

**SAP 2005**

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

**2005 edition**

This document describes SAP 2005 version 9.80, dated October 2005. SAP assessors and other users should ensure that they are using the latest version of the document. Information on this and any updates will be published on the BRE website below.

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## SAP Worksheet (version 9.80)

### Tables

## SUMMARY

This manual describes the Government's Standard Assessment Procedure (SAP) for assessing the energy performance of dwellings. The indicators of the energy performance are energy consumption per unit floor area, an energy cost rating (the SAP rating), an Environmental Impact rating (based on CO<sub>2</sub> emissions) and a 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 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 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 Energy Performance of Buildings Directive. The calculation should be carried out using a computer program that implements the worksheet and is approved for SAP calculations (BRE approves SAP software on behalf of the Department

for Environment, Food and Rural Affairs; the Office of the Deputy Prime Minister; the Scottish Executive; the National Assembly for Wales; and the Department of Finance and Personnel).

## **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
- 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
- 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.

Ratings are not affected by the geographical location, so that a given dwelling has the same rating in all parts of the UK.

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 European standards BS EN 832 and BS EN ISO 13790.

The Standard Assessment Procedure was first published by the DOE (now the Department for Environment, Food and Rural Affairs, DEFRA) 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. A consolidated edition was published as SAP 1998, and a revised version was published in 2001 (SAP 2001).

The present edition is SAP 2005 in which:

- The SAP scale has been revised to 1 to 100, where 100 now represents zero energy cost. It can be above 100 for dwellings that are net exporters.
- The dwelling CO<sub>2</sub> Emission Rate (DER) together with an Environmental Impact rating replace the Carbon Index.
- Energy for lighting is included.
- Solar water heating has been revised.
- Cylinder loss has been revised; manufacturer's data for heat loss becomes the preferred source of cylinder loss.
- The effect of thermal bridging is taken into the account.
- It incorporates additional renewable and energy saving technologies.
- It provides a method for estimating a tendency to high internal temperature in summer;
- Data tables have been updated (e.g. fuel costs, CO<sub>2</sub> emissions, boiler efficiency and heating controls, etc).
- The measure of energy is now kWh rather than GJ.

## **SCOPE OF THE SAP PROCEDURE**

The procedure is applicable to self-contained dwellings of total floor area (as defined in Section 1, Dwelling Dimensions) not exceeding 450 m<sup>2</sup>.

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

*Note: Dwellings of floor area greater than 450 m<sup>2</sup>, common areas of blocks of flats such as 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, where 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.

## GENERAL PRINCIPLES

### Input precision and rounding

Data should be entered 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 built context.

#### U-values – walls, floors, roofs

For new build, U-values should have been calculated on the basis of the actual construction.

#### Admittances

A list of admittance values is provided in Appendix P, which are suitable for most cases. However, other values can be used if appropriate.

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

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 – 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. (Only the values in Table 6b are to be used for light transmittance.).

Normally the frame factors in Table 6c are used. However, manufacturer's values are permitted provided they are representative of the actual windows.

#### Boiler efficiency – gas and oil

Boiler efficiency can be from the SEDBUK database (preferably) or from a manufacturer's declaration given in the terms stated in D3.

#### Boiler efficiency – solid fuel

Boiler efficiency can be from the boiler efficiency database (preferably) or from a manufacturer's declaration.

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\* Operated by the British Fenestration Rating Council

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

Efficiency can be from a manufacturer's declaration given in terms of E2 (gas and oil) or terms to be published separately (solid fuel).

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

The manufacturer's declared loss obtained in terms of the applicable BS and expressed in kWh/day, can be used in place of data from Table 2. (Tables 2a and 2b are applied to declared loss as well as to loss from Table 2).

#### Pressure test result

The result of a pressure test can be used instead of the default calculations of 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 linear heat loss coefficient can be used if obtained from test results.

#### Specific fan power

Specific fan power for these mechanical ventilation systems:

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

can be used in place of the default values in Table 4g, subject to conditions for acceptance of manufacturer's values of specific fan power that are issued in terms of Q2 in Appendix Q.

#### **Existing properties**

The SAP calculation procedure for existing properties follows that for new dwellings. However, some of the data items are usually defaulted or inferred. For further details see Appendix S.

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 room fraction 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, using linear interpolation where appropriate, by reference to Tables 1 to 15 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 the floor area.

**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, or the lowest floor of a dwelling with more than one storey, the measurement should be from floor surface to ceiling surface.

**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 entered. 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 they are heated by fixed heating devices;
- *should be included* if there is direct access into the dwelling but no separating door, whether heated or not;
- *should not be included* if they are unheated and there is a separating door into the dwelling. In this context ‘porch’ means an addition protruding from the line of the external wall of the dwelling; an entrance lobby that is within such line *should be included*.

**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* only if consisting of heated and habitable rooms.

**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 they are habitable rooms, accessed by a fixed staircase.
- roof spaces (even though within the insulated envelope, i.e. where the roof insulation is provided at rafter level) *should not be included* unless they are habitable rooms accessed by a fixed staircase.

When porches or 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 calculated accordingly (see section 3.3).

