kW).  $\Phi_{case}$  and  $\Phi_{water}$  are obtained from the database record for the range cooker boiler. Where there are two main heating systems, this applies if the range cooker boiler is system 1 or system 2.*

**8c. Space cooling requirement**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Heat loss rate $L_m$ (calculated using 24°C internal temperature and external temperature for the applicable climate (see Appendix U))													
(100) <sub>m</sub> =						(100) <sub>6</sub>	(100) <sub>7</sub>	(100) <sub>8</sub>					(100)

Utilisation factor for loss $\eta_m$													
(101) <sub>m</sub> =						(101) <sub>6</sub>	(101) <sub>7</sub>	(101) <sub>8</sub>					(101)

Useful loss, $\eta_m L_m$ (watts) = (100) <sub>m</sub> × (101) <sub>m</sub>													
(102) <sub>m</sub> =						(102) <sub>6</sub>	(102) <sub>7</sub>	(102) <sub>8</sub>					(102)

Gains (internal gains as for heating except that column (A) of Table 5 is always used; solar gains calculated for the applicable climate, see Appendix U)													
(103) <sub>m</sub> =						(103) <sub>6</sub>	(103) <sub>7</sub>	(103) <sub>8</sub>					(103)

Space cooling requirement for month, whole dwelling, continuous ( kWh) = 0.024 × [(103) <sub>m</sub> - (102) <sub>m</sub> ] × (41) <sub>m</sub>													
(104) <sub>m</sub> =						(104) <sub>6</sub>	(104) <sub>7</sub>	(104) <sub>8</sub>					
													Total = Σ(104) <sub>6,8</sub> =
													(104)

Cooled fraction													
													$f_c = \text{cooled area} \div (4) =$
													(105)

Intermittency factor (Table 10b)													
(106) <sub>m</sub>						(106) <sub>6</sub>	(106) <sub>7</sub>	(106) <sub>8</sub>					
													Total = Σ(106) <sub>6,8</sub> =
													(106)

Space cooling requirement for month = (104) <sub>m</sub> × (105) × (106) <sub>m</sub>													
(107) <sub>m</sub>						(107) <sub>6</sub>	(107) <sub>7</sub>	(107) <sub>8</sub>					
													Total = Σ(107) <sub>6,8</sub> =
													(107)

Space cooling requirement in kWh/m <sup>2</sup> /year													
													(107) ÷ (4) =
													(108)

**8f. Fabric Energy Efficiency** (calculated only under special conditions, see section 11)

Fabric Energy Efficiency													
													(99) + (108) =
													(109)

**9a. Energy requirements – Individual heating systems including micro-CHP**

**Space heating:**

Fraction of space heat from secondary/supplementary system (Table 11)	"0" if none	<input type="text"/>	(201)
Fraction of space heat from main system(s)	$(202) = 1 - (201) =$	<input type="text"/>	(202)
Fraction of main heating from main system 2	<i>if no second main system enter "0"</i>	<input type="text"/>	(203)
Fraction of total space heat from main system 1	$(204) = (202) \times [1 - (203)] =$	<input type="text"/>	(204)
Fraction of total space heat from main system 2	$(205) = (202) \times (203) =$	<input type="text"/>	(205)
Efficiency of main space heating system 1 (in %)		<input type="text"/>	(206)
<i>(from database or Table 4a/4b, adjusted where appropriate by the amount shown in the 'space efficiency adjustment' column of Table 4c; for gas and oil boilers see 9.2.1)</i>			
<i>If there is a second main system complete (207)</i>			
Efficiency of main space heating system 2 (in %)		<input type="text"/>	(207)
<i>(from database or Table 4a/4b, adjusted where appropriate by the amount shown in the 'space efficiency adjustment' column of Table 4c; for gas and oil boilers see 9.2.1)</i>			
Efficiency of secondary/supplementary heating system, %	<i>(from Table 4a or Appendix E)</i>	<input type="text"/>	(208)
Cooling System Seasonal Energy Efficiency Ratio (see Table 10c)		<input type="text"/>	(209)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	kWh/year
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----------

Space heating requirement (calculated above)

(98) <sub>1</sub>	(98) <sub>2</sub>	(98) <sub>3</sub>	(98) <sub>4</sub>	(98) <sub>5</sub>	–	–	–	–	(98) <sub>10</sub>	(98) <sub>11</sub>	(98) <sub>12</sub>
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Space heating fuel (main heating system 1), kWh/month

$(211)_m = (98)_m \times (204) \times 100 \div (206)$

(211) <sub>m</sub>	(211) <sub>1</sub>	(211) <sub>2</sub>	(211) <sub>3</sub>	(211) <sub>4</sub>	(211) <sub>5</sub>	–	–	–	–	(211) <sub>10</sub>	(211) <sub>11</sub>	(211) <sub>12</sub>
--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	---	---	---	---	---------------------	---------------------	---------------------

Total (kWh/year) =  $\Sigma(211)_{1..5,10..12} =$   (211)

Space heating fuel (main heating system 2), kWh/month, omit if no second main heating system

$(213)_m = (98)_m \times (205) \times 100 \div (207)$

(213) <sub>m</sub>	(213) <sub>1</sub>	(213) <sub>2</sub>	(213) <sub>3</sub>	(213) <sub>4</sub>	(213) <sub>5</sub>	–	–	–	–	(213) <sub>10</sub>	(213) <sub>11</sub>	(213) <sub>12</sub>
--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	---	---	---	---	---------------------	---------------------	---------------------

Total (kWh/year) =  $\Sigma(213)_{1..5,10..12} =$   (213)

Space heating fuel (secondary), kWh/month

$(215)_m = (98)_m \times (201) \times 100 \div (208)$

(215) <sub>m</sub>	(215) <sub>1</sub>	(215) <sub>2</sub>	(215) <sub>3</sub>	(215) <sub>4</sub>	(215) <sub>5</sub>	–	–	–	–	(215) <sub>10</sub>	(215) <sub>11</sub>	(215) <sub>12</sub>
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Total (kWh/year) =  $\Sigma(215)_{1..5,10..12} =$   (215)

**Water heating**

Output from water heater (calculated above)

(64) <sub>1</sub>	(64) <sub>2</sub>	(64) <sub>3</sub>	(64) <sub>4</sub>	(64) <sub>5</sub>	(64) <sub>6</sub>	(64) <sub>7</sub>	(64) <sub>8</sub>	(64) <sub>9</sub>	(64) <sub>10</sub>	(64) <sub>11</sub>	(64) <sub>12</sub>
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Efficiency of water heater

Monthly value  $(217)_m$  taken as annual value from database record or Table 4a and adjusted where appropriate by the amount shown in the 'DHW efficiency adjustment' column of Table 4c. There are two exceptions:

A) Gas/oil boiler main system 1 or 2 used for water heating:  $(217)_m =$  value calculated for each month using equation (D1) in Appendix D using database record, or taken from Table 4a. In either case, then adjust where appropriate by the amount shown in the 'DHW efficiency adjustment' column of Table 4c

B) mCHP main system 1 or 2 used for water heating:  $(217)_m =$  value calculated for each month using equation (N8) in Appendix N using database record

(217) <sub>m</sub>	(217) <sub>1</sub>	(217) <sub>2</sub>	(217) <sub>3</sub>	(217) <sub>4</sub>	(217) <sub>5</sub>	(217) <sub>6</sub>	(217) <sub>7</sub>	(217) <sub>8</sub>	(217) <sub>9</sub>	(217) <sub>10</sub>	(217) <sub>11</sub>	(217) <sub>12</sub>
--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	--------------------	---------------------	---------------------	---------------------

(217)



Fuel for water heating, kWh/month

$$(219)_m = (64)_m \times 100 \div (217)_m$$

(219) <sub>m</sub>	(219) <sub>1</sub>	(219) <sub>2</sub>	(219) <sub>3</sub>	(219) <sub>4</sub>	(219) <sub>5</sub>	(219) <sub>6</sub>	(219) <sub>7</sub>	(219) <sub>8</sub>	(219) <sub>9</sub>	(219) <sub>10</sub>	(219) <sub>11</sub>	(219) <sub>12</sub>	
Total = $\Sigma(219a)_{1...12} =$													(219)

(for a DHW-only heat network use (305), (306) and (310a) or (310b), with (304a)=1.0 or (304b)=1.0, instead of (219))

**Space cooling**

Space cooling fuel, kWh/month

$$(221)_m = (107)_m \div (209)$$

(221) <sub>m</sub>						(221) <sub>6</sub>	(221) <sub>7</sub>	(221a) <sub>8</sub>					
Total = $\Sigma(221)_{6..8} =$													(221)

**Annual totals**

	kWh/year	kWh/year
Space heating fuel used, main system 1		(211)
Space heating fuel used, main system 2		(213)
Space heating fuel used, secondary		(215)
Water heating fuel used		(219)
Electricity for instantaneous electric shower(s)		(64a)
Space cooling fuel used (if there is a fixed cooling system, if not enter 0)		(221)

**Electricity for pumps, fans and electric keep-hot** (Table 4f):

mechanical ventilation fans - balanced, extract or positive input from outside		(230a)
warm air heating system fans		(230b)
heating circulation pump or water pump within warm air heating unit		(230c)
oil boiler auxiliary (oil pump, flue fan, etc; excludes circulation pump)		(230d)
gas boiler auxiliary (flue fan, etc; excludes circulation pump)		(230e)
maintaining electric keep-hot facility for gas combi boiler		(230f)
pump for solar water heating		(230g)
pump for storage WWHRS (see section G3.3)		(230h)
Total electricity for the above, kWh/year	sum of (230a)...(230h) =	(231)

**Electricity for lighting** (calculated in Appendix L)

	(232)
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**Energy saving/generation technologies** (Appendices M, N and Q)

Electricity generated by PVs (Appendix M) (negative quantity)		(233)
Electricity generated by wind turbine (Appendix M) (negative quantity)		(234)
Electricity used or net electricity generated by micro-CHP (Appendix N) (negative if net generation)		(235)
Electricity generated by hydro-electric generator (Appendix M) (negative quantity)		(235a)

**Appendix Q items:** annual energy (items not already included on a monthly basis)

	Fuel	kWh/year
Appendix Q, <item 1 description>		
energy saved or generated (enter as negative quantity)		(236a)
energy used (positive quantity)		(237a)
Appendix Q, <item 2 description>		
energy saved or generated (enter as negative quantity)		(236b)
energy used (positive quantity)		(237b)

(continue this list if additional items)

Total delivered energy for all uses  $(64a) + (211)...(221) + (231) + (232)...(237b) =$  (238)

**10a. Fuel costs – Individual heating systems including micro-CHP**

	Fuel kWh/year		Fuel price (Table 12)		Fuel cost £/year
Space heating - main system 1	(211)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (240)
Space heating - main system 2	(213)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (241)
Space heating - secondary	(215)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (242)
Water heating (electric off-peak tariff)					
High-rate fraction (Table 13, or Appendix F for electric CPSU)					<input type="text"/> (243)
Low-rate fraction			1.0 - (243) =		<input type="text"/> (244)
High-rate cost	(219) × (243)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (245)
Low-rate cost	(219) × (244)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (246)
Water heating cost (other fuel)	(219)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (247)
<i>(for a DHW-only heat network use (342a) or (342b) instead of (247))</i>					
Energy for instantaneous electric shower(s)	(64a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (247a)
Space cooling	(221)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (248)
Pumps, fans and electric keep-hot	(231)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (249)
<i>(if off-peak tariff, list each of (230a) to (230g) separately as applicable and apply fuel price according to Table 12a)</i>					
Energy for lighting	(232)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (250)
Additional standing charges (Table 12)					<input type="text"/> (251)
Energy saving/generation technologies	(233) to (235a) as applicable, repeat line (252) as needed				
<description>	one of (233) to (235a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (252)
Appendix Q items: repeat lines (253) and (254) as needed					
<description>, energy saved	one of (236a) etc	×	<input type="text"/>	× 0.01 =	<input type="text"/> (253)
<description>, energy used	one of (237a) etc	×	<input type="text"/>	× 0.01 =	<input type="text"/> (254)
<b>Total energy cost</b>					<input type="text"/> (255)
<b>(240)...(242) + (245)...(254) =</b>					

**11a. SAP rating – Individual heating systems including micro-CHP**

Energy cost deflator (Table 12):		<input type="text"/> 0.42	(256)
Energy cost factor (ECF)		<input type="text"/> [(255) × (256)] ÷ [(4) + 45.0] =	(257)
SAP rating (Section 13)		<input type="text"/>	(258)

**12a. CO<sub>2</sub> emissions – Individual heating systems including micro-CHP**

	Energy kWh/year		Emission factor kg CO <sub>2</sub> /kWh	=	Emissions kg CO <sub>2</sub> /year
Space heating - main system 1	(211)	×	<input type="text"/>	=	<input type="text"/> (261)
Space heating - main system 2	(213)	×	<input type="text"/>	=	<input type="text"/> (262)
Space heating - secondary	(215)	×	<input type="text"/>	=	<input type="text"/> (263)
Energy for water heating <i>(for a DHW-only heat network use (361) to (373) instead of (264))</i>	(219)	×	<input type="text"/>	=	<input type="text"/> (264)
Energy for instantaneous electric shower(s)	(64a)	×	<input type="text"/>	=	<input type="text"/> (264a)
Space and water heating	(261) + (262) + (263) + (264) + (264a) =			=	<input type="text"/> (265)
Space cooling	(221)	×	<input type="text"/>	=	<input type="text"/> (266)
Electricity for pumps, fans and electric keep-hot	(231)	×	<input type="text"/>	=	<input type="text"/> (267)
Electricity for lighting	(232)	×	<input type="text"/>	=	<input type="text"/> (268)
Energy saving/generation technologies	(233) to (235a) as applicable, repeat line (269) as needed				
<description>	one of (233) to (235a)	×	<input type="text"/>	=	<input type="text"/> (269)
Appendix Q items	repeat lines (270) and (271) as needed				
<description>, energy saved *	one of (236a) etc	×	<input type="text"/>	=	<input type="text"/> (270)
<description>, energy used *	one of (237a) etc	×	<input type="text"/>	=	<input type="text"/> (271)
* where the item is concerned only with CO <sub>2</sub> emissions use the right-hand column only.					
Total CO <sub>2</sub> , kg/year	sum of (265)...(271) =			=	<input type="text"/> (272)
<b>Dwelling CO<sub>2</sub> Emission Rate</b>	(272) ÷ (4) =			=	<input type="text"/> (273)
El rating (section 14)	<input type="text"/> (274)				

## Heat networks

### 9b. Energy requirements – Heat networks

*This part is used for space heating, space cooling or water heating provided by a heat network.*

Fraction of space heat from secondary/supplementary heating (Table 11) "0" if none  (301)  
 Fraction of space heat from heat network  $1 - (301) =$   (302)

*The heat network may obtain heat from several sources. The procedure allows for CHP and up to four other heat sources; the latter includes boilers, heat pumps, geothermal and waste heat from power stations. See Appendix C.*

Fraction of heat from CHP  (303a)  
 Fraction of heat from heat source 2 (fractions obtained from  (303b)  
 Fraction of heat from heat source 3 operational records or  (303c)  
 Fraction of heat from heat source 4 design specification; omit  (303d)  
 Fraction of heat from heat source 5 line if not applicable)  (303e)