In flats, if corridors and stairwells are heated, treat walls between the flat and heated corridors/stairwells as non-heat loss walls (i.e. assuming the same temperature on either side of the walls).

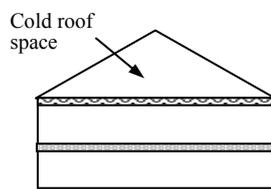
No special treatment should be given in cases where a central heating boiler is located in an unheated garage (i.e. the floor area used for the assessment should be the same as if the boiler were in the kitchen or a utility room).

**Pitched roofs**

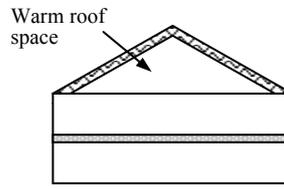
There are three main types of pitched roof construction:

1. pitched roof with insulation at ceiling level, insulated between (and perhaps also above) joists;

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;
3. pitched roof insulated either at ceiling level or at rafter level, with roof space converted into habitable space.

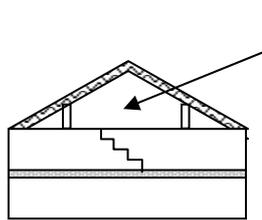


a) Insulation at ceiling level



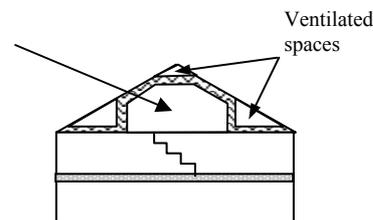
b) Insulation at rafter level

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



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

Room in roof



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 entered 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 pressurisation test or, in the absence of pressure test, using the SAP ventilation algorithm.

Whether or not a pressurisation test has been carried out, the ventilation algorithm requires the 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 boxes (7) to (9a) 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           | 40                                    |
| Open flue         | 20                                    |
| Fan               | 10                                    |
| Passive vent      | 10                                    |
| Flueless gas fire | 40                                    |

## 2.1 Chimneys and flues

Ventilation rates for chimneys and flues should be entered only when they are unrestricted and suitable for use.

For the purposes of the 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. The following are also counted as flues:

- a chimney for solid fuel appliances with controlled flow of the air supply;
- a flexible flue liner sealed into a chimney;
- a chimney fitted with a damper;
- a chimney fitted with an open-flue gas fire where the flue products outlet is sealed to the chimney;
- a blocked up fireplace fitted with ventilators (if ventilator area does not exceed 30 000 mm<sup>2</sup>)

Ventilation rates should be entered only for open flues; they should not be included for room-sealed boilers or room heaters. Ventilation rates for specific closed appliances may be introduced (see Appendix Q).

## 2.2 Fans and passive vents

**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, but those that form part of a whole-dwelling mechanical ventilation system are treated separately (see section 2.6) and are not included here.

**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 entered into the worksheet.

**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 boxes (11) to (18) 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).

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\* In the case of a new dwelling, subject to the requirements of building regulations that apply in the administration where the dwelling will be constructed, a design value or a specified value of air permeability can be used for the calculation.

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

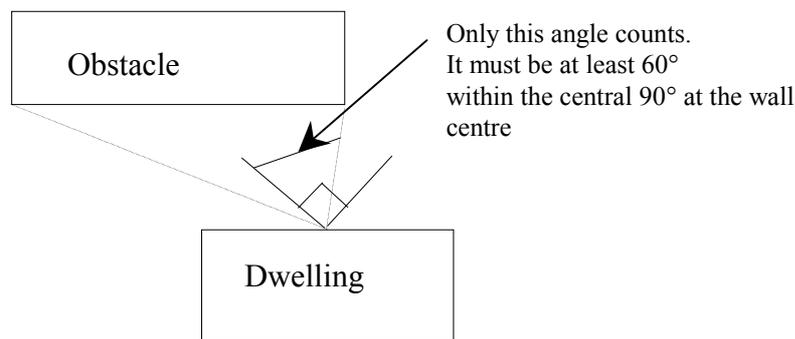


Figure 1 Shelter angle

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).

Any party wall should be counted as a sheltered side.

For new dwellings it will often be appropriate to assume that two sides of the dwelling are sheltered.

## 2.6 Mechanical ventilation

**Balanced whole house mechanical ventilation** is a fan driven ventilation system, which provides fresh air to the rooms in the dwelling and also extracts exhaust air from the dwelling. The system may or may not be fitted with a heat recovery unit. The SAP calculation is based on a throughput of 0.5 air changes per hour through the mechanical system, plus infiltration.

For buildings with heat recovery from exhaust to inlet air, the heat loss by mechanical ventilation is reduced by the factor  $\eta_v$  where  $\eta_v = 0.66$  is the efficiency of heat recovery system.

**Positive input ventilation** is a fan driven ventilation system, which often provides ventilation to the dwelling from the loft space. The SAP calculation procedure for systems which use the loft to pre-heat the ventilation air is the same as for natural ventilation, including  $20 \text{ m}^3/\text{h}$  ventilation rate equivalent to two extract fans or passive vents. (The energy used by the fan is taken as counterbalancing the effect of using slightly warmer air from the loft space compared with outside). Some positive input ventilation systems supply the air directly from the outside and the procedure for these systems is the same as for mechanical extract ventilation.

**Mechanical extract ventilation** refers to 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, plus infiltration.

The calculation requires information on specific fan power (SFP) of mechanical ventilation fans. Default data are provided in Table 4g. Alternatively values based on tests may be used subject to conditions for

acceptance of manufacturer's values of specific fan power that are issued in terms of Q2 in Appendix Q. SFP should account for any transformers.

### 3 HEAT LOSSES

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. Losses or gains through party walls to spaces in other dwellings or premises that are normally expected to be heated are assumed to be zero.

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 12524 or the CIBSE Guide Section A3<sup>[6]</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 or in the Approved Document 'Basements for dwellings'<sup>[7]</sup>.

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, 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.

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

$$U_{w,\text{effective}} = \frac{1}{\frac{1}{U_w} + 0.04}$$

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

For the purposes of the SAP, rooflights are treated as roof windows.

### 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).

$$U = \frac{1}{\frac{1}{U_o} + R_u}$$

where:  $U$  = resultant U-value of element adjacent to unheated space,  $W/m^2K$ ;  
 $U_o$  = U-value of the element between heated and unheated spaces calculated as if there were no unheated space adjacent to the element,  $W/m^2K$ ;  
 $R_u$  = effective thermal resistance of unheated space from the appropriate table below.

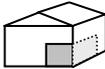
$R_u$  for typical unheated structures (including garages, access corridors to flats and rooms in roof) with typical U-values of their elements are given below. These can be used when the precise details on the structure providing an unheated space are not available, or not crucial.

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 the dwelling). 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.

**Table 3.1  $R_u$  for integral single garages** (single garage is a garage for one car)

| 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        | 0.68                      | 0.33                 |
| Single fully integral                         | One wall and floor                   | 0.54                      | 0.25                 |
| Single, partially integral displaced forward  | Side wall, end wall and floor        | 0.56                      | 0.26                 |

**Table 3.2  $R_u$  for integral double garages** (double garage is a garage for two cars)

| 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                         | 0.59                      | 0.28                 |
| Double, half integral                        | Side wall, halves of the garage end wall and floor    | 0.34                      | n/a                  |
| Double, partially integral displaced forward | Part of the garage side wall, end wall and some floor | 0.28                      | n/a                  |

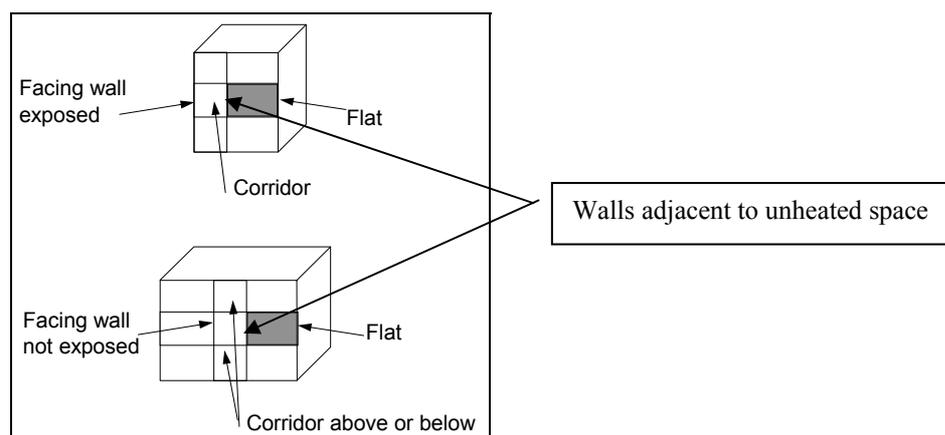
<sup>1</sup>inside garage – when the insulated envelope of the dwelling goes round the outside of the garage

<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 they are not included in the calculation. 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                               |                                  | 0.82  |
| Facing wall not exposed                           |                                  | 0.90  |
| Access corridors:                                 |                                  |       |
| Facing wall exposed, corridors above and below    | facing wall, floor and ceiling   | 0.28  |
| Facing wall exposed, corridor above or below      | facing wall, floor or ceiling    | 0.31  |
| Facing wall not exposed, corridor above and below | floor and ceiling                | 0.40  |
| Facing wall not exposed, corridor above or below  | floor or ceiling                 | 0.43  |

### 3.3.3 Conservatories

A conservatory is usually defined in building regulations as an extension attached to a dwelling which has not less than three-quarters of the area of its roof and one half of the area of its external walls made of translucent material. 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-stripping 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).

### 3.3.5 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.

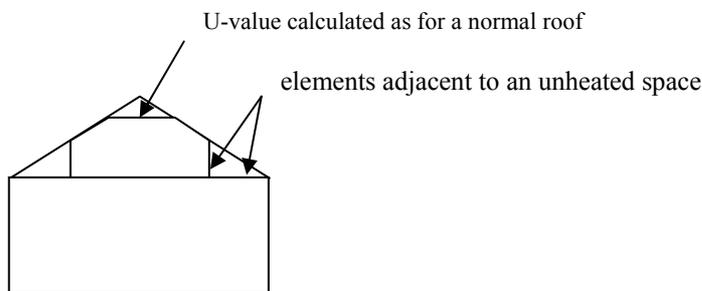


Figure 3.2 Room in roof

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 | $R_u$ for elements |
|---|--|--------------------|
| Room in roof built into a pitched roof insulated at ceiling level | insulated wall of room in roof                   | 0.50               |
|   | or insulated ceiling of room below               | 0.50               |

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

In other cases  $R_u$  should be calculated using the following formula

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

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

### 3.4 Thermal bridging

The SAP calculation now 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.