Fraction of total space heat from CHP  $(302) \times (303a) =$   (304a)

Fraction of total space heat from heat source 2 <description>  $(302) \times (303b) =$   (304b)

Fraction of total space heat from heat source 3 <description>  $(302) \times (303c) =$   (304c)

Fraction of total space heat from heat source 4 <description>  $(302) \times (303d) =$   (304d)

Fraction of total space heat from heat source 5 <description>  $(302) \times (303e) =$   (304e)

Factor for control and charging method (Table 4c(3)) for space heating  (305)

Factor for charging method (Table 4c(3)) for water heating  (305a)

Distribution loss factor (Table 12c) for heat network  (306)

#### Space heating

		kWh/year
Annual space heating requirement	<input type="text"/> (98)	
Space heat from CHP	$(98) \times (304a) \times (305) \times (306) =$	<input type="text"/> (307a)
Space heat from heat source 2	$(98) \times (304b) \times (305) \times (306) =$	<input type="text"/> (307b)
Space heat from heat source 3	$(98) \times (304c) \times (305) \times (306) =$	<input type="text"/> (307c)
Space heat from heat source 4	$(98) \times (304d) \times (305) \times (306) =$	<input type="text"/> (307d)
Space heat from heat source 5	$(98) \times (304e) \times (305) \times (306) =$	<input type="text"/> (307e)
Efficiency of secondary/supplementary heating system in % (from Table 4a or Appendix E)	<input type="text"/> (308)	
Space heating fuel for secondary/supplementary system	$(98) \times (301) \times 100 \div (308) =$	<input type="text"/> (309)

#### Water heating

Annual water heating requirement	<input type="text"/> (64)	
If DHW from heat network:		
Water heat from CHP	$(64) \times (303a) \times (305a) \times (306) =$	<input type="text"/> (310a)
Water heat from heat source 2	$(64) \times (303b) \times (305a) \times (306) =$	<input type="text"/> (310b)
Water heat from heat source 3	$(64) \times (303c) \times (305a) \times (306) =$	<input type="text"/> (310c)
Water heat from heat source 4	$(64) \times (303d) \times (305a) \times (306) =$	<input type="text"/> (310d)
Water heat from heat source 5	$(64) \times (303e) \times (305a) \times (306) =$	<input type="text"/> (310e)
If DHW by immersion or instantaneous heater within dwelling:		
Efficiency of water heater	<input type="text"/> (311)	
Water heated by immersion or instantaneous heater	$(64) \times 100 \div (311) =$	<input type="text"/> (312)
Electricity used for instantaneous electric shower(s)	$(312a) = (64a)$	<input type="text"/> (312a)
Electricity used for heat distribution	$0.01 \times [(307a)...(307e) + (310a)...(310e)] =$	<input type="text"/> (313)
Cooling System Seasonal Energy Efficiency Ratio	<input type="text"/> (314)	
Space cooling (if there is a fixed cooling system, if not enter 0)	$= (107) \div (314) =$	<input type="text"/> (315)

Electricity for pumps and fans within dwelling (Table 4f):

mechanical ventilation - balanced, extract or positive input from outside

	(330a)
--	--------

warm air heating system fans

	(330b)
--	--------

pump for solar water heating

	(330g)
--	--------

pump for storage WWHRS (see section G3.3)

	(330h)
--	--------

Total electricity for the above, kWh/year

(330a) + ... + (330h) = 

--

 (331)

**Electricity for lighting** (calculated in Appendix L)

	(332)
--	-------

**Energy saving/generation technologies** (Appendices M and Q)

Electricity generated by PVs (Appendix M) (negative quantity)

	(333)
--	-------

Electricity generated by wind turbine (Appendix M) (negative quantity)

	(334)
--	-------

Electricity generated by hydro-electric generator (Appendix M) (negative quantity)

	(335a)
--	--------

**Appendix Q items:** annual energy (items not already included on a monthly basis)

Fuel kWh/year

Appendix Q, <item 1 description>

energy saved or generated (enter as negative quantity)

		(336a)
--	--	--------

energy used (positive quantity)

		(337a)
--	--	--------

Appendix Q, <item 2 description>

energy saved or generated (enter as negative quantity)

		(336b)
--	--	--------

energy used (positive quantity)

		(337b)
--	--	--------

*(continue this list if additional items)*

Total delivered energy for all uses

(307) + (309) + (310) + (312) + (312a) + (315) + (331) + (332)...(237b) = 

--

 (338)

**10b. Fuel costs – Heat networks**

	Heat or fuel required kWh/year		Fuel price (Table 12)		Fuel cost £/year
Space heating from CHP	(307a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (340a)
Space heating from heat source 2	(307b)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (340b)
Space heating from heat source 3	(307c)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (340c)
Space heating from heat source 4	(307d)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (340d)
Space heating from heat source 5	(307e)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (340e)
Space heating (secondary)	(309)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (341)
Water heating from CHP	(310a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (342a)
Water heating from heat source 2	(310b)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (342b)
Water heating from heat source 3	(310c)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (342c)
Water heating from heat source 4	(310d)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (342d)
Water heating from heat source 5	(310e)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (342e)
If water heated by immersion heater:					
High-rate fraction (Table 13)			<input type="text"/>		(343)
Low-rate fraction		1.0 - (343) =	<input type="text"/>		(344)
			Fuel price		
High-rate cost, or cost for single immersion	(312) × (343) ×		<input type="text"/>	× 0.01 =	<input type="text"/> (345)
Low-rate cost	(312) × (344) ×		<input type="text"/>	× 0.01 =	<input type="text"/> (346)
If water heated by instantaneous water heater	(312)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (347)
Energy used by instantaneous electric shower(s)	(64a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (347a)
Space cooling	(315)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (348)
Pumps and fans	(331)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (349)
<i>(if off-peak tariff, list each of (330a) to (330g) separately as applicable and apply fuel price according to Table 12a)</i>					
Electricity for lighting	(332)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (350)
Additional standing charges (Table 12)					<input type="text"/> (351)
Energy saving/generation technologies	(333) to (335a) as applicable, repeat line (352) as needed				
<description>	one of (333) to (335a)	×	<input type="text"/>	× 0.01 =	<input type="text"/> (352)
Appendix Q items: repeat lines (253) and (259) as needed					
<description>, energy saved	one of (336a) etc	×	<input type="text"/>	× 0.01 =	<input type="text"/> (353)
<description>, energy used	one of (337a) etc	×	<input type="text"/>	× 0.01 =	<input type="text"/> (354)
<b>Total energy cost</b>				= (340a)...(342e) + (345)...(354) =	<input type="text"/> (355)

**11b. SAP rating – Heat networks**

Energy cost deflator (Table 12):		<input type="text"/> 0.42	(356)
Energy cost factor (ECF)	[(355) × (356)] ÷ [(4) + 45.0] =	<input type="text"/>	(357)
SAP rating (Section 13)		<input type="text"/>	(358)

**12b. CO<sub>2</sub> Emissions – Heat networks**

CO<sub>2</sub> from CHP (space and water heating) Omit (361) to (366) if no CHP

Power efficiency of CHP unit (e.g. 25%) from operational records or design spec.  (361)  
 Heat efficiency of CHP unit (e.g. 50%) from operational records or design specification  (362)

		Energy used kWh/year	×	Emission factor kgCO <sub>2</sub> /kWh	=	CO <sub>2</sub> emission kgCO <sub>2</sub> /year	
Space heating from CHP	$(307a) \times 100 \div (362) =$	<input type="text"/>	×	Note A	=	<input type="text"/>	(363)
less credit emissions for electricity	$-(307a) \times (361) \div (362) =$	<input type="text"/>	×	Note B	=	<input type="text"/>	(364)
Water heated by CHP	$(310a) \times 100 \div (362) =$	<input type="text"/>	×	Note A	=	<input type="text"/>	(365)
less credit emissions for electricity	$-(310a) \times (361) \div (362) =$	<input type="text"/>	×	Note B	=	<input type="text"/>	(366)

Note A: factor for CHP fuel. Note B: factor for electricity generated by CHP

CO<sub>2</sub> from other sources of space and water heating (not CHP)

Efficiency of heat source 2 (%)  If there is CHP using two fuels repeat (361) to (366) for the second fuel (367b)  
 Efficiency of heat source 3 (%)  (367c)  
 Efficiency of heat source 4 (%)  (367d)  
 Efficiency of heat source 5 (%)  (367e)

CO<sub>2</sub> associated with heat source 2  $[(307b)+(310b)] \times 100 \div (367b) \times$   =  (368)  
 CO<sub>2</sub> associated with heat source 3  $[(307c)+(310c)] \times 100 \div (367c) \times$   =  (369)  
 CO<sub>2</sub> associated with heat source 4  $[(307d)+(310d)] \times 100 \div (367d) \times$   =  (370)  
 CO<sub>2</sub> associated with heat source 5  $[(307e)+(310e)] \times 100 \div (367e) \times$   =  (371)

Electrical energy for heat distribution (313) ×  =  (372)

Total CO<sub>2</sub> associated with heat networks (363)...(366) + (368)...(372) =  (373)  
 if it is negative set (373) to zero (unless condition in C7 of Appendix C is met)  (373)

Space heating (secondary) (309) ×  =  (374)

Water heating by immersion heater or instantaneous heater (312) ×  =  (375)

Energy used by instantaneous electric shower(s) (347a) ×  =  (375a)

Total CO<sub>2</sub> associated with space and water heating (373) + (374) + (375) =  (376)

Space cooling (315) ×  =  (377)

Electricity for pumps and fans within dwelling (331) ×  =  (378)

Electricity for lighting (332) ×  =  (379)

Energy saving/generation technologies (333) to (334) as applicable, repeat line (380) as needed  
 <description> one of (333) to (334) ×  =  (380)

Appendix Q items repeat lines (381) and (382) as needed  
 <description>, energy saved one of (336a) etc ×  =  (381)

<description>, energy used one of (337a) etc ×  =  (382)

Total CO<sub>2</sub>, kg/year sum of (376)...(382) =  (383)

**Dwelling CO<sub>2</sub> Emission Rate** (383) ÷ (4) =  (384)

EI rating (section 14)  (385)

## FORMULAE AND TABLES

**Table 1a: Number of days in month,  $n_m$**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
m	1	2	3	4	5	6	7	8	9	10	11	12
$n_m =$	31	28	31	30	31	30	31	31	30	31	30	31

**Table 1b: Occupancy**

<b>Assumed number of occupants</b>
<p>if TFA &gt; 13.9: <math>N = 1 + 1.76 \times [1 - \exp(-0.000349 \times (TFA - 13.9)^2)] + 0.0013 \times (TFA - 13.9)</math>            if TFA ≤ 13.9: <math>N = 1</math></p> <p>N is the assumed number of occupants, TFA is the total floor area of the dwelling.</p>

**[Tables 1c and 1d have been removed. Data now included in Appendix J.]**

**Table 1e: Heat capacities for some common constructions**

The heat capacity of a building element is a measure of how much heat the element is able to store. It is calculated from the properties of the materials making up the building element. Heat capacity is part of calculation of energy demand for buildings and is often calculated by U-value calculators as an additional feature.

The calculation methods are given in BS EN ISO 13786; two methods are defined in the standard for calculating heat capacity:

- a detailed calculation (clause 8 of BS EN ISO 13786);
- a simplified calculation by the effective thickness method (Annex C of BS EN ISO 13786).

Heat capacity per unit area,  $\kappa$  in kJ/m<sup>2</sup>K, for a construction element can be calculated from:<sup>44</sup>

$$\kappa = 10^{-6} \times \sum (d_j \rho_j c_j)$$

where:

$d_j$  is the thickness of layer (mm)

$\rho_j$  is density of layer (kg/m<sup>3</sup>)

$c_j$  is specific heat capacity of layer (J/kg·K)

the summation is over all layers in the element, starting at the inside surface and stopping at whichever of these conditions occurs first (which may mean part way through a layer):

- half way through the element;
- an insulation layer (thermal conductivity ≤ 0.08 W/m·K);
- total thickness of 100 mm.

The elements to be included are walls, floors and roofs (windows and doors have negligible capacity), including all internal and party walls and floors. In the case of internal walls and floors, the capacity is needed for each side of the element.

The heat capacity of a building component is calculated first without taking account of the surface resistance, using the most suitable of the conditions given above. Account of surface resistances is then taken into the account in accordance with section C3 of BS EN ISO 13786.

<sup>44</sup> The calculation of both simplified and detailed method is given in ISO 13786, Thermal performance of building components – Dynamic thermal characteristics – Calculation methods.



Air layers are included in the calculation of heat capacity; use the resistance of air cavity (which depends on the thickness of the cavity), and the following parameters:

Density of air	$\rho=1.0 \text{ kg/m}^3$
----------------	---------------------------

Use typical heat capacity for other materials (see BS EN ISO 10456 and CIBSE Guide) for:

Specific heat capacity of air	$c_p=1000 \text{ J/(kg}\cdot\text{K)}$
Brick, concrete and stone	$c_p=840 \text{ J/(kg}\cdot\text{K)}$
Gypsum, plasters and renders	$c_p=840 \text{ J/(kg}\cdot\text{K)}$
Glass	$c_p=750 \text{ J/(kg}\cdot\text{K)}$
PU foam, rigid	$c_p=1800 \text{ J/(kg}\cdot\text{K)}$
Timber	$c_p=1600 \text{ J/(kg}\cdot\text{K)}$
Plywood	$c_p=1700 \text{ J/(kg}\cdot\text{K)}$
Mineral wool, expanded and extruded polystyrene	$c_p=1450 \text{ J/(kg}\cdot\text{K)}$
Plasterboard,	$c_p=840 \text{ J/(kg}\cdot\text{K)}$

See BS EN ISO 10456 and CIBSE Guide A for more design values for specific heat capacity of insulation and masonry materials.

The table gives some typical values.

Construction	Heat capacity $\kappa$ (kJ/m <sup>2</sup> K)
<b>Ground floors</b>	
Suspended timber, insulation between joists	20
Slab on ground, screed over insulation	110
Suspended concrete floor, carpeted	75
<b>Exposed floors</b>	
Timber exposed floor, insulation between joists	20
<b>External walls - masonry, solid, external insulation</b>	
Solid wall: dense plaster, 200 mm dense block, insulated externally	190
Solid wall: plasterboard on dabs or battens, 200 mm dense block, insulated externally	150
Solid wall: dense plaster, 210 mm brick, insulated externally	135
Solid wall: plasterboard on dabs or battens, 210 mm brick, insulated externally	110
<b>External walls - masonry, solid, internal insulation</b>	
Solid wall: dense plaster, insulation, any outside structure	17
Solid wall: plasterboard on dabs or battens, insulation, any outside structure	9
<b>External walls - cavity masonry walls, full or partial cavity fill</b>	
Cavity wall: dense plaster, dense block, filled cavity, any outside structure	190
Cavity wall; dense plaster, lightweight aggregate block, filled cavity, any outside structure	140
Cavity wall: dense plaster, AAC block, filled cavity, any outside structure	70
Cavity wall: plasterboard on dabs or battens, dense block, filled cavity, any outside structure	150
Cavity wall; plasterboard on dabs or battens, lightweight aggregate block, filled cavity, any outside structure	110
Cavity wall: plasterboard on dabs or battens, AAC block, filled cavity, any outside structure	60
<b>External walls – timber or steel frame</b>	
Timber framed wall (one layer of plasterboard)	9
Timber framed wall (two layers of plasterboard)	18
Steel frame wall (warm frame or hybrid construction)	14
<b>Roofs</b>	
Plasterboard, insulated at ceiling level	9
Plasterboard, insulated slope	9
Plasterboard, insulated flat roof	9
<b>Party walls</b>	
Dense plaster both sides, dense blocks, cavity or cavity fill (E-WM-1)*	180
Dense plaster both sides, lightweight aggregate blocks, cavity or cavity fill (E-WM-2)*	140
Single plasterboard on dabs on both sides, dense blocks, cavity or cavity fill (E-WM-3)*	70
Single plasterboard on dabs both sides, lightweight aggregate blocks, cavity or cavity fill (E-WM-4)*	110
Single plasterboard on both sides, dense cellular blocks, cavity (E-WM-5)*	70

<b>Construction</b>	<b>Heat capacity <math>\kappa</math> (kJ/m<sup>2</sup>K)</b>
Plasterboard on dabs mounted on cement render on both sides, AAC blocks, cavity (E-WM-6 or E-WM-7)*	45
Double plasterboard on both sides, twin timber frame with or without sheathing board (E-WT-1 or E-WT-2)*	20
Steel frame (E-WS-1 to E-WS-3)*	20
<b>Party floors (<math>\kappa</math> from above / <math>\kappa</math> from below)</b>	
Precast concrete planks floor, screed, carpeted (E-FC-1)*	40 / 30
Concrete floor slab, carpeted (E-FC-2)*	80 / 100
Precast concrete plank floor (screed laid on insulation) ,carpeted (E-FC-3)*	40 / 30
Precast concrete plank floor (screed laid on rubber),carpeted (E-FC-4)*	70 / 30
In-situ concrete slab supported by profiled metal deck, carpeted (E-FS-1)*	64 / 90
Timber I-joists, carpeted (E-FT-1)*	30 / 20
<b>Internal partitions</b>	
Plasterboard on timber frame	9
Dense block, dense plaster	100
Dense block, plasterboard on dabs	75
<b>Floor/ceiling/ between floors in a house (<math>\kappa</math> from above / <math>\kappa</math> from below)</b>	
Carpeted chipboard floor, plasterboard ceiling	18 / 9

\* Reference in the Robust Details for Part E “Resistance to the passage of sound”

### Table 1f: Thermal mass parameter

The  $\kappa$  values are used to calculate the TMP variable (Thermal Mass Parameter), worksheet (35), which is used to characterise the thermal mass of the building. It is:

$$TMP = \frac{\sum \kappa \times A}{TFA}$$

where the summation is over all walls, floors and roofs bounding the dwelling (including party walls and floors/ceilings) together with both sides of all internal walls and floors/ceilings.

**Table 2: Hot water storage loss factor**

If the manufacturer's declared loss is available, see Table 2b.

In the absence of manufacturer's declared cylinder<sup>45</sup> loss, the loss factor  $L$  from Table 2 is multiplied by the cylinder volume in litres, by the volume factor from Table 2a, and by the appropriate temperature factor from Table 2b, to obtain the loss rate. These data apply to cylinders heated by gas, oil and solid fuel boilers and by electric immersion, and to stores within combi boilers not tested to EN 13203-2 or OPS 26.

In the case of a combination boiler:

- the storage loss factor is zero if the efficiency is taken from Table 4b;
- the loss is to be included for a storage combination boiler if its efficiency is the manufacturer's declared value or is obtained from the Boiler Database (in which case its insulation thickness and volume are also to be provided by the manufacturer or obtained from the Database), using the loss factor for a factory insulated cylinder.

Insulation thickness, mm	Cylinder loss factor (L) kWh/litre/day	
	Factory insulated cylinder thermal store store in combi boiler	Loose cylinder jacket
0	0.1425	0.1425
12	0.0394	0.0760
25	0.0240	0.0516
35	0.0191	0.0418
38	0.0181	0.0396
50	0.0152	0.0330
80	0.0115	0.0240
120	0.0094	0.0183
160	0.0084	0.0152

Notes:

- Alternatively the heat loss factor,  $L$ , may be calculated for insulation thickness of  $t$  mm as follows:  
Cylinder, loose jacket:  $L = 0.005 + 1.76/(t + 12.8)$   
Cylinder, factory insulated:  $L = 0.005 + 0.55/(t + 4.0)$
- The data for factory insulated cylinder apply to all cases other than an electric CPSU where the insulation is applied in the course of manufacture irrespective of the insulation material used, e.g. the water store in a storage combi or a gas CPSU.
- For an electric CPSU, the loss is 0.022 kWh/litre/day.

**Table 2a: Volume factor for cylinders and storage combis**

Volume $V_c$	Volume Factor VF	Volume $V_c$	Volume Factor VF
40	1.442	180	0.874
60	1.259	200	0.843
80	1.145	220	0.817
100	1.063	240	0.794
120	1.00	260	0.773
140	0.950	280	0.754
160	0.908	300	0.737

Notes:

- When using the data in Table 2, the loss is to be multiplied by the volume factor.
- Alternatively, the volume factor can be calculated using the equation  $VF = (120 / V_c)^{1/3}$

<sup>45</sup> In this and the following tables, the term 'cylinder' includes thermal stores and other similar water storage vessels.

**Table 2b: Factors applied to losses for cylinders, thermal stores and CPSUs, and to storage combi boilers not tested to EN 13203-2 or OPS 26**

Type of water storage	Temperature Factor	
	for manufacturer's declared loss	for loss from Table 2
Cylinder, electric immersion	0.60	0.60
Cylinder, indirect	0.60 <sup>a) b)</sup>	0.60 <sup>a) b)</sup>
Storage combi boiler, primary store	n/a	Store volume $\geq$ 115 litres: 2.54 Store volume $<$ 115 litres: $2.54 + 0.00682 \times (115 - V_c)$
Storage combi boiler, secondary store	n/a	Store volume $\geq$ 115 litres: 1.86 Store volume $<$ 115 litres: $1.86 + 0.00496 \times (115 - V_c)$
Instantaneous combi boiler with close-coupled store (Appendix G)	0.60 <sup>a) b)</sup>	0.60 <sup>a) b)</sup>
Hot water only thermal store	0.89 <sup>c) d)</sup>	1.08 <sup>c) d)</sup>
Integrated thermal store or gas- or oil-fired CPSU	0.89 <sup>c) d)</sup>	1.08 <sup>c) d)</sup>
Electric CPSU: for winter operating temperature $T_w$ ( $^{\circ}\text{C}$ )	$1.09 + 0.012 \times (T_w - 85)$	1.00
Heat Interface Unit (HIU) in a heat network	1.0	1.0

Notes:

$V_c$  is the volume of the store in the combi boiler

<sup>a)</sup> Multiply Temperature Factor by 1.3 if a cylinder thermostat is absent.

<sup>b)</sup> Multiply Temperature Factor by 0.9 if there is separate time control of domestic hot water (boiler systems, warm air systems and heat pump systems)

<sup>c)</sup> Multiply Temperature Factor by 0.81 if the thermal store or CPSU has separate timer for heating the store

<sup>d)</sup> Multiply Temperature Factor by 1.1 if the thermal store or CPSU is not in an airing cupboard

If a storage combi boiler has been tested to EN 13203-2 or OPS 26 see Tables 3b and 3c.

**Table 3: Primary circuit loss**

Primary circuit loss applies when hot water is heated by a heat generator (e.g. boiler) connected to a hot water storage vessel via insulated or uninsulated pipes (the primary pipework). Primary loss is set to zero for the following:

- Electric immersion heater
- Combi boiler
- CPSU (including electric CPSU)
- Boiler and thermal store within a single casing
- Separate boiler and thermal store connected by no more than 1.5 m of insulated pipework

For other cases (indirect cylinders and thermal stores connected by uninsulated pipework or more than 1.5 m of insulated pipework) the loss in kWh/month is calculated as follows.

$$\text{Primary loss} = n_m \times 14 \times [ \{ 0.0091 \times p + 0.0245 \times (1 - p) \} \times h + 0.0263 ]$$

where p is the fraction of primary pipework that is insulated and h is the number of hours per day of circulation of water within the primary circuit. Apply the following values of p and h:

Pipework insulation	Fraction insulated, p
Uninsulated primary pipework	0.0
First 1m from cylinder insulated	0.1
All accessible pipework insulated	0.3
Fully insulated primary pipework	1.0

Hot water controls	Hours per day, h	
	Winter	Summer
No cylinder thermostat	11	3
Cylinder thermostat, water heating not separately timed	5	3
Cylinder thermostat, water heating separately timed	3	3

Use summer value for June, July, August and September and winter value for other months. Thermal stores have a cylinder thermostat and separate timing.

Reduce the primary loss if there is solar water heating, see H2 in Appendix H.

For heat networks apply the formula above with p = 1.0 and h = 3 for all months.

**Table 3a: Additional losses for combi boilers not tested to EN 13203-2 or OPS 26**

Combi type	kWh/month
Instantaneous, without keep-hot facility*	$600 \times f_u \times n_m / 365$
Instantaneous, with keep-hot facility controlled by time clock	$600 \times n_m / 365$
Instantaneous, with keep-hot facility not controlled by time clock	$900 \times n_m / 365$
Storage combi boiler**, store volume $V_c \geq 55$ litres	0
Storage combi boiler**, store volume $V_c < 55$ litres	$[600 - (V_c - 15) \times 15] \times f_u \times n_m / 365$

For  $n_m$  see Table 1a

If the daily hot water usage,  $V_{d,m}$ , is less than 100 litres/day,  $f_u = V_{d,m} / 100$ , otherwise  $f_u = 1.0$

Notes to Table 3a:

\* "keep-hot facility" is defined in Appendix D, section D1.16. The facility to keep water hot may have an on/off switch for the user, or it may be controlled by a time clock. If the store is 15 litres or more, the boiler is a storage combination boiler.

In the case of keep-hot:

- 1) If the keep-hot facility is maintained hot solely by burning fuel, use the appropriate loss for combi boiler from Table 3a and proceed with the calculation as normal.

- 2) If the keep-hot facility is maintained by electricity (or a mixture of electricity and fuel):
- include appropriate combi loss from Table 3a in worksheet  $(61)_m$ .
  - calculate energy required for water heating as  $[(64)_m - (61)_m] \times 100 \div (217)_m$  and enter in worksheet  $(219)_m$ .
- See also Table 4f.
- 3) In the case of an electrically powered keep-hot facility where the power rating of the keep-hot heater is obtained from the Product Characteristics database, the electric part of the total combi loss should be taken as:
- $$LE = 0.024 \times n_m \times P \text{ (kWh/month) (subject to maximum of the value from Table 3a, 3b or 3c)}$$
- where  $P$  is the power rating of the heater in watts  
with the remainder provided by the fuel.

\*\* “storage combi boilers” are defined in Appendix D. Apply these values in the case of a combi boiler with a close-coupled store with  $V_c$  as the volume of the close-coupled store (Appendix G).

**Table 3b: Losses for combi boilers tested to EN 13203-2 or OPS 26, profile M only**

Combi type	Storage loss $(56)_m$ , kWh/month	Additional loss $(61)_m$ , kWh/month
Instantaneous without FGHRs	0	$[(45)_m \times r_1 \times f_u] + [F_1 \times n_m]$
Instantaneous with FGHRs not fitted with a close-coupled store	0	$[F_1 \times n_m]$
Instantaneous with FGHRs fitted with a close-coupled store	(temperature factor from Table 2b) $\times$ (store loss from database record for the FGHRs) $\times n_m$	$[F_1 \times n_m]$
Storage combi without FGHRs	$F_1 \times n_m$	$(45)_m \times r_1 \times f_u$
Storage combi with FGHRs	$F_1 \times n_m$	0

These values are obtained from the database record for the boiler:

rejected energy proportion,  $r_1$

loss factor  $F_1$

For  $n_m$  see Table 1a

If the daily hot water usage,  $V_{d,m}$ , is less than 100 litres/day,  $f_u = V_{d,m} / 100$ , otherwise  $f_u = 1.0$

See notes below Table 3a.

See Appendix G for FGHRs.

Load profile M is defined in EN 13202-2.

**Table 3c: Losses for combi boilers tested to EN 13203-2 or OPS 26, two profiles**

Table 3c applies when the combi boiler has been tested using:

- profile M and profile S, or
- profile M and profile L

Combi type	Storage loss (56) <sub>m</sub> , kWh/month	Additional loss (61) <sub>m</sub> , kWh/month
Instantaneous without FGHRs	0	$(45)_m \times [r_1 + \text{DVF} \times F_3] \times f_u + [F_2 \times n_m]$
Instantaneous with FGHRs not fitted with a close-coupled store	0	$[F_2 \times n_m]$
Instantaneous with FGHRs fitted with a close-coupled store	(temperature factor from Table 2b) $\times$ (store loss from database record for the FGHRs) $\times n_m$	$[F_2 \times n_m]$
Storage combi without FGHRs	$F_2 \times n_m$	$(45)_m \times [r_1 + \text{DVF} \times F_3] \times f_u$
Storage combi with FGHRs	$F_2 \times n_m$	0

These values are obtained from the database record for the boiler:  
 rejected energy proportion,  $r_1$   
 loss factors  $F_2$  and  $F_3$

For  $n_m$  see Table 1a

The daily volume factor DVF depends on the daily volume for the month,  $V_{d,m}$ , and the profiles used for testing as follows:

- Profiles M and S: if  $V_{d,m} < 36.0$ ,  $\text{DVF} = 64.2$   
 if  $V_{d,m} > 100.2$ ,  $\text{DVF} = 0$   
 otherwise  $\text{DVF} = 100.2 - V_{d,m}$
- Profiles M and L: if  $V_{d,m} < 100.2$ ,  $\text{DVF} = 0$   
 if  $V_{d,m} > 199.8$ ,  $\text{DVF} = -99.6$   
 otherwise  $\text{DVF} = 100.2 - V_{d,m}$

If the daily hot water usage,  $V_{d,m}$ , is less than 100 litres/day,  $f_u = V_{d,m} / 100$ , otherwise  $f_u = 1.0$

See notes below Table 3a.

See Appendix G for FGHRs.

Profiles S, M and L are defined in EN 13202-2.