Usually, however, specific values for thermal bridges are not known, and the calculation can be done by including an allowance based on the total exposed surface area. Further details are in Appendix K.

### 3.5 Dwellings that are part of larger premises

In the case of a dwelling that is part of a larger building 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:

- a) to have zero heat loss if the spaces adjacent to the dwelling are normally heated to similar levels as a dwelling, or
- b) as heat loss elements to an unheated space if the spaces are unheated, heated only intermittently or heated only to a low level.

## 4 DOMESTIC HOT WATER

The demand for hot water is derived from the floor area of the dwelling and is given in Table 1. The energy required to produce that amount of hot water is then calculated, taking account of losses in heating, storage and distribution. Heat to the dwelling from storage cylinders and distribution pipe work is also estimated ['heat gains from water heating', box (52)] so that it can be taken into account in the calculation of space heating requirements.

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 cylinder, tank or thermal store. '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.

Stored hot water systems can either be served by an electric immersion heater or obtain heat from a boiler or a heat pump through a primary circuit. In both cases, water storage 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);
- community heating schemes.

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

For cylinders the preferred way of establishing cylinder losses is from measured data on the cylinder concerned, according to BS 1566.

For thermal stores and CPSUs (including electric CPSUs) the preferred way of establishing heat losses is from measured data on the thermal store or CPSU concerned, according to the WMA Performance Specification for thermal stores.

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 Boiler 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 combi boilers the additional losses in Table 3a are included to allow for the draw-off of water until an adequate temperature at the taps is attained. The data in Table 3a are provisional pending the availability of test results according to the standards to be written under EU Mandate 324.

The efficiency for both space and water heating is reduced by 5% if the boiler is not interlocked for both space and water heating (see section 9.3.9).

For community heating, if there is a hot water cylinder within the dwelling, its size and the appropriate loss factors should be used. If there is not a hot water cylinder within the dwelling the calculation should assume a cylinder of 110 litres and loss factor of 2.2 kWh/litre/year. The efficiency for water heating is incorporated in the price of heat for community schemes in Table 12, and 100% (adjusted where appropriate by the amount in the "efficiency adjustment" column of Table 4c) is used in box (86) in these cases.

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.

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) heat pump systems where an immersion is provided to operate in conjunction with the heat pump as described in Appendix G, and (b) solid fuel room heaters with a back boiler where an immersion heater is provided to heat water in the summer (see section 10.3.3).

## **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). The internal gains are obtained by interpolating the data in Table 5 or by using the formula provided after Table 5. A reduction in gains is applied for low-energy lights, as calculated in Appendix L.

Gains from central heating pumps located within the heated space and other items should be added and then entered in box (53b), 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

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

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 a surface from Table 6a, 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) (see Table 6c)

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

In the case of a window certified by the British Fenestration Rating Council (BFRC), see [www.bfrc.org](http://www.bfrc.org), 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

$$G_{\text{solar}} = A_w \times S \times g_{\text{window}} \times Z$$

Solar gains should be calculated separately for each orientation and for rooflights, 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 the following definitions apply:

| Category | Description | Glazing area | Solar gain included |
|----------|-------------|--------------|---------------------|
| 1        | Solid door  | < 30 %       | No                  |
| 2        | Glazed door | 30% - 60%    | No                  |
| 3        | Window      | > 60 %       | Yes                 |

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 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 boxes (56) - (64), to obtain the entry for box (65).

## 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 from Table 7.

\* 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.

## 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 is based on the heating requirements 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 of the living area is obtained from Table 8, using the 'Heat loss parameter' (HLP), obtained from box (38) in the worksheet, and the type of heating system, obtained from the 'Heating type' column of Table 4a or 4d. The temperature is adjusted to take account of the level of heat gains previously calculated in sections 5 and 6 of the worksheet and also for certain control options as indicated in Table 4e.

The temperature difference between the living area and the rest of the dwelling is obtained from Table 9, using the HLP and the 'Control' column of Table 4e.

### 7.1 Living area fraction

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 DEGREE-DAYS

The degree-days depend on the 'base' temperature, which is calculated by adjusting the mean internal temperature to take account of the heat provided by gains. Degree-days for different base temperatures are obtained from Table 10, using linear interpolation for intermediate values.

## 9 SPACE HEATING REQUIREMENTS

The 'useful' energy required from the heating system is calculated from degree-days and specific heat loss. The quantity of fuel or electric energy required to meet that demand is then calculated, taking account of the efficiency of the space heating system (obtained from Boiler Database or from 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 (at standard tariff).

For community heating schemes and combined heat and power, see Appendix C. A heating system supplying more than one dwelling should be regarded as a community scheme. This includes schemes for blocks of flats as well as more extended district schemes.

For an electric CPSU, see Appendix F.

For heat pumps, see Appendix G.