**Table 4a: Heating systems (space and water)**

1. The table shows space heating efficiency. The same efficiency applies for water heating when hot water is supplied from a boiler system.
2. For independent water heaters see section at the end of table.
3. 'Responsiveness' (R) is used to calculate mean internal temperature (Table 9b).
4. Systems marked "rd" in the right-hand column are part of the reduced data set (see S10 in Appendix S)
5. Heating systems, heating controls and fuels are assigned a code number for identification purposes

	Efficiency %	Heating type	Respon- siveness (R)	Code	Rd SAP
<b>Category 1 : NO HEATING SYSTEM PRESENT</b>					
<i>Refer to Group 0 in Table 4e for control options and temperature adjustments due to control</i>					
Electric heaters (assumed)	100	1	1.0	699	rd
<b>Category 2 : BOILER SYSTEMS WITH RADIATORS OR UNDERFLOOR HEATING</b>					
<b>Gas boilers and oil boilers</b>					
<i>For efficiency, use product database if possible, otherwise use efficiency from Table 4b.</i>					
<i>Use Table 4c for efficiency adjustments.</i>					
<i>Use Table 4d for heating type and responsiveness.</i>					
<i>Refer to Group 1 in Table 4e for control options and temperature adjustments due to control.</i>					
<b>Solid fuel boilers</b>					
<i>For efficiency, use product database if possible, otherwise use efficiency from this table. Column (A) gives minimum values for HETAS approved appliances, use column (B) for other appliances (see section 9.2.4). For open fires with back boilers and closed room heaters with boilers the efficiencies are the sum of heat to water and heat to room. See Table 12b for fuel options.</i>					
<i>Refer to Group 1 in Table 4e for control options</i>					
	(A)	(B)			
Manual feed independent boiler	65	60	2	0.75	151 rd
Auto (gravity) feed independent boiler	70	65	2	0.75	153 rd
Wood chip/pellet independent boiler	75	70	2	0.75	155 rd
Open fire with back boiler to radiators	63	55	3	0.50	156 rd
Closed room heater with boiler to radiators	67	65	3	0.50	158 rd
Stove (pellet-fired) with boiler to radiators	75	70	2	0.75	159 rd
Range cooker boiler (integral oven and boiler)	50	45	3	0.50	160 rd
Range cooker boiler (independent oven and boiler)	60	55	3	0.50	161
<b>Electric boilers</b>					
<i>Refer to Group 1 in Table 4e for control options</i>					
Direct acting electric boiler	100		From Table 4d	191	rd
Electric CPSU in heated space <sup>a)</sup> – radiators or underfloor	100		1	1.0	192 rd
Electric dry core storage boiler in heated space <sup>a) b)</sup>	100		2	0.75	193 rd
Electric dry core storage boiler in unheated space <sup>a) b)</sup>	85		2	0.75	194
Electric water storage boiler in heated space <sup>a) b)</sup>	100		2	0.75	195 rd
Electric water storage boiler in unheated space <sup>a) b)</sup>	85		2	0.75	196
<sup>a)</sup> Heated space means within the boundary of the dwelling as defined in section 1, "Dwelling dimensions"					
<sup>b)</sup> Store within boiler capable of meeting all space heating needs					
<b>Category 3 : MICRO-COGENERATION (MICRO-CHP)</b>					
<i>See Appendix N. Performance data to be obtained from product database.</i>					
<i>Refer to Group 1 in Table 4e for control options and temperature adjustments due to control.</i>					
<b>Category 4 : HEAT PUMPS WITH RADIATORS OR UNDERFLOOR HEATING</b>					
<i>Where the heat pump is included in the product characteristics database use the applicable data to assess via Appendix N. In other cases use the efficiency from this table.</i>					
<i>Refer to Group 2 in Table 4e for control options.</i>					



	Efficiency %	Heating type	Respon- siveness (R)	Code	Rd SAP
<b>Electric heat pumps</b>					
<i>Where an MCS Installation Certificate or equivalent is available, see 9.2.7</i>					
	space	water			
Ground source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	230	170	From Table 4d	211	rd
Water source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	230	170	From Table 4d	213	rd
Air source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	170	170	From Table 4d	214	rd
Ground source heat pump in other cases	170	170	From Table 4d	221	rd
Water source heat pump, in other cases	170	170	From Table 4d	223	rd
Air source heat pump in other cases	170	170	From Table 4d	224	rd
* see 9.3					
<b>Gas-fired heat pumps</b>					
Ground source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	120	84	From Table 4d	215	rd
Water source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	120	84	From Table 4d	216	rd
Air source heat pump with flow temperature $\leq 35^{\circ}\text{C}$ *	110	77	From Table 4d	217	rd
Ground source heat pump in other cases	84	84	From Table 4d	225	rd
Water source heat pump in other cases	84	84	From Table 4d	226	rd
Air source heat pump in other cases	77	77	From Table 4d	227	rd
* see 9.3					

### Category 5 : HEAT PUMPS WITH WARM AIR DISTRIBUTION

*Where the heat pump is included in the product characteristics database use the applicable data to assess via Appendix N. In other cases use the efficiency from this table. Refer to Group 5 in Table 4e for control options.*

#### Electric heat pumps

	space	water				
Ground source heat pump	230	170	1	1.0	521	rd
Water source heat pump	230	170	1	1.0	523	rd
Air source heat pump	170	170	1	1.0	524	rd

#### Gas-fired heat pumps

Ground source heat pump	120	84	1	1.0	525	
Water source heat pump	120	84	1	1.0	526	
Air source heat pump	110	77	1	1.0	527	

### Category 6 : HEAT NETWORKS

*Multiply the energy use by the factor for controls and charging method in Table 4c*

*For calculation of CO<sub>2</sub> emissions: if known, use manufacturer's declared efficiency instead of value from this table.*

*Refer to Group 3 in Table 4e for control options.*

*Check Table 4c for efficiency adjustment due to controls.*

*Allow for distribution loss (see Table 12c).*

Boilers (SAP)	80 †		From table 4d	2 ‡		
CHP (SAP)	75 †		From table 4d	1 ‡		
Waste heat from power station (SAP)	100		From table 4d	4 ‡		
Heat pump (SAP)	300 †		From table 4d	3 ‡		
Geothermal heat source (SAP)	100		From table 4d	5 ‡		
† use manufacturer's value where available ‡ code heat source						
Boilers only (RdSAP)	80		From table 4d	301	rd	
CHP and boilers (RdSAP)	75		From table 4d	302	rd	
Heat pump (RdSAP)	300		From table 4d	304	rd	
Heat network database	-		From table 4d	310	rd	

### Category 7 : ELECTRIC STORAGE SYSTEMS

*Refer to Group 4 in Table 4e for control options.*

*Off-peak tariffs:*

Old (large volume) storage heaters	100	6	0.0	401	rd	
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	Efficiency %	Heating type	Respon- siveness (R)	Code	Rd SAP
Slimline storage heaters	100	5	0.2	402	rd
Convector storage heaters	100	5	0.2	403	
Fan storage heaters	100	4	0.4	404	rd
Slimline storage heaters with Celect-type control	100	4	0.4	405	
Convector storage heaters with Celect-type control	100	4	0.4	406	
Fan storage heaters with Celect-type control	100	3	0.6	407	
Integrated storage+direct-acting heater	100	3	0.6	408	rd
High heat retention storage heaters § § heater specification in accordance with section 9.2.8 all heaters must qualify	100	2	0.8	409	rd
<i>24-hour heating tariff:</i>					
Slimline storage heaters	100	4	0.4	402	rd
Convector storage heaters	100	4	0.4	403	
Fan storage heaters	100	4	0.4	404	rd
Slimline storage heaters with Celect-type control	100	3	0.6	405	
Convector storage heaters with Celect-type control	100	3	0.6	406	
Fan storage heaters with Celect-type control	100	3	0.6	407	
High heat retention storage heaters § § heater specification in accordance with section 9.2.8 all heaters must qualify	100	2	0.8	409	rd
<b>Category 8 : ELECTRIC UNDERFLOOR HEATING</b>					
<i>Refer to Group 7 in Table 4e for control options.</i>					
<i>Off-peak tariffs:</i>					
In concrete slab (off-peak only)	100	5	0.0	421	rd
Integrated (storage+direct-acting)	100	4	0.25	422	rd
Integrated (storage+direct-acting) with low (off-peak) tariff control	100	3	0.50	423	
<i>Standard or off-peak tariff:</i>					
In screed above insulation	100	2	0.75	424	rd
In timber floor, or immediately below floor covering	100	1	1	425	
<b>Category 9 : WARM AIR SYSTEMS (NOT HEAT PUMP)</b>					
<i>Use product database if possible, otherwise use efficiency from this table.</i>					
<i>Refer to Group 5 in Table 4e for control options.</i>					
<b>Gas-fired warm air with fan-assisted flue</b>					
Ducted, on-off control, pre 1998	70	1	1.0	501	
Ducted, on-off control, 1998 or later	76	1	1.0	502	rd
Ducted, modulating control, pre 1998	72	1	1.0	503	
Ducted, modulating control, 1998 or later	78	1	1.0	504	
Room heater with in-floor ducts	69	1	1.0	505	
Condensing	81	1	1.0	520	
<b>Gas-fired warm air with balanced or open flue</b>					
Ducted or stub-ducted, on-off control, pre 1998	70	1	1.0	506	rd
Ducted or stub-ducted, on-off control, 1998 or later	76	1	1.0	507	
Ducted or stub-ducted, modulating control, pre 1998	72	1	1.0	508	
Ducted or stub-ducted, modulating control, 1998 or later	78	1	1.0	509	
Ducted or stub-ducted with flue heat recovery	85	1	1.0	510	rd
Condensing	81	1	1.0	511	rd
<b>Oil-fired warm air</b>					
Ducted output (on/off control)	70	1	1.0	512	rd
Ducted output (modulating control)	72	1	1.0	513	
Stub duct system	70	1	1.0	514	

	Efficiency %	Heating type	Respon- siveness (R)	Code	Rd SAP		
<b>Electric warm air</b>							
Electricaire system	100	2	0.75	515	rd		
<b>Category 10 : ROOM HEATERS</b>							
<i>Refer to Group 6 in Table 4e for control options.</i>							
<i>If declared efficiency is available (see Appendix E) use instead of value from table.</i>							
<i>The normal flue type is indicated as OF (open), RS (room-sealed) or C (chimney)</i>							
<b>Gas (including LPG) room heaters:</b>							
<i>Column (A) gives efficiency values for mains gas, column (B) for LPG</i>							
	<b>Flue</b>	(A)	(B)				
Gas fire, open flue, pre-1980 (open fronted)	OF	50	50	1	1.0	601	rd
Gas fire, open flue, pre-1980 (open fronted), with back boiler unit	OF*	50	50	1	1.0	602	rd
Gas fire, open flue, 1980 or later (open fronted), sitting proud of, and sealed to, fireplace opening	OF	63	64	1	1.0	603	rd
Gas fire, open flue, 1980 or later (open fronted), sitting proud of, and sealed to, fireplace opening, with back boiler unit	OF*	63	64	1	1.0	604	rd
Flush fitting Live Fuel Effect gas fire (open fronted), sealed to fireplace opening	OF	40	41	1	1.0	605	rd
Flush fitting Live Fuel Effect gas fire (open fronted), sealed to fireplace opening, with back boiler unit	OF*	40	41	1	1.0	606	rd
Flush fitting Live Fuel Effect gas fire (open fronted), fan assisted, sealed to fireplace opening	OF	45	46	1	1.0	607	rd
Gas fire or wall heater, balanced flue	RS	58	60	1	1.0	609	rd
Gas fire, closed fronted, fan assisted	RS	72	73	1	1.0	610	rd
Condensing gas fire	RS	85	85	1	1.0	611	rd
Decorative Fuel Effect gas fire, open to chimney	C	20	20	1	1.0	612	rd
Flueless gas fire, secondary heating only	none	90	92	1	1.0	613	rd
<i>(add additional ventilation in worksheet (9a))</i>							
<i>* The back boiler and the gas fire share the same flue</i>							
<b>Oil room heaters:</b>							
	<b>Flue</b>						
Room heater, pre 2000	OF	55		1	1.0	621	rd
Room heater, pre 2000, with boiler (no radiators)	OF	65		1	1.0	622	rd
Room heater, 2000 or later	OF	60		1	1.0	623	rd
Room heater, 2000 or later with boiler (no radiators)	OF	70		1	1.0	624	rd
Bioethanol heater, secondary heating only	none	94		1	1.0	625	rd
<b>Solid fuel room heaters</b>							
<i>Column (A) gives minimum values for HETAS approved appliances, use column (B) for other appliances (see section 9.2.3).</i>							
	<b>Flue</b>	(A)	(B)				
Open fire in grate	C	37	32	3	0.50	631	rd
Open fire with back boiler (no radiators)	C	50	50	3	0.50	632	rd
Closed room heater	OF*	65	60	3	0.50	633	rd
Closed room heater with boiler (no radiators)	OF*	67	65	3	0.50	634	rd
Stove (pellet fired)	OF*	70	65	2	0.75	635	rd
Stove (pellet fired) with boiler (no radiators)	OF*	75	70	2	0.75	636	rd
<i>* some wood-burning appliances have a room-sealed flue</i>							
<b>Electric (direct acting) room heaters:</b>							
Panel, convector or radiant heaters		100		1	1.0	691	rd
Water- or oil-filled radiators		100		1	1.0	694	rd
Fan heaters		100		1	1.0	692	rd
Portable electric heaters		100		1	1.0	693	rd

	Efficiency %	Heating type	Respon- siveness (R)	Code	Rd SAP
<b>Category 11 : OTHER SPACE HEATING SYSTEMS</b>					
<i>Refer to Group 7 in Table 4e for control options.</i>					
Electric ceiling heating	100	2	0.75	701	rd
<b>HOT WATER SYSTEMS</b>					
No hot water system present - electric immersion assumed	100			999	rd
From main heating system	efficiency of main system, except:			901	rd
Back boiler (hot water only), gas*	65				rd
Circulator built into a gas warm air system, pre 1998	65				rd
Circulator built into a gas warm air system, 1998 or later	73				rd
Heat exchanger in a gas warm air system, condensing unit	74				rd
From second main system	efficiency of second main system, exceptions as above			914	rd
From secondary system	efficiency of secondary heater, except:			902	rd
Back boiler (hot water only), gas*	65				rd
Electric immersion	100			903	rd
Single-point gas water heater (instantaneous at point of use)	70			907	rd
Multi-point gas water heater (instantaneous serving several taps)	65			908	rd
Electric instantaneous at point of use	100			909	rd
Gas boiler/circulator for water heating only*	65			911	rd
Oil boiler/circulator for water heating only*	70			912	rd
Solid fuel boiler/circulator for water heating only	55			913	rd
Range cooker with boiler for water heating only:*					
Gas, single burner with permanent pilot	46			921	rd
Gas, single burner with automatic ignition	50			922	rd
Gas, twin burner with permanent pilot pre 1998	60			923	
Gas, twin burner with automatic ignition pre 1998	65			924	rd
Gas, twin burner with permanent pilot 1998 or later	65			925	
Gas, twin burner with automatic ignition 1998 or later	70			926	
Oil, single burner	60			927	rd
Oil, twin burner pre 1998	70			928	rd
Oil, twin burner 1998 or later	75			929	
Solid fuel, integral oven and boiler	45			930	rd
Solid fuel, independent oven and boiler	55			931	rd
Electric heat pump for water heating only*	170			941	rd
Hot-water only heat network (SAP)	See Heat Networks further up this table			950	
Hot-water only heat network (RdSAP) - boilers	80			950	rd
Hot-water only heat network (RdSAP) - CHP	75			951	rd
Hot-water only heat network (RdSAP) - heat pump	300			952	rd
Hot-water only heat network (RdSAP) - heat network in PCDB	-			953	rd

\* If available use data from the boiler database instead of the value in this table. This is done by assigning a second main heating system with space heating fraction of 0.

**Table 4b: Seasonal efficiency for gas and oil boilers**

1. This table is to be used only for gas and oil boilers which cannot be located in the database.
2. See section 9.2.1 for application of the efficiency values in this table.
3. See Appendix B for guidance on boiler classification.
4. Apply efficiency adjustments in Table 4c if appropriate.
5. See Table 4d for heating type and responsiveness.
6. Systems marked "rd" in the right-hand column are part of the reduced data set (see S10 in Appendix S)

Boiler	Efficiency, %		Code	Rd SAP
	Winter	Summer		
<b>Gas boilers (including LPG and biogas) 1998 or later</b>				
Regular non-condensing with automatic ignition	74	64	101	rd
Regular condensing with automatic ignition	84	74	102	rd
Non-condensing combi with automatic ignition	74	65	103	rd
Condensing combi with automatic ignition	84	75	104	rd
Regular non-condensing with permanent pilot light	70	60	105	rd
Regular condensing with permanent pilot light	80	70	106	
Non-condensing combi with permanent pilot light	70	61	107	rd
Condensing combi with permanent pilot light	80	71	108	
Back boiler to radiators (select gas fire as secondary heater, see section 9.2.8)	66	56	109	rd
<b>Gas boilers (including LPG and biogas) pre-1998, with fan-assisted flue</b>				
Regular, low thermal capacity	73	63	110	
Regular, high or unknown thermal capacity	69	59	111	rd
Combi	71	62	112	rd
Condensing combi	84	75	113	rd
Regular, condensing	84	74	114	rd
<b>Gas boilers (including LPG and biogas) pre-1998, with balanced or open flue</b>				
Regular, wall mounted	66	56	115	rd
Regular, floor mounted, pre 1979	56	46	116	rd
Regular, floor mounted, 1979 to 1997	66	56	117	rd
Combi	66	57	118	rd
Back boiler to radiators (select gas fire as secondary heater, see section 9.2.8)	66	56	119	rd
<b>Combined Primary Storage Units (CPSU) (mains gas, LPG and biogas)</b>				
With automatic ignition (non-condensing)	74	72	120	rd
With automatic ignition (condensing)	83	81	121	rd
With permanent pilot (non-condensing)	70	68	122	
With permanent pilot (condensing)	79	77	123	
<b>Oil boilers</b>				
Standard oil boiler pre-1985	66	54	124	
Standard oil boiler 1985 to 1997	71	59	125	rd
Standard oil boiler, 1998 or later	80	68	126	rd
Condensing	84	72	127	rd
Combi, pre-1998	71	62	128	rd
Combi, 1998 or later	77	68	129	rd
Condensing combi	82	73	130	rd
Oil room heater with boiler to radiators, pre 2000	66	54	131	rd
Oil room heater with boiler to radiators, 2000 or later	71	59	132	rd
<b>Range cooker boilers (mains gas, LPG and biogas)</b>				
Single burner with permanent pilot	47	37	133	rd
Single burner with automatic ignition	51	41	134	rd
Twin burner with permanent pilot (non-condensing) pre 1998	61	51	135	
Twin burner with automatic ignition (non-condensing) pre 1998	66	56	136	rd
Twin burner with permanent pilot (non-condensing) 1998 or later	66	56	137	

Twin burner with automatic ignition (non-condensing) 1998 or later	71	61	138	
<b>Range cooker boilers (oil)</b>				
Single burner	61	49	139	rd
Twin burner (non-condensing) pre 1998	71	59	140	rd
Twin burner (non-condensing) 1998 or later	76	64	141	

**Table 4c: Efficiency adjustments**

Heating system (providing space heating and/or DHW)	Efficiency adjustment, %		
<b>Gas or oil boiler systems:</b> (not micro-CHP)			
<i>The adjustments are to be applied to the space and water heating seasonal efficiency for both tested efficiency values and efficiency values from Table 4b.</i>			
(1) Efficiency adjustment due to lower temperature of distribution system:	----- Space -----		DHW
	Natural gas	Oil or LPG	
Condensing boiler with compensating controls <sup>a)</sup>	see Appendix D		0
Condensing boiler with flow temperature lower than default <sup>a) b)</sup>	see Appendix D		0
Condensing boiler with thermal store <sup>a)</sup>	0	0	0
(2) Efficiency adjustment due to control system	Space		DHW
No thermostatic control of room temperature – regular boiler <sup>c)</sup>	-5		-5
No thermostatic control of room temperature – combi <sup>c)</sup>	-5		0
No thermostatic control of room temperature – CPSU, or regular boiler with integral thermal store or hot-water-only thermal store	-5		0
No boiler interlock - regular boiler (including back boiler) <sup>c)</sup>	-5		-5
No boiler interlock - combi <sup>c)</sup>	-5		0
<b>Heat networks:</b>			
(3) Factor for controls and charging method (control code as defined in Table 4e)	Multiply energy use by:		
	Space		DHW
2301 Flat rate charging <sup>d)</sup> , no thermostatic control of room temperature	1.10		1.05
2302 Flat rate charging, programmer, no room thermostat	1.10		1.05
2303 Flat rate charging, room thermostat only	1.05		1.05
2304 Flat rate charging, programmer and room thermostat	1.05		1.05
2307 Flat rate charging, TRVs	1.05		1.05
2305 Flat rate charging, programmer and TRVs	1.05		1.05
2311 Flat rate charging*, programmer and at least two room thermostats	1.05		1.05
2308 Charging system linked to use of heating, room thermostat only	1.05		1.0
2309 Charging system linked to use of heating, programmer and room thermostat	1.05		1.0
2310 Charging system linked to use of heating, TRVs	1.0		1.0
2306 Charging system linked to use of heating, programmer and TRVs	1.0		1.0
2312 Charging system linked to use of heating, programmer and at least two room thermostats	1.0		1.0
DHW-only system, flat rate charging	-		1.05
DHW-only system, charging linked to use	-		1.0

**Notes to Table 4c:**

- a) Efficiency adjustments are affected by flue gas heat recovery systems if present – see G1.7.
- b) Adjustment is applicable if the heating system has been designed and installed as described in 9.3. Where the design flow temperature is unknown a default design return temperature of 60°C is assumed – See Appendix D.
- c) These do not accumulate as no thermostatic control or presence of a bypass means that there is no boiler interlock.
- d) 'Flat rate charging' means that households pay for the heat according to a fixed monthly or annual amount, not depending on the amount of heat actually used. If the charges vary for other reasons, for example according to dwelling size, it is still classified as flat rate. 'Charging system linked to use of

*heat network' refers to a system in which the charges are substantially related to the amount of heat used.*

**Table 4d: Heating type and responsiveness for gas and oil boilers and heat networks, depending on heat emitter**

Heat emitter	Heating type	Responsiveness (R)
Systems with radiators:	1	1.0
Underfloor heating (wet system):		
pipes in insulated timber floor	1	1.0
pipes in screed above insulation	2	0.75
pipes in concrete slab	4	0.25
Underfloor heating and radiators		
pipes in insulated timber floor	1	1.0
pipes in screed above insulation	2	0.75
pipes in concrete slab	4	0.25
Warm air via fan coil units	1	1.0

**Table 4e: Heating system controls**

1. Use Table 4a to select appropriate Group in this table.
2. 'Control' indicates the appropriate control type to use in Table 9.
3. The 'Temperature adjustment' modifies the mean internal temperature and is added to worksheet (92)<sub>m</sub>.
4. Controls marked "rd" in the right-hand column are part of the reduced data set (see S10 in Appendix S).
5. A programmable room thermostat is equivalent to a programmer and room thermostat.

Type of control	Control	Temperature adjustment, °C	Reference to other possible adjustments	Code	rd SAP
<b>GROUP 0: NO HEATING SYSTEM PRESENT</b>					
None	2	+0.3	n/a	2699	rd
<b>GROUP 1: BOILER SYSTEMS WITH RADIATORS OR UNDERFLOOR HEATING (and micro-CHP)</b>					
<i>Not applicable (boiler provides DHW only)</i>					
No time or thermostatic control of room temperature	1	+0.6	Table 4c(2)	2101	rd
Programmer, no room thermostat	1	+0.6	Table 4c(2)	2102	rd
Room thermostat only	1	0	Table 4c(2)	2103	rd
Programmer and room thermostat	1	0	Table 4c(2)	2104	rd
Programmer and at least two room thermostats	2	0	Table 4c(2)	2105	rd
Room thermostat and TRVs	2	0	Table 4c(2)	2113	rd
Programmer, room thermostat and TRVs	2	0	Table 4c(2)	2106	rd
TRVs and bypass	2	0	Table 4c(2)	2111	rd
Programmer, TRVs and bypass	2	0	Table 4c(2)	2107	rd
Programmer, TRVs and flow switch	2	0	Table 4c(2)	2108	rd
Programmer, TRVs and boiler energy manager	2	0	Table 4c(2)	2109	rd
Time and temperature zone control by arrangement of plumbing and electrical services (see 9.4.14)	3	0	Table 4c(2)	2110	rd
Time and temperature zone control by device in PCDB (see 9.4.14)	3	0	Table 4c(2)	2112	rd
Other control from PCDB	From PCDB record	From PCDB record	Table 4c(2)	2113	rd
<b>Adjustments for features of control systems:</b> (applicable to any control option above and in addition to the adjustments selected above)					
Delayed start thermostat	one of the above	-0.15	n/a		
Enhanced load compensator or weather compensator	one of the above	0	Table 4c(1)		
Temperature control of water heating (cylinderstat)	n/a	n/a	Tables 2b and 3		rd
Time control of water heating (separate programming)	n/a	n/a	Table 2b		
<b>Adjustments for features other than controls:</b>					
Temperature adjustment for CPSU or integrated thermal store	n/a	-0.1	n/a		rd
Low temperature heat distribution system	n/a	n/a	Table 4c(1)		rd



Table 4e continued

Type of control	Control	Temperature adjustment, °C	Reference to other possible adjustments	Code	Rd SAP
<b>GROUP 2: HEAT PUMPS WITH RADIATORS OR UNDERFLOOR HEATING</b>					
<i>Not applicable (heat pump provides DHW only)</i>					
No time or thermostatic control of room temperature	1	+0.3	n/a	2100	rd
Programmer, no room thermostat	1	+0.3	n/a	2201	rd
Room thermostat only	1	0	n/a	2202	rd
Programmer and room thermostat	1	0	n/a	2203	rd
Programmer and at least two room thermostats	2	0	n/a	2204	rd
Room thermostat and TRVs	2	0	n/a	2205	rd
Programmer, TRVs and bypass	2	0	n/a	2209	rd
Time and temperature zone control by arrangement of plumbing and electrical services (see 9.4.14)	3	0	n/a	2206	rd
Time and temperature zone control by device in PCDB (see 9.4.14)	3	0	n/a	2207	rd
Other control from PCDB	From PCDB record	From PCDB record	Table 4c(2)	2208	rd
<b>Adjustments for features of control systems:</b> (applicable to any control option above and in addition to the adjustments selected above)					
Temperature control of water heating (cylinderstat)	n/a	n/a	Tables 2b and 3		rd
Time control of water heating (separate programming)	n/a	n/a	Table 2b		
<b>Adjustments for features other than controls:</b>					
Temperature adjustment for integrated thermal store	n/a	-0.1	n/a		rd
<b>GROUP 3: HEAT NETWORKS</b>					
Flat rate charging*, no thermostatic control of room temperature	1	+0.3	Table 4c(3)	2301	rd
Flat rate charging*, programmer, no room thermostat	1	+0.3	Table 4c(3)	2302	rd
Flat rate charging*, room thermostat only	1	0	Table 4c(3)	2303	rd
Flat rate charging*, programmer and room thermostat	1	0	Table 4c(3)	2304	rd
Flat rate charging*, room thermostat and TRVs	2	0	Table 4c(3)	2313	rd
Flat rate charging*, TRVs	2	0	Table 4c(3)	2307	rd
Flat rate charging*, programmer and TRVs	2	0	Table 4c(3)	2305	rd
Flat rate charging*, programmer and at least two room thermostats	2	0	Table 4c(3)	2311	rd
Charging system linked to use of heating, room thermostat only	2	0	Table 4c(3)	2308	rd
Charging system linked to use of heating, programmer and room thermostat	2	0	Table 4c(3)	2309	rd
Charging system linked to use of heating, room thermostat and TRVs	3	0	Table 4c(3)	2314	rd
Charging system linked to use of heating, TRVs	3	0	Table 4c(3)	2310	rd
Charging system linked to use of heating, programmer and TRVs	3	0	Table 4c(3)	2306	rd
Charging system linked to use of heating, programmer and at least two room thermostats	3	0	Table 4c(3)	2312	rd
* 'Flat rate charging' means that households pay for the heat according to a fixed monthly or annual amount, not depending on the amount of heat actually used. If the charges vary for other reasons, for example according to dwelling size, it is still classified as flat rate. Other entries refer to a system in which the charges are substantially related to the amount of heat used.					
<b>GROUP 4: ELECTRIC STORAGE SYSTEMS</b>					
Manual charge control	3	+0.7	n/a	2401	rd
Automatic charge control	3	+0.4	n/a	2402	rd

Ceect-type controls	3	+0.4	n/a	2403	
Controls for high heat retention storage heaters §	3	0	n/a	2404	rd
§ applies to high heat retention storage heaters (code 409) only					

Table 4e continued

Type of control	Control	Temperature adjustment, °C	Reference to other possible adjustments	Code	Rd SAP
<b>GROUP 5: WARM AIR SYSTEMS (including heat pumps with warm air distribution)</b>					
No time or thermostatic control of room temperature	1	+0.3	n/a	2501	rd
Programmer, no room thermostat	1	+0.3	n/a	2502	rd
Room thermostat only	1	0	n/a	2503	rd
Programmer and room thermostat	1	0	n/a	2504	rd
Programmer and at least two room thermostats	2	0	n/a	2505	rd
Time and temperature zone control	3	0	n/a	2506	rd
<b>GROUP 6: ROOM HEATER SYSTEMS</b>					
No thermostatic control of room temperature	2	+0.3	n/a	2601	rd
Appliance thermostats	3	0	n/a	2602	rd
Programmer and appliance thermostats	3	0	n/a	2603	rd
Room thermostats only	3	0	n/a	2604	rd
Programmer and room thermostats	3	0	n/a	2605	rd
<b>GROUP 7: OTHER SYSTEMS</b>					
No time or thermostatic control of room temperature	1	+0.3	n/a	2701	rd
Programmer, no room thermostat	1	+0.3	n/a	2702	rd
Room thermostat only	1	0	n/a	2703	rd
Programmer and room thermostat	1	0	n/a	2704	rd
Temperature zone control	2	0	n/a	2705	rd
Time and temperature zone control	3	0	n/a	2706	rd