### 9.2 Heating system efficiency

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

Boiler efficiency may be obtained from:

- a) The Government's Boiler Efficiency Database;
- b) Certified manufacturer's data;
- c) Table 4b of this document.

The preferred source of boiler efficiency is the Government's Boiler Efficiency Database, which contains boiler efficiency figures intended for use in SAP. If a new boiler is not included in the database, manufacturer's data certified as explained in paragraph D3 (Appendix D) should be used if available. If there is no entry in the database and certified manufacturer's data is not available an indicative seasonal efficiency should be taken from Table 4b.

In the Boiler Efficiency Database, boilers that are currently in production are normally shown with SAP seasonal efficiency calculated from test results by the SEDBUK method. SEDBUK stands for Seasonal Efficiency of Domestic Boilers in the UK. Most other (old/obsolete) boilers have estimated values from SAP Table 4b. The database may be viewed on Internet website [www.boilers.org.uk](http://www.boilers.org.uk) and may also be downloaded to suitable SAP calculation programs. It is updated at the start of every month. SAP calculations should always use the most up to date version of the database.

### 9.2.2 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 Government's Boiler Efficiency Database;
- b) Certified manufacturer's data;
- c) Table 4b of this document.

For twin burner models the preferred source of efficiency is from the database, which contains the boiler seasonal efficiency figure and case heat emission figure intended for use in SAP. If a new range cooker boiler is not included in the database, manufacturer's data certified as explained in paragraph D6 (Appendix D) may be used. If there is no entry in the database or certified manufacturer's data is not available or it is not of the twin burner type, an indicative seasonal efficiency should be taken from Table 4b.

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

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

Boiler efficiency may be obtained from:

- a) The Government's Boiler Efficiency Database;
- b) Certified manufacturer's data;
- c) Table 4a of this document.

The preferred source of boiler efficiency is the Government's Boiler Efficiency Database. If a new boiler is not included in the database, manufacturer's certified data should be used if available. Appendix J defines how the efficiency for calculations is determined from test data. If there is no entry in the database and certified manufacturer's data is not available 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 roomheaters 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 property being modelled. These systems are assigned a lower responsiveness to allow for limitations on the controllability of heat output to the room.

#### **9.2.4 Room heaters**

Where available, manufacturer's declared values should be used for the efficiency of gas or oil 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 1 of BS 7977-1:2002.

##### 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).

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).

#### **9.2.5 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 Heating controls**

The type of controls incorporated into the heating system influences the SAP rating. This section gives specifications of the types of controls mentioned in Table 4e.

#### **9.3.1 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.

#### **9.3.2 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.

### **9.3.3 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.

### **9.3.4 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.

### **9.3.5 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.

### **9.3.6 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.

### **9.3.7 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.

### **9.3.8 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.

### **9.3.9 Boiler interlock**

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 4e 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 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 in the SAP 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 may 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 must therefore be considered as having no interlock.

A boiler system with no room thermostat - even if there is a cylinder thermostat - must be considered as having no interlock.

For solid fuel boilers and dry core 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, except where the system has "No thermostatic control", for which the efficiency reduction of 5% is made to the space and water heating efficiencies.

Note: TRVs alone do not perform the boiler interlock function and require the addition of a separate room thermostat in one room.

### **9.3.10 Bypass**

A fixed bypass is an arrangement of pipes that ensures a minimum flow rate is maintained through the boiler. This is achieved either by ensuring that one radiator stays open or by adding a short pipe with a valve between the flow and return pipe. A radiator without a TRV or hand valve is a common form of fixed bypass.

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

### **9.3.11 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, and if present, weather compensation or load compensation.

### **9.3.12 Time and temperature zone controls**

In order for a system to be specified with time and temperature zone control, it must be possible to program the *heating times* of at least two zones independently, as well as having independent temperature controls. It is not necessary for these zones to correspond exactly with the zone division that defines the living area fraction.

In the case of wet systems this involves separate plumbing circuits, either with its own programmer, or separate channels in the same programmer. (By contrast, TRVs provide only independent temperature control.)

Time and temperature zone control can be obtained for electric systems, including underfloor heating, by providing separate temperature and time controls for different rooms.

### **9.3.13 Weather 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 outside the building.

### **9.3.14 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.

### **9.3.15 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 and CELECT-type control.

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, 10.3.2).

A CELECT-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 TOTAL ENERGY USE AND FUEL COSTS**

### **10.1 Energy use**

The annual energy use is calculated for the following items:

- main space heating system;
- secondary space heating;
- domestic hot water heating;
- electricity for pumps and fans (including mechanical ventilation if present);

- electricity for lighting.

## 10.2 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 the purpose of this calculation.

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

## 10.3 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.

### 10.3.1 Gas systems

The choices 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 should use the same fuel as the main system.

### 10.3.2 Electric systems

There are three special heating tariffs available for storage type systems: 7 hour off-peak, 10-hour off-peak and 24-hour heating tariff.