**Table 4f: Electricity for fans and pumps and electric keep-hot facility**

Equipment	kWh/year
<b>Heating system:</b>	
Circulation pump, 2013 or later	41 <sup>a) b)</sup>
Circulation pump, 2012 or earlier	165 <sup>a) b)</sup>
Circulation pump, unknown date	115
Oil boiler <sup>e)</sup> – flue fan and oil pump	100 <sup>d)</sup>
Gas boiler – flue fan (if fan assisted flue)	45 <sup>d)</sup>
Gas-fired heat pump – flue fan (if fan assisted flue)	45
Gas-fired warm air system – flue fan (if fan assisted flue)	45
Warm air heating system fans <sup>e)</sup>	SFP × 0.4 × V
<b>Keep-hot facility of a combi boiler:</b>	
Electricity for maintaining keep-hot facility <sup>f) g)</sup>	
- keep-hot facility, controlled by time clock	600
- keep-hot facility, not controlled by time clock	900
<b>Ventilation system:</b>	
Mechanical extract ventilation <sup>h)</sup>	IUF × SFP × 1.22 × V
Balanced whole house mechanical ventilation fans <sup>h)</sup>	IUF × SFP × 2.44 × n <sub>mech</sub> × V
Positive input ventilation (from loft space)	0
Positive input ventilation (from outside) <sup>h)</sup>	IUF × SFP × 1.22 × V
<b>Solar water heating pump:</b>	
Solar water heating pump, electrically powered	[25 + (5 × (H1))] × (2000 ÷ 1000)
Solar water heating pump, PV powered	0

**Notes:**

- <sup>a)</sup> Multiply by a factor of 1.3 if room thermostat is absent.
- <sup>b)</sup> Not applicable for electric heat pumps. Where there are two main heating systems, assume each has its own circulation pump and therefore include two figures from this table. 2013 or later applies to a new dwelling.
- <sup>c)</sup> Applies to all oil boilers that provide main heating, but not if boiler provides hot water only. Where there are two main heating systems include two figures from this table.
- <sup>d)</sup> To be overwritten if electrical energy value is entered in PCDB. These are based on electrical power measurements from Ecodesign regulations (811/2013).
- <sup>e)</sup> SFP is the specific fan power from the database record for the warm air unit if applicable; otherwise 1.5 W/(l/s). These values of SFP include the in-use factor.  
If the heating system is a warm air unit and there is balanced whole house mechanical ventilation, the electricity for warm air circulation should not be included in addition to the electricity for mechanical ventilation. However it is included for a warm air system and MEV or PIV from outside. V is the volume of the dwelling in m<sup>3</sup>.
- <sup>f)</sup> See notes to Table 3a for the definition of keep-hot facility.
- <sup>g)</sup> In the case of an electrically powered keep-hot facility (powered by a mixture of electricity and fuel) where the power rating of the keep-hot heater is obtained from the Product Characteristics database, the electric part of the keep-hot energy use should be taken as:  

$$LE = 8.76 \times P \text{ (kWh/year)}$$
(subject to a maximum of the value from Table 3a, 3b or 3c)  
where P is the power rating of the heater in watts  
with the remainder (either 600 – LE or 900 – LE) provided by the fuel.  
If the power rating of the electric heater is not known assume all the keep-hot energy is supplied by electricity.

<sup>h)</sup> *SFP is specific fan power in W/(litre/sec), see paragraph 2.6 and Table 4g; IUF is the applicable in-use factor from the PCDB; V is volume of the dwelling in m<sup>3</sup>; n<sub>mech</sub> is the throughput of the MVHR system, see paragraph 2.6.*

**Table 4g: Default specific fan power for mechanical ventilation systems and heat recovery efficiency for MVHR systems**

1. The data in Table 4g are used where values via the database for the specific product are not available.
2. The SFP values apply to both rigid and flexible ducting.
3. Values of specific fan power and heat recovery efficiency are to be multiplied by the appropriate in-use factor for default data (Table 4h).

Type of mechanical ventilation	SFP, W/(litre/sec)	Heat recovery efficiency
Mechanical extract ventilation (centralised or decentralised), or positive input ventilation from outside	0.8	-
Balanced whole house mechanical ventilation, without heat recovery	2.0	-
Balanced whole house mechanical ventilation, with heat recovery	2.0	66%

**Table 4h: In-use factors for mechanical ventilation systems**

*In-use factors are applied to the data for mechanical ventilation systems in all cases. This table is provided for information purposes only, the factors are held in the PCDB for use with SAP calculation software. These may be updated from time to time.*

Type of mechanical ventilation	Approved installation scheme or measured SFP	In-use factor for Specific fan power			In-use factor for Efficiency			
		Flexible duct	Rigid duct	No duct	Level 1 - Insulated ducts <sup>e)</sup>	Level 2 - insulated ducts <sup>f)</sup>	Insulated ducts <sup>g)</sup>	Uninsulated ducts <sup>h)</sup>
Mechanical extract ventilation, centralised <sup>a)</sup>	No	1.70	1.40	-	System installed exclusively within heated envelope	System <u>not</u> installed exclusively within heated envelope	0.5	0.25
	Yes	1.60	1.30	-				
Mechanical extract ventilation or positive input ventilation from outside, decentralised <sup>a)</sup>	No	1.45	1.30	1.15				
	Yes	1.45	1.30	1.15				
Balanced whole house mechanical ventilation, without heat recovery <sup>a)</sup>	No	1.70	1.40 <sup>c)</sup>	-				
	Yes	1.60	1.25 <sup>c)</sup>	-				
	Measured SFP <sup>d)</sup>	1.10		-				
Balanced whole house mechanical ventilation, with heat recovery <sup>a)</sup>	No	1.70	1.40 <sup>c)</sup>	-	0.9	0.8	0.5	0.25
	Yes	1.60	1.25 <sup>c)</sup>	-				
	Measured SFP <sup>d)</sup>	1.10		-				
Where default data from Table 4g has been used (all types) <sup>b)</sup>	-	2.5			0.70		0.25	

- a) Use these values for data from the PCDB.
- b) Use these values for data from Table 4g.
- c) The values for rigid ducts also apply to semi-rigid ducts provided that the semi-rigid ducts are listed in the PCDB.
- d) Refer to Section 2.6.2 – “Data required”
- e) Requirements to satisfy Level 1 insulated ducts definition:
  - i) For supply (or extract, whichever is longer) duct lengths less than or equal to 2m, the duct system must be continuously insulated throughout to a minimum depth of 25mm with an insulant thermal conductivity of 0.04 W/m.K or less
  - ii) For supply (or extract, whichever is longer) duct lengths greater than 2m, the duct system must be continuously insulated throughout to a minimum depth of 50mm with an insulant thermal conductivity of 0.04 W/m.K or less
- f) The definition of Level 2 insulated ducts is where Level 1 is not satisfied or the insulation specification is unknown
- g) Duct system continuously insulated throughout to a minimum depth of 25mm with an insulant thermal conductivity of 0.04 W/m.K or less, as required by the Domestic Ventilation Compliance Guide.
- h) Duct system insulation not meeting the requirements of d), i.e. insulation depth less than 25mm or not present.

**Table 5: Internal heat gains**

The formulae provide heat gains in watts.

Source	(A) Typical gains	(B) Reduced gains
Metabolic	$60 \times N$	$50 \times N$
Lighting	equation (L12) in Appendix L	equation (L12a) in Appendix L
Appliances	equation (L16) in Appendix L	equation (L16a) in Appendix L
Cooking	$35 + 7 \times N$	$23 + 5 \times N$
Water heating	$1000 \times (65)_m \div (n_m \times 24)$	$1000 \times (65)_m \div (n_m \times 24)$
Losses	$-40 \times N$	$-40 \times N$
Pumps and fans	Table 5a	Table 5a

Notes:

1.  $N$  is the assumed number of occupants, based on floor area.
2. Losses comprise heat to incoming cold water and evaporation.
3. Column (B) applies to the calculation of the space heating requirements for the DFEE, TDEE, DER and TER for new dwellings. Column (A) applies in all other cases (including the calculation of space cooling requirements and overheating assessments).

**Table 5a: Gains from pumps and fans**

Function	Gains (W)
Central heating pump in heated space, 2013 or later	3 <sup>a)</sup>
Central heating pump in heated space, 2012 or earlier	10 <sup>a)</sup>
Central heating pump in heated space, unknown date	7 <sup>a)</sup>
Oil boiler pump, inside dwelling	10 <sup>b)</sup>
Warm air heating system fans <sup>a) c)</sup>	$SFP \times 0.04 \times V$
Fans for positive input ventilation from outside <sup>d)</sup>	$IUF \times SFP \times 0.12 \times V$
Fans for balanced whole house mechanical ventilation without heat recovery <sup>d)</sup>	$IUF \times SFP \times 0.06 \times V$

Notes:

- <sup>a)</sup> For each space heating distribution system when there are two. Does not apply if a heating system used solely for domestic hot water. Does not apply to cooling calculations or to heat networks. 2013 or later applies to a new dwelling. Set to zero in summer months.
- <sup>b)</sup> Does not apply to cooling calculations and only for boiler providing main heating. In addition to central heating pump, but not if oil pump is outside dwelling. Set to zero in summer months.
- <sup>c)</sup> SFP is the specific fan power from the database record for the warm air unit if applicable; otherwise 1.5 W/(l/s). These values of SFP include an in-use factor  
If the heating system is a warm air unit and there is balanced whole house mechanical ventilation, the gains for the warm air system should not be included.
- <sup>d)</sup> SFP is specific fan power in W/(litre/sec), IUF is the applicable in-use factor.

V is the volume of the dwelling.

Gains are not added in for MVHR systems (because their effect is included in the MVHR efficiency), nor for MEV systems.

Table 6a deleted. For solar radiation see Table U3.



**Table 6b: Transmittance factors for glazing**

Type of glazing	Total solar energy transmittance, $g_{\perp}$ (for calculation of solar gains in section 6 of the worksheet)	Light transmittance, $g_L$ (for calculation of lighting requirement in Appendix L)
Single glazed	0.85	0.90
Double glazed (air or argon filled)	0.76	} 0.80
Double glazed (low-E, hard-coat)	0.72	
Double glazed (low-E, soft-coat)	0.63	
Window with secondary glazing	0.76	0.80
Triple glazed (air or argon filled)	0.68	} 0.70
Triple glazed (low-E, hard-coat)	0.64	
Triple glazed (low-E, soft-coat)	0.57	

Notes:

1. The values are for normal incidence of solar radiation and they are multiplied by 0.9 (both solar and light transmittance) in calculations.
2. When the window U-value is declared by the manufacturer (rather than from Table 6e) the solar transmittance should also be obtained from the manufacturer. In this case, ascertain whether the solar transmittance is related to the glazing only or to the whole window: see section 6.1.
3. Light transmittance should always be taken from Table 6b, irrespective of the source of the U-value and solar transmittance.

**Table 6c: Frame factors for windows and glazed doors**

Frame type	Frame factor (proportion of opening that is glazed)
Wood	0.7
Metal	0.8
Metal, thermal break	0.8
PVC-U	0.7
Unknown (e.g. U-value from window rating scheme data)	0.7

Note: If known, the actual frame factor should be used instead of the data in Table 6c. Frame factors can be assigned per window (or per group of similar windows) or as an average for each façade of the dwelling.

**Table 6d: Solar and light access factors**

Overshading	% of sky blocked by obstacles.	Winter solar access factor (for calculation of solar gains for heating)	Summer solar access factor (for calculation of solar gains for cooling and summer temperatures in Appendix P)	Light access factor (for calculation of lighting requirement in Appendix L)
Heavy	> 80%	0.3	0.5	0.5
More than average	>60% - 80%	0.54	0.7	0.67
Average or unknown	20% - 60%	0.77	0.9	0.83
Very little	< 20%	1.0	1.0	1.0

Notes

1. The overshading category of "very little" is not appropriate for new dwellings. In this case use 'average or unknown' even if 'very little' is selected.
2. A solar access factor of 1.0 and a light access factor of 1.0 should be used for roof windows.
3. The same factor is used for all glazing in the dwelling (not a different factor for each orientation or each opening).

**Table 6e: Default U-values (W/m<sup>2</sup>K) for windows, doors and roof windows**

The values apply to the entire area of the window opening, including both frame and glass, and take account of the proportion of the area occupied by the frame and the heat conducted through it. Unless known otherwise, double and triple glazing should be taken as air-filled without low-E coating. If the U-value of the components of the window (glazed unit and frame) are known, window U-values may alternatively be taken from the tables in Annex F of BS EN ISO 10077-1, using the tables for 20% frame for metal-framed windows and those for 30% frame for wood or PVC-U framed windows.

When available, the manufacturer's certified U-values for windows or doors should be used in preference to the data in this table. Adjustments for roof windows as in Note 1 to the table should be applied to manufacturer's window U-values unless the manufacturer provides a U-value specifically for a roof window. For rooflights use the data for roof windows.

Description of glazing	Type of frame					
	Window with wood or PVC frame (for roof windows use adjustment in Note 1)			Window with metal frame with 4mm thermal break (use adjustments in Note 1 and Note 2)		
	6mm gap	12mm gap	16mm+ gap	6mm gap	12mm gap	16mm+ gap
double-glazed, air filled	3.1	2.8	2.7	3.7	3.4	3.3
double-glazed, air filled (low-E, $\epsilon_n = 0.2$ , hard coat)	2.7	2.2	2.1	3.3	2.8	2.6
double-glazed, air filled (low-E, $\epsilon_n = 0.15$ , hard coat)	2.7	2.2	2	3.3	2.7	2.5
double-glazed, air filled (low-E, $\epsilon_n = 0.1$ , soft coat)	2.6	2.1	1.9	3.2	2.6	2.4
double-glazed, air filled (low-E, $\epsilon_n = 0.05$ , soft coat)	2.6	2	1.8	3.2	2.5	2.3
double-glazed, argon filled	2.9	2.7	2.6	3.5	3.3	3.2
double-glazed, argon filled (low-E, $\epsilon_n = 0.2$ , hard coat)	2.5	2.1	2	3	2.6	2.5
double-glazed, argon filled (low-E, $\epsilon_n = 0.15$ , hard coat)	2.4	2	1.9	3	2.5	2.4
double-glazed, argon filled (low-E, $\epsilon_n = 0.1$ , soft coat)	2.3	1.9	1.8	2.9	2.4	2.3
double-glazed, argon filled (low-E, $\epsilon_n = 0.05$ , soft coat)	2.3	1.8	1.7	2.8	2.2	2.1
triple glazed, air filled	2.4	2.1	2	2.9	2.6	2.5
triple-glazed, air filled (low-E, $\epsilon_n = 0.2$ , hard coat)	2.1	1.7	1.6	2.6	2.1	2
triple-glazed, air filled (low-E, $\epsilon_n = 0.15$ , hard coat)	2.1	1.7	1.6	2.5	2.1	2
triple-glazed, air filled (low-E, $\epsilon_n = 0.1$ , soft coat)	2	1.6	1.5	2.5	2	1.9
triple-glazed, air filled (low-E, $\epsilon_n = 0.05$ , soft coat)	1.9	1.5	1.4	2.4	1.9	1.8
triple-glazed, argon filled	2.2	2	1.9	2.8	2.5	2.4

triple-glazed, argon filled (low-E, $\epsilon_n = 0.2$ , hard coat)	1.9	1.6	1.5	2.3	2	1.9
triple-glazed, argon filled (low-E, $\epsilon_n = 0.15$ , hard coat)	1.8	1.5	1.4	2.3	1.9	1.8
triple-glazed, argon filled (low-E, $\epsilon_n = 0.1$ , soft coat)	1.8	1.5	1.4	2.2	1.9	1.8
triple-glazed, argon filled (low-E, $\epsilon_n = 0.05$ , soft coat)	1.7	1.4	1.3	2.2	1.8	1.7
Windows and doors, single-glazed	4.8			5.7		
Window with secondary glazing	2.4					
Solid wooden door to outside	3					
Solid wooden door to unheated corridor	1.4					

Notes:

- For roof windows apply the following adjustments to U-values which are (i) taken from Table 6e or (ii) provided by manufacturer unless specifically stated to apply to roof windows. These adjustments do not apply to U-values sourced from a window rating scheme.

<u>All frame types</u>	<u>U-value adjustment for roof window, W/m<sup>2</sup>K</u>
Single glazed	+0.5
Double glazed or secondary glazing	+0.3
Triple glazed	+0.2

- For windows or roof windows with metal frames apply the following adjustments to U-values taken from Table 6e:

<u>Metal frames</u>	<u>U-value adjustment, W/m<sup>2</sup>K</u>
	<u>Window or roof window</u>
Metal frame, no thermal break	+0.3
Metal frame, thermal break 4 mm	0
Metal frame, thermal break 8 mm	-0.1
Metal frame, thermal break 12 mm	-0.2
Metal frame, thermal break 20 mm	-0.3
Metal frame, thermal break 32 mm	-0.4

- For doors which are half-glazed (approximately) the U-value of the door is the average of the appropriate window U-value and that of the non-glazed part of the door (e.g. solid wooden door [U-value of 3.0 W/m<sup>2</sup>K] half-glazed with double glazing [low-E, hard coat, argon filled, 6 mm gap, U-value of 2.5 W/m<sup>2</sup>K] has a resultant U-value of  $0.5(3.0+2.5) = 2.75$  W/m<sup>2</sup>K).

Table 7 deleted. For wind speed see Table U2.

Table 8 deleted. For external temperature see Table U1.

### Calculation of mean internal temperature for heating

Calculation of mean internal temperature is based on the heating patterns defined in Table 9.

**Table 9: Heating periods and heating temperatures**

Living area		Elsewhere		
Temperature $T_{h1}$ (°C)	Hours of heating off $t_{off}$	Heating control type (Table 4e)	Temperature $T_{h2}$ °C	Hours of heating off $t_{off}$
21	Weekday: 7 and 8 <sup>a</sup>	1	21 – 0.5 HLP	Weekday: 7 and 8 <sup>a</sup> Weekend: 7 and 8 <sup>a</sup>
	Weekend: 7 and 8 <sup>a</sup>	2	$21 - HLP + HLP^2 / 12$	Weekday: 7 and 8 <sup>a</sup> Weekend: 7 and 8 <sup>a</sup>
		3	$21 - HLP + HLP^2 / 12$	All days: 9 and 8 <sup>b</sup>
	From PCDB <sup>c</sup>	From PCDB	If control type 1: 21 – 0.5 HLP If control type 2 or 3: $21 - HLP + HLP^2 / 12$	From PCDB <sup>c</sup>
<sup>a</sup> heating 0700-0900 and 1600-2300 <sup>b</sup> heating 0700-0900 and 1800-2300. The first (daytime) off period is instead taken from the applicable database record for communicating or programmable TRVs. <sup>c</sup> the length of the off periods is taken from the applicable PCDB record for the control (applies for control type 2113 and 2209) If $HLP > 6.0$ use $HLP = 6.0$ for calculation of $T_{h2}$				

During heating periods the temperature is as given in Table 9 and at other times it falls towards the temperature that would apply without heating ( $T_{sc}$  as defined in Table 9b). The calculation is done separately for the living area and for elsewhere and the two values combined in proportion to the respective floor areas.

**Table 9a: Utilisation factor for heating**

<p><i>Symbols and units</i></p> <p>H = heat transfer coefficient, (39)<sub>m</sub> (W/K)</p> <p>G = total gains, (84)<sub>m</sub> (W)</p> <p><math>T_i</math> = internal temperature (°C)</p> <p><math>T_e</math> = external temperature, (96)<sub>m</sub> (°C)</p> <p>TMP = Thermal Mass Parameter, (35), (kJ/m<sup>2</sup>K) (= <math>C_m</math> for building / total floor area)</p> <p>HLP = Heat Loss Parameter, (40)<sub>m</sub> (W/m<sup>2</sup>K)</p> <p><math>\tau</math> = time constant (h)</p> <p><math>\eta</math> = utilisation factor</p> <p>L = heat loss rate (W)</p>
<p><i>Calculation of utilisation factor</i></p> <p><math>\tau = TMP / (3.6 \times HLP)</math></p> <p><math>a = 1 + \tau / 15</math></p> <p><math>L = H (T_i - T_e)</math></p> <p><math>\gamma = G / L</math>      <i>Notes: if <math>L = 0</math> set <math>\gamma = 10^6</math> ; to avoid instability when <math>\gamma</math> is close to 1 round <math>\gamma</math> to 8 decimal places</i></p>

if $\gamma > 0$ and $\gamma \neq 1$ :	$\eta = \frac{1 - \gamma^a}{1 - \gamma^{a+1}}$
if $\gamma = 1$ :	$\eta = \frac{a}{a + 1}$
if $\gamma \leq 0$ :	$\eta = 1$

**Table 9b: Temperature reduction when heating is off**

<p><math>\tau</math> = time constant (from Table 9a)</p> <p><math>t_{\text{off}}</math> = number of hours that heating is off</p> <p><math>T_h</math> = temperature during heating period (Table 9)</p> <p><math>T_{\text{sc}}</math> = internal temperature without heating</p> <p><math>R</math> = responsiveness of main heating system (Table 4a or Table 4d)          or where there are two main systems <math>R</math> is a weighted average of <math>R</math> for the two systems:  <math>R = (203) \times R_{\text{system2}} + [1 - (203)] \times R_{\text{system1}}</math></p>
<p><math>t_c = 4 + 0.25 \tau</math></p> <p><math>T_{\text{sc}} = (1 - R) \times (T_h - 2.0) + R (T_e + \eta G / H)</math></p> <p>if <math>t_{\text{off}} \leq t_c</math>     <math>u = 0.5 t_{\text{off}}^2 \times (T_h - T_{\text{sc}}) / (24 \times t_c)</math></p> <p>if <math>t_{\text{off}} &gt; t_c</math>     <math>u = (T_h - T_{\text{sc}}) \times (t_{\text{off}} - 0.5 t_c) / 24</math></p>

**Table 9c: Heating requirement**

<p>The following is done using data for the applicable month.</p> <p><u>Living area</u></p> <ol style="list-style-type: none"> <li>Set <math>T_i</math> to the temperature for the living area during heating periods (Table 9)</li> <li>Calculate the utilisation factor (Table 9a)</li> <li>Calculate the temperature reduction (Table 9b) for each off period (Table 9), <math>u_1</math> and <math>u_2</math>, for weekdays</li> <li><math>T_{\text{weekday}} = T_h - (u_1 + u_2)</math></li> <li>Calculate the temperature reduction (Table 9b) for each off period (Table 9), <math>u_1</math> and <math>u_2</math>, for weekends</li> <li><math>T_{\text{weekend}} = T_h - (u_1 + u_2)</math></li> <li>Mean temperature (living area) <math>T_1 = (5 T_{\text{weekday}} + 2 T_{\text{weekend}}) / 7</math></li> </ol> <p><u>Rest of dwelling</u></p> <ol style="list-style-type: none"> <li>Set <math>T_i</math> to the temperature for elsewhere during heating periods (Table 9)</li> <li>Repeat steps 2 to 7 above to obtain the mean temperature (rest of dwelling), <math>T_2</math></li> </ol> <p><u>Whole dwelling</u></p> <ol style="list-style-type: none"> <li>Mean internal temperature = <math>f_{\text{LA}} \times T_1 + (1 - f_{\text{LA}}) \times T_2</math>  <math>f_{\text{LA}}</math> is the living area fraction, (91)</li> <li>Apply adjustment to the mean internal temperature from Table 4e, where appropriate</li> <li>Set <math>T_i</math> to the mean internal temperature obtained at step 11 and re-calculate the utilisation factor</li> <li>Heat requirement for month in kWh, (98)<sub>m</sub>, is</li> </ol>
---

$$Q_{\text{heat}} = 0.024 \times (L_m - \eta_m G_m) \times n_m$$

where  $n_m$  is the number of days in the month

Set  $Q_{\text{heat}}$  to 0 if negative or less than 1 kWh.

Include the heating requirement for each month from October to May (disregarding June to September).

When there are two main heating systems the procedure is adapted as follows, depending on whether both systems serve the whole house or each system serves different parts.

#### 1. Both systems heat whole house

When both systems heat all the house (or at least all those rooms with heat emitters connected to the systems), the fraction of main heat from main system 2, worksheet (203), is provided as part of the specification of the systems. Main system 1 is that which provides the greatest amount of heat. The heating controls for both systems must be compatible (same control type), and the control type concerned is used in Table 9 for the calculation of MIT in the rest of dwelling, worksheet (89)<sub>m</sub> and (90)<sub>m</sub>, and for the calculation of MIT for the whole dwelling, worksheet (93)<sub>m</sub>.

#### 2. The two systems heat different parts of the house

When the systems heat different parts of the house they are treated as being separate. The fraction of main heat from main system 2, worksheet (203), is in the absence of specific information the fraction of the total floor area heated by main system 2. Main system 1 is that which provides heat to the living area, and heating controls for each system are specified according to those fitted to each system (and so can be different).

Calculate the mean internal temperature (MIT) for the living area according to Tables 9, 9a, 9b and 9c or, in the case of a system assessed via Appendix N, using equation (N5). This is the same as if there were only one main system except for a weighted responsiveness.

If the fraction of the dwelling heated by main system 2, (203), is greater than the rest of house area, 1 - (91), calculate the MIT for the rest of the dwelling for the heating control specified for main system 2. Otherwise calculate the MIT for the rest of the dwelling twice, once for the heating control specified for main system 1 and once for the heating control specified for main system 2; this includes a different heating duration, where applicable, for systems assessed via Appendix N. Obtain the average of these two temperatures with weighting factors

(203) / [1 - (91)] for the temperature calculated for the controls on main system 2;

[1 - (203) - (91)] / [1 - (91)] for the temperature calculated for the controls on main system 1;

and use that average as  $T_2$  for the calculation of worksheet (92)<sub>m</sub>.

In the calculation of MIT for the whole dwelling, worksheet (93)<sub>m</sub>, use the temperature adjustment from Table 4e for the heating controls on each main system, weighted by the fraction of the dwelling heated by each system, i.e. by  $(1 - (203))$  for system 1 and (203) for system 2.

## Calculation of cooling requirements

**Table 10a: Utilisation factor for cooling**

<i>Symbols and units</i>	
H = heat transfer coefficient, (39) <sub>m</sub> (W/K)	
G = total gains (W), (103) <sub>m</sub> , which for cooling calculations do not include gains in Table 5a	
T <sub>i</sub> = internal temperature = 24°C	
T <sub>e</sub> = external temperature (°C), as defined in Appendix U	
TMP = Thermal Mass Parameter, (35), in kJ/m <sup>2</sup> K (= C <sub>m</sub> for building / total floor area)	
HLP = Heat Loss Parameter, (40) <sub>m</sub> , in W/m <sup>2</sup> K	
L = heat loss rate (W)	
τ = time constant (h)	
η = utilisation factor	
<i>Calculation of utilisation factor</i>	
τ =	$TMP / (3.6 \times HLP)$
a =	$1 + \tau / 15$
L =	$H (T_i - T_e)$
γ = G / L	<i>Notes: if L = 0 set γ = 10<sup>6</sup> ; to avoid instability when γ is close to 1 round γ to 8 decimal places</i>
if γ > 0 and γ ≠ 1:	$\eta = \frac{1 - \gamma^{-a}}{1 - \gamma^{-(a+1)}}$
if γ = 1:	$\eta = \frac{a}{a + 1}$
if γ ≤ 0:	η = 1

**Table 10b: Cooling requirement**

1.	Cooling requirement for continuous cooling of whole house for month in kWh, (104) <sub>m</sub> , is $0.024 \times (G_m - \eta_m L_m) \times n_m$ <i>n<sub>m</sub> is the number of days in the month</i>
2.	Multiply by the fraction of the total floor area that is cooled, f <sub>cool</sub> .
3.	Multiply by an intermittency factor, f <sub>intermittent</sub> , where f <sub>intermittent</sub> = 0.25 (based on 6 hours/day operation).
4.	The cooling requirement for the part of the dwelling that is cooled allowing for standard hours of operation is: $Q_{cool} = 0.024 \times (G_m - \eta_m L_m) \times n_m \times f_{cool} \times f_{intermittent}$ Set Q <sub>cool</sub> to zero if negative or less than 1 kWh.
5.	Divide Q <sub>cool</sub> by the System Seasonal Energy Efficiency Ratio (SEER), see Table 10c.
Include the cooling requirements for each month from June to August (disregarding September to May). The fuel cost, CO <sub>2</sub> emission factor and primary emission factor are those for electricity in Table 12. The energy for cooling is included in the FEE in all cases and in the DER, ratings and fuel costs when there is a fixed cooling system.	

**Table 10c: Seasonal Energy Efficiency Ratio (SEER)**

Energy efficiency class	SEER for fixed air conditioners (electrically driven, all types)
A+++	$\geq 8.50$
A++	$\geq 6.10$
A+	$\geq 5.60$
A	$\geq 5.10$
B	$\geq 4.60$
C	$\geq 4.10$
D	$\geq 3.60$
E	$\geq 3.10$
F	$\geq 2.60$
G	$< 2.60$
Unknown	4.30

Energy efficiency classes are defined by EU Regulation No. 626/2011, whilst minimum performance standards are defined by No. 206/2012. SAP only recognises fixed air conditioning appliances; the above SEER values are derived from Ecodesign regulation minimum requirements.

Note: If the air conditioner is reversible so as to provide space heating it should be assessed as a heat pump when in space heating mode, using either default or PCDB data. SEER data for heat pumps providing cooling may be entered in the PCDB.