7-hour off-peak is what would generally be called Economy-7 in England, Wales and Northern Ireland, or Economy White Meter in Scotland. This tariff should be selected when the off-peak availability is during a single period overnight: the actual duration can be between 7 and 8½ hours. When the main system is off-peak electricity, any systems that use electricity outside the low tariff times are charged at the on-peak rate (i.e. pumps and fans, electric secondary heating and a percentage of the water heating). Standard rate electricity should not generally be specified in dwellings making use of one of these special electricity tariffs. For proportions of electricity used at the on-peak and off-peak rates see Table 12a.

10-hour tariff off-peak provides 10 hours of off-peak electricity in 3 periods (typically 5 hours during the night, 3 hours in the afternoon and 2 hours in the evening) for space and water heating; lights, appliances etc. will use standard tariff. The 10-hour off-peak tariff is available only in certain areas.

The 24-hour tariff is for use with storage based systems where the primary and secondary heating, water heating and electricity for pump and fans 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. 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 and about 20% at on-peak times. 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 off-peak period, and is modelled by a higher system responsiveness.

A secondary system is always to be specified when the main system is electric storage heaters or off-peak electric underfloor heating.

### 10.3.3 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 the summer. In that case a fraction  $N/365$  of the annual water heating is provided by the boiler and  $1-N/365$  by the alternative system where  $N$  is the length of the heating season. For SAP 2005,  $N = 238$  days.

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).

For further information including a list of currently authorised fuels and exempted appliances see [www.uksmokecontrolareas.co.uk](http://www.uksmokecontrolareas.co.uk).

#### **10.4 Secondary fuel types**

Secondary heating systems are taken from the room heaters section of Table 4a and the fuel options will in practice be determined by the fuel used for the main heating system.

#### **10.5 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 on-peak rates). 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.

#### **10.6 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

The tariff at which this electricity is charged is the on-peak rate if the heating and/or hot water uses an off-peak tariff, otherwise it is the standard tariff. Note that the allowance in this section for fan assisted flues only applies for boilers - fan assisted flues for gas fires should not be counted. Data are given in Table 4f.

#### **10.7 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. The tariff at which electricity for lighting is charged is the on-peak rate if the heating and/or hot water uses an off-peak tariff, otherwise it is the standard tariff.

## **11 ENERGY COST RATING**

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

$$\begin{aligned} \text{if ECF} \geq 3.5, \quad \text{SAP 2005} &= 111 - 110 \times \log_{10}(\text{ECF}) & (1) \\ \text{if ECF} < 3.5, \quad \text{SAP 2005} &= 100 - 13.96 \times \text{ECF} & (2) \end{aligned}$$

where ECF = Energy cost factor, calculated in box (99) or (99\*).

SAP ratings can also be obtained by using Table 14.

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

The SAP rating scale (1-100) 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 15.

## 12 CARBON DIOXIDE EMISSIONS AND PRIMARY ENERGY

The Dwelling CO<sub>2</sub> Emission Rate (DER) is equal to the CO<sub>2</sub> emissions per unit floor area for space and water heating and lighting, less the emissions saved by energy generation technologies, expressed in kg/m<sup>2</sup>/year to two decimal places.

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 community heating without combined heat and power (CHP); or
- b) community heating with CHP and waste heat from power stations.

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

$$\text{CF} = (\text{CO}_2 \text{ emissions}) / (\text{TFA} + 45) \quad (3)$$

$$\text{if CF} \geq 28.3 \quad \text{EI rating} = 200 - 95 \times \log_{10}(\text{CF}) \quad (4)$$

$$\text{if CF} < 28.3 \quad \text{EI rating} = 100 - 1.34 \times \text{CF} \quad (5)$$

where the CO<sub>2</sub> emissions are calculated in box (112) or box (119\*) and TFA is the total floor area of the dwelling as in box (5).

The EI rating scale (1-100) 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 15.

The total primary energy can also be calculated using the primary energy factors in Table 12 in place of the CO<sub>2</sub> emission factors.

## 13 BUILDING REGULATIONS

Building regulations may refer to CO<sub>2</sub> emissions as calculated by the SAP as a method of demonstrating compliance with regulations for the conservation of fuel and power.

Any specifications for the calculations contained within applicable regulatory documents are to be applied for calculations undertaken to demonstrate compliance with regulations. The current requirements of regulations can be checked against documents available at:

|                  |  |
|------------------|--|
| England & Wales  | <a href="http://www.odpm.gov.uk">www.odpm.gov.uk</a>                                   |
| Scotland         | <a href="http://www.sbsa.gov.uk">www.sbsa.gov.uk</a>                                   |
| Northern Ireland | <a href="http://www.buildingregulationsni.gov.uk">www.buildingregulationsni.gov.uk</a> |

Appendix R gives reference values to define a notional dwelling, which may be referred to in building regulations in connection with establishing 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 and Anderson B R**, *A guide to the development of BREDEM*. BRE Information Paper IP 4/95, BRE, Garston, 1995.
4. **Anderson B R, P F Chapman, N G Cutland, C M Dickson and L D Shorrock**. *BREDEM-12 Model description*. BRE, Garston, 1996.
5. **Anderson B R**, *Energy assessment for dwellings using BREDEM worksheets*, BRE Information Paper IP 13/88, BRE, Garston, 1988.
6. **CIBSE Guide A3**, The Chartered Institution of Building Services Engineers, CIBSE, London, 1999.
7. **Basements for dwellings**. Approved Document, British Cement Association, BCA, Crowthorne, 1997. ISBN 0-7210-1508-5

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## 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 heat loss coefficient - Calculation method                                    | Heat loss rate from whole building           |
| BS EN 12524**      | Building materials and products - Hydrothermal properties - Tabulated design values   | List of thermal conductivity values          |
| 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                          |

\* under review

\*\* being subsumed into ISO 10456

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## Appendix A: Primary and secondary heating systems

### A1 General principles

**The primary** 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 categorised on the basis of generic types in Tables 4a and 4b. Occasionally there may be two central heating systems, for example two separate boilers used to heat different parts of the property. In this case the calculation should be undertaken using the system that heats the largest part of the property.

**The secondary** heating system is based upon a room heater. Secondary heating systems are taken from the room heaters section of Table 4a and the fuel options will in practice usually be determined by the fuel used for the main heating system.

A secondary heating system is to be specified if:

- a) the main system is not sufficient in itself to heat the dwelling to the level on which the SAP is based (21°C in the living area and 18°C elsewhere);
- or
- b) fixed secondary heaters are present (e.g. a gas fire or a chimney and hearth capable of supporting an open coal fire).

In case a), assume direct-acting electric heaters if no actual secondary heaters are present. A secondary system is always specified when the main system is electric storage heaters or off-peak electric underfloor heating.

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.

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.

In some cases it may not be immediately clear which of two systems present should be classified as the main system and which as the secondary. In these cases the system which is cheapest to use should be taken as the primary, and if there is still doubt, i.e. if they are both equally cheap to use, select the system that heats the living room. The other system can still be input as a secondary system but it needs to be input as a room heater. A room heater system should be chosen so that its efficiency closely reflects (but does not exceed) that of the actual system (as defined by Table 4a). The chosen room heater should also use the same fuel/tariff as the actual system.

If two types of secondary heater are present, that which heats the greater number of rooms should be specified as the secondary system (and the other secondary heaters ignored). If that condition does not resolve the choice, the system which is the cheapest to run should be specified.

### A2 Procedure for determining the heating systems

- (1) Identify the main heating system. 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.

- (2) If there is still doubt about which system should be selected as the main system, select the system that supplies useful heat to the dwelling at lowest cost (obtained by dividing fuel cost by conversion efficiency).
- (3) Use the responsiveness of the main heating system in calculating the mean internal temperature in section 7 of the SAP calculation.
- (4) Obtain the proportion of use for the secondary heating system from Table 11.
- (5) Obtain the efficiency of the secondary heating system, either from manufacturer's declaration (see Appendix E) or from Table 4a.

Calculate the space heating fuel requirements for both main and secondary heating systems as specified in section 9 of the SAP calculation.

### **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 primary and secondary heating is decided as follows.

- (1) Count the number of habitable rooms as defined in S9 in Appendix S.
- (2) If 25% or less of the habitable rooms are actually heated, and are heated by a fuel other than electricity, the (assumed) electric system is the primary and the other fuel is the secondary. 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 not exceeding 50%, the heaters in these rooms are the primary and the (assumed) electric heaters are the secondary.
- (4) If more than 50% of rooms are heated, the normal rules apply.

*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 primary heating and electricity the secondary. If there were 4 habitable rooms, and one gas fire (1 out of 4), the primary 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 (2) 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 primary system irrespective of the number of rooms heated. For this purpose, DHL is the heat loss coefficient as calculated at box (37) of the worksheet, multiplied by a design temperature difference of 20 K.

#### **A3.4 Broken heating systems**

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 primary heating system, the rules in A3.2 should be followed.

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

### B1 Boilers in the database

The boiler 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 the SEDBUK value is not available. The following notes give guidance for the categories in Table 2 and 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 D1.10 to D1.12 in 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 mainly water which is directly usable as domestic hot water.

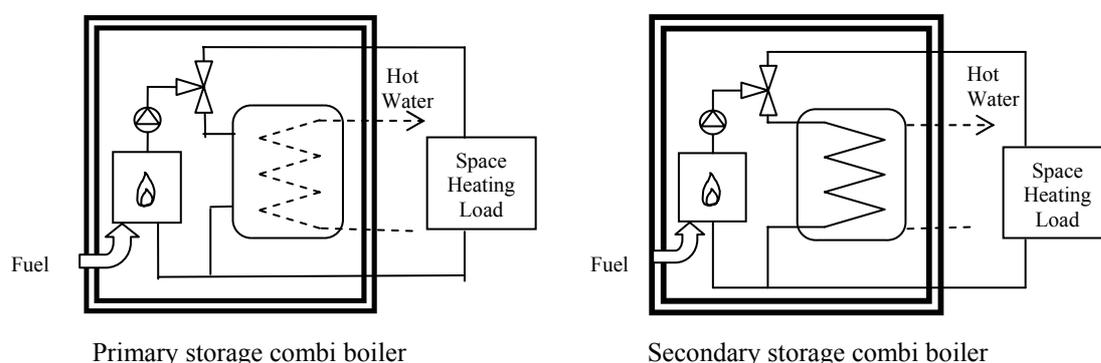


Figure B1 Primary and secondary storage combi boilers

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.