**Table 11: Fraction of heat supplied by secondary heating systems**

<b>Main heating system</b>	<b>Secondary system</b>	<b>Fraction from secondary</b>
All gas, oil and solid fuel systems	all secondary systems	0.10
Micro-cogeneration	all secondary systems	see Appendix N
Heat pump, data from database	all secondary systems	0.10
Heat pump, data from Table 4a	all secondary systems	0.10
Electric storage heaters (not integrated)	all secondary systems	
- not fan-assisted		0.15
- fan-assisted		0.10
- high heat retention (as defined in 9.2.8)		0.10
Integrated storage/direct-acting electric systems	all secondary systems	0.10
Electric CPSU	all secondary systems	0.10
Electric room heaters	all secondary systems	0.20
Other electric systems	all secondary systems	0.10
Heat networks	all secondary systems	0.10

*Notes:*

1. *See also Appendix A.*
2. *If an off-peak tariff is present, see Table 12a for proportions at the high and low rates*
3. *If there are two main systems, 'main heating system' is that heating the living area*

**Table 12: Fuel prices, emission factors and primary energy factors**

Fuel	Standing charge, £ (a)	Unit price p/kWh	Emissions kg CO <sub>2e</sub> per kWh (b)	Primary energy factor	Fuel code
<b>Gas:</b>					
mains gas	87	3.94	0.210	1.122	1
bulk LPG	69	6.47	0.241	1.163	2
bottled LPG		10.46	0.241	1.163	3
LPG subject to Special Condition 18 (c)	95	4.72	0.241	1.163	9
biogas (including anaerobic digestion)	70	8.15	0.024	1.286	7
<b>Oil:</b>					
heating oil		3.76	0.298	1.188	4
biodiesel from any biomass source (d)		7.10	0.038	1.437	71
biodiesel from vegetable oil only (e)		7.10	0.018	1.042	73
appliances able to use mineral oil or biodiesel		5.06	0.298	1.188	74
B30K (f)		5.67	0.220	1.263	75
bioethanol from any biomass source		47	0.105	1.472	76
<b>Solid fuel: (g)</b>					
house coal		4.15	0.395	1.101	11
anthracite		4.24	0.395	1.101	15
manufactured smokeless fuel		5.20	0.366	1.289	12
wood logs		4.65	0.028	1.046	20
wood pellets (in bags for secondary heating)		6.09	0.053	1.325	22
wood pellets (bulk supply for main heating)		5.51	0.053	1.325	23
wood chips		3.48	0.023	1.046	21
dual fuel appliance (mineral and wood)		4.52	0.092	1.056	10
<b>Electricity: (a)</b>					
standard tariff	72	16.55	0.233	1.738	30
7-hour tariff (high rate) (h)	8	19.47	0.233	1.738	32
7-hour tariff (low rate) (h)		7.60	0.233	1.738	31
10-hour tariff (high rate) (h)	7	17.98	0.233	1.738	34
10-hour tariff (low rate) (h)		10.27	0.233	1.738	33
18-hour tariff (high rate) (h)	11	15.04	0.233	1.738	38
18-hour tariff (low rate) (h)		10.2	0.233	1.738	40
24-hour heating tariff	31	9.83	0.233	1.738	35
electricity sold to grid		0 (i)	0.233	1.738	36
electricity displaced from grid			0.233	1.738	37
electricity exported to grid		3.8	0.233	1.738	37
electricity, any tariff (i)		-	0.233	1.738	39
<b>Heat networks: (k)</b>					
heat from boilers – mains gas	87 (l)	4.8	0.210	1.122	51
heat from boilers – LPG		4.8	0.241	1.163	52
heat from boilers – oil		4.8	0.335(m)	1.188	53
heat from boilers that can use mineral oil or biodiesel		4.8	0.335	1.188	56
heat from boilers using biodiesel from any biomass source		4.8	0.038	1.437	57
heat from boilers using biodiesel from vegetable oil only		4.8	0.018	1.042	58
heat from boilers – B30D (f)		4.8	0.269	1.264	55
heat from boilers – coal		4.8	0.375(n)	1.101	54
heat from electric heat pump		4.8	0.233	1.738	41
heat from boilers – waste combustion		4.8	0.074	1.169	42
heat from boilers – biomass		4.8	0.029(o)	1.037	43
heat from boilers – biogas (landfill or sewage gas)		4.8	0.024	1.286	44
waste heat from power station		3.36	0.026(p)	0.809	45
geothermal heat source		3.36	0.018	0.782	46
heat from CHP		3.36	as above(q)	as above(q)	48
electricity generated by CHP			0.233	1.738	49
electricity for pumping in distribution network			0.233	1.738	50

Energy Cost Deflator (i) = 0.37

Notes to Table 12:

- (a) *The standing charge given for electric off-peak tariffs is extra amount, over and above the amount for the standard domestic tariff.*  
*For calculations including regulated energy uses only (e.g. regulation compliance, energy ratings):*
- *The standing charge for electricity standard tariff is omitted;*
  - *The standing charge for off-peak electricity is added to space and water heating costs where either main heating or hot water uses off-peak electricity;*
  - *The standing charge for gas is added to space and water heating costs where the gas is used for space heating (main or secondary) or for water heating.*
- For calculations inclusive of unregulated energy uses (e.g. occupancy assessment):*
- *The standing charge for electricity standard tariff is included in all cases;*
  - *The standing charge for off-peak electricity is included in addition if an off-peak tariff applies;*
  - *The standing charge for gas is included where the gas is used for any calculated energy use.*
- The unit price used for 'electricity exported to grid' is the 2018 wholesale electricity price taken from Annex M of 'Projections of greenhouse gas emissions and energy demand from 2016 to 2035'. (It is not based on the export rate used for the Feed in Tariff.)*
- (b) *These are CO<sub>2</sub> equivalent figures which include the global warming impact of CH<sub>4</sub> and N<sub>2</sub>O as well as CO<sub>2</sub>. Figures for specific heat networks may be included in the Product Characteristics Database.*
- (c) [www.ofgem.gov.uk/networks/gasdistrotherwork/Documents1/7940-Independentnetworksopenletter.pdf](http://www.ofgem.gov.uk/networks/gasdistrotherwork/Documents1/7940-Independentnetworksopenletter.pdf)
- (d) *For appliances that specifically use biodiesel wholly derived from any biomass sources*
- (e) *For appliances that specifically use biodiesel wholly derived from vegetable sources*
- (f) *For appliances that specifically use a blend of 30% biodiesel from cooking oil and 70% kerosene (B30K) or 70% gas oil (B30D)*
- (g) *The specific fuel should be assumed for those appliances that can only burn the particular fuel (including Exempted Appliances within Smoke Control Areas).*  
*Where a main heating appliance is classed as dual fuel (i.e mineral and wood), the data for dual fuel should be used, except where the dwelling is in a Smoke Control Area, when the data for solid mineral fuel should be used.*  
*Wood should be specified as fuel for a main heating system only if there is adequate provision (at least 1.5 m<sup>3</sup>) for storage of the fuel.*  
*Outside Smoke Control Areas an open fire should be considered as dual fuel, and a closed room heater without boiler if capable of burning wood as burning wood logs.*
- (h) *With certain appliances using an off-peak tariff, some of the consumption is at the low rate and some at the high rate. The high-rate fractions to be used are given in Table 12a, the remainder being provided at the low rate.*
- (i) *Deducted from costs, emissions or primary energy*
- (j) *This code is used to define the fuel for any electric system. Other codes for electricity are to provide cost data, depending on the applicable electricity tariff.*
- (k) *Cost is per unit of heat supplied, emission and primary factors are per unit of fuel used*
- (l) *Include half this value if only DHW is provided by a heat network*
- (m) *Based on the mix of petroleum products used to generate heat in the UK (predominantly diesel).*
- (n) *Value for non-domestic coal*
- (o) *Based on the mix of biomass sources used to generate heat in the UK.*
- (p) *Takes account of the reduction in electricity generation that occurs where heat is produced at a high enough temperature to supply a heat network.*
- (q) *Use factor for heat network with boilers according to fuel used.*
- (r) *An energy cost deflator term is applied before the rating is calculated. It will vary with the weighted average price of heating fuels in future so that the SAP rating is not affected by the general rate of fuel price inflation. However, individual SAP ratings are affected by relative changes in the price of particular heating fuels.*

The emissions factors are “CO<sub>2</sub> equivalent” values, which include CH<sub>4</sub> and N<sub>2</sub>O in addition to CO<sub>2</sub>

The emission factors and primary energy factors for electricity in Table 12 are a 3-year projection for 2018-2020.

**Table 12a: High-rate fractions for systems using 7-hour and 10-hour tariffs for systems that provide both space and water heating**

This table is used for electric space and water heating systems which take electricity at both high and the low rates. Use an electricity price weighted between the high-rate and low-rate unit price using the fraction from the table. If there are two main systems, 'system' is that heating the living area. Secondary heating with fraction according to Table 11 is applied as well.

System	Tariff	Fraction at high rate	
		Space heating	Water heating
Integrated (storage+direct-acting) systems (applies to storage heaters 408 and underfloor heating 422 and 423)	7-hour	0.20	-
Other storage heaters	7-hour or 24-hour	0.00	-
Electric dry core or water storage boiler	7-hour	0.00	-
Electricaire	7-hour	0.00	-
Direct-acting electric boiler <sup>(a)</sup>	7-hour	0.90	-
	10-hour	0.50	-
Electric CPSU	10-hour	Fraction from Appendix F	Fraction from Appendix F
Underfloor heating (in screed above insulation, in timber floor or immediately below floor covering)	7-hour	0.90	-
	10-hour	0.50	-
Ground/water source heat pump: calculated by Appendix N	7-hour or 10-hour	0.80	0.70
otherwise:			
space heating	7-hour	0.70	-
do.	10-hour	0.60	-
water heating with off-peak immersion	7-hour or 10-hour	-	0.17
water heating without immersion heater	7-hour or 10-hour	-	0.70
Air source heat pump: calculated by Appendix N	7-hour or 10-hour	0.80	0.70
otherwise			
space heating	7-hour	0.90	-
do.	10-hour	0.60	-
water heating with off-peak immersion	7-hour or 10-hour	-	0.17
water heating without immersion heater	7-hour or 10-hour	-	0.70
Other direct-acting electric heating (including electric secondary heating)	7-hour	1.00	-
	10-hour	0.50	-
Immersion water heater	7-hour or 10-hour	-	Fraction from Table 13
Heat pump serving DHW-only			

*Note*

(a) An electric boiler can provide space heating only, with a separate cylinder and immersion heater for DHW, or the DHW cylinder can be within the boiler casing. The calculation is the same for both cases.

Other electricity uses	Tariff	Fraction at high rate
Fans for mechanical ventilation systems	7-hour	0.71
	10-hour	0.58
All other uses, and locally generated electricity	7-hour	0.90
	10-hour	0.80

**Table 12b: Solid Fuels**

The table shows the fuels that can normally be used on the different types of solid fuel appliance. It should be regarded as only indicative: it is always necessary to follow the appliance manufacturer's instructions. See also section 12.4.5 and note (g) to Table 12 as regards fuel selection for SAP calculations.

<b>Appliance</b>	<b>Possible fuels</b>	
	<b>Within Smoke Control Area</b>	<b>Outside Smoke Control Area</b>
Auto (gravity) feed boiler	Anthracite grains and beans	Anthracite grains and beans
Manual feed boiler	Anthracite nuts Authorised Smokeless	Anthracite nuts Smokeless Wood logs
Wood chip boiler	Wood chips if Exempted Appliance	Wood chips
Wood pellet boiler	Wood pellets if Exempted Appliance	Wood pellets
Open fire (with or without back boiler)	Authorised Smokeless	House coal Smokeless Wood logs
Closed room heater (with or without boiler)	Anthracite nuts Authorised Smokeless Wood logs if Exempted Appliance	House coal Anthracite nuts Smokeless Wood logs
Pellet-fired stove	Wood pellets if Exempted Appliance	Wood pellets
Range cooker boiler	Anthracite	Anthracite Wood logs

**Table 12c: Distribution loss factor for heat networks**

For heat networks that have applied for entry in the PCDB, a Distribution Loss Factor is calculated and recorded for use in SAP assessments. Heat generator efficiency, and for Combined Heat and Power units, the electrical generation efficiency and heat fraction is also recorded. These values should always be used.

Where a PCDB data record is unavailable, Table 12c provides Distribution Loss Factors by dwelling age for RdSAP assessments, which is taken to relate to dwelling heat load and therefore implied network heat density. Default values for new buildings are also provided for reference, though these are subject to review and are therefore recorded in the PCDB for use by SAP software.

<b>Age Band</b>	<b>Year range</b>	<b>Distribution Loss Factor</b>
A	Pre 1900	1.2
B	1900-1929	1.26
C	1930-1949	1.33
D	1950-1966	1.37
E	1967-1975	1.41
F	1976-1982	1.43
G	1983-1990	1.45
H	1991-1995	1.46
I	1996-2002	1.48
J	2003-2006	1.49
K	2007 onwards	1.5
New dwelling connected to heat network not designed and commissioned in accordance with <i>"Heat Networks: Code of Practice for the UK"</i>		2.0
New dwelling connected to heat network designed and commissioned in accordance with <i>"Heat Networks: Code of Practice for the UK"</i>		1.5

**Table 13: High-rate fraction for electric DHW heating**

Dwelling total floor area, m <sup>2</sup>	Cylinder size, litres										
	7-hour tariff						10-hour tariff				
	110		160		210	245	110		160		210
	Immersion (dual/single)						Immersion (dual/single)				
	dual	single	dual	single	dual	dual	dual	single	dual	single	dual
20	0.11	0.55	0.06	0.16	0.01	0	0.05	0.14	0	0	0
40	0.12	0.56	0.07	0.18	0.02	0	0.06	0.16	0	0	0
60	0.15	0.58	0.09	0.21	0.03	0	0.08	0.19	0	0	0
80	0.17	0.60	0.10	0.24	0.04	0	0.09	0.21	0	0	0
100	0.18	0.61	0.11	0.25	0.04	0	0.10	0.23	0	0	0
120	0.18	0.61	0.11	0.26	0.04	0	0.11	0.23	0	0	0
140	0.18	0.61	0.11	0.26	0.04	0	0.11	0.24	0	0	0
160	0.19	0.61	0.12	0.26	0.04	0	0.11	0.24	0	0.01	0
180	0.19	0.61	0.12	0.26	0.05	0	0.11	0.24	0	0.01	0
200	0.19	0.61	0.12	0.27	0.05	0	0.11	0.24	0	0.01	0
220	0.19	0.61	0.12	0.27	0.05	0	0.11	0.24	0	0.01	0
240	0.19	0.61	0.12	0.27	0.05	0	0.11	0.24	0	0.01	0
260	0.19	0.62	0.12	0.27	0.05	0	0.11	0.25	0	0.02	0
more than 260	use formulae below										

**Notes:**

- 1) Table 13 shows fractions of electricity required at the high rate for cylinders with dual and single immersion heaters, for tariffs providing at least 7 hours of heating per day at the low rate and for tariffs providing at least 10 hours of heating per day at the low rate. This table should also be used for heat pumps providing water heating only (treating as though dual immersion).
- 2) Alternatively, the fraction may be calculated from the following equations:  
tariffs providing at least 7 hours of heating per day at the low rate  
Dual immersion:  $[(6.8 - 0.024V)N + 14 - 0.07V]/100$   
Single immersion:  $[(14530 - 762N)/V - 80 + 10N]/100$   
  
tariffs providing at least 10 hours of heating per day at the low rate  
Dual immersion:  $[(6.8 - 0.036V)N + 14 - 0.105V]/100$   
Single immersion:  $[(14530 - 762N)/(1.5V) - 80 + 10N]/100$   
  
where  $V$  is the cylinder volume (excluding any dedicated solar volume in the case of a combined cylinder) and  $N$  is as defined in Table 1b. (If these formulae give a value less than zero, set the high-rate fraction to zero; if greater than one, set to one.)
- 3) Do not use this table to obtain the high-rate fraction for an electric CPSU. Calculate the high-rate fraction using the procedure described in Appendix F.
- 4) Do not use this table for the high-rate fraction for domestic hot water heated by heat pumps providing both space and water heating; in such case use the high-rate fraction given in Table 12a.

**Table 14: Rating bands**

The rating is assigned to a rating band according to the following table. It applies to both the SAP rating and the Environmental Impact rating.

<b>Rating</b>	<b>Band</b>
1 to 20	G
21 to 38	F
39 to 54	E
55 to 68	D
69 to 80	C
81 to 91	B
92 or more	A