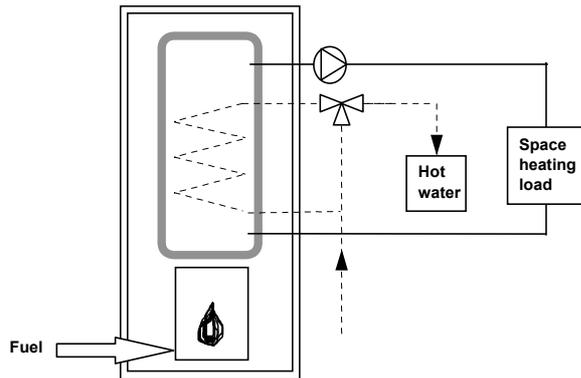
## B2.4 Boiler selected by date

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 D 1.13. 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.

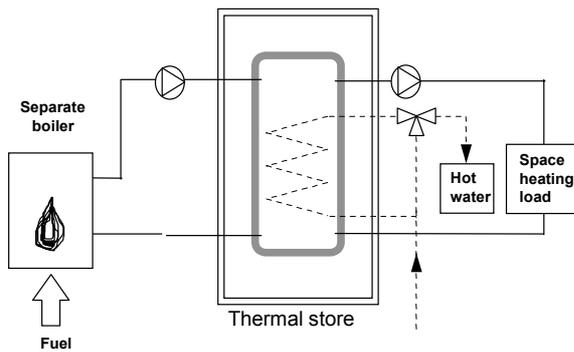
### B3.1 Integrated thermal store

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 WMA (formerly British Gas) specification for integrated thermal stores\* 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 WMA 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.

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\* **Performance specification for Thermal Stores.** Waterheater Manufacturers Association, 1999.

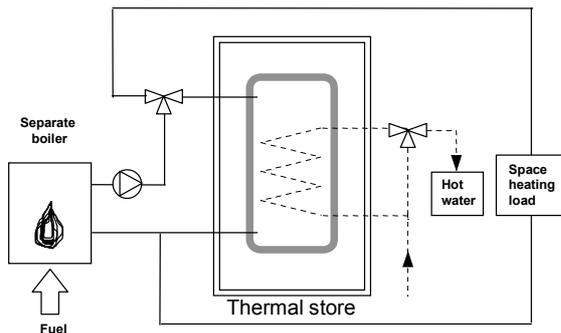


**Figure B3 Integrated thermal store**

### 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.

For an appliance to qualify as a hot water only thermal store, the WMA 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 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 heating

For the twin burner type, the efficiency can be can be from the boiler efficiency database, manufacturer's declaration or Table 4b, as explained in section 9.2.2 of this document.

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

**B4.2 Single burner ranger cooker/water heater**

This type provides a cooking function and some heating of domestic hot water. For SAP calculations all heating of domestic hot water should be based on an electric immersion heater.

**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: Community heating, including schemes with Combined Heat and Power (CHP) and schemes that recover heat from power stations.

### C1 Community heating where heat is produced by centralised unit by dedicated plant

In community schemes, also known as group or district schemes, heat produced centrally serves a number of dwellings or communal areas.

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

There are essentially two ways of producing heat for community heating by a dedicated plant:

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

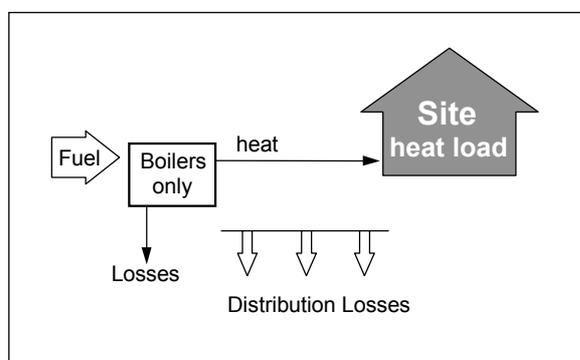


Figure C1 Community heating with heat supplied by boilers only

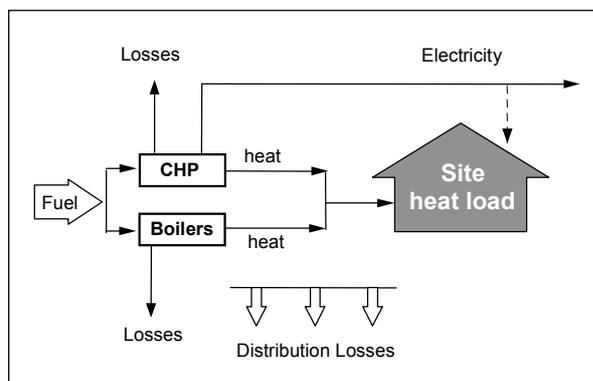


Figure C2 Community heating with heat supplied by a combination of boilers and CHP

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

The 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, should be estimated, either on the basis of operational records or in the case of a new scheme on the basis of its design specification. Heat efficiency is defined as the annual useful heat supplied from a CHP scheme divided by the total annual fuel input. The power efficiency is the total annual power output divided by the total annual fuel input.

The heat efficiency of the CHP should be based on the useful heat supplied by the CHP to the community heating, excluding any dumped heat (see Figure C3).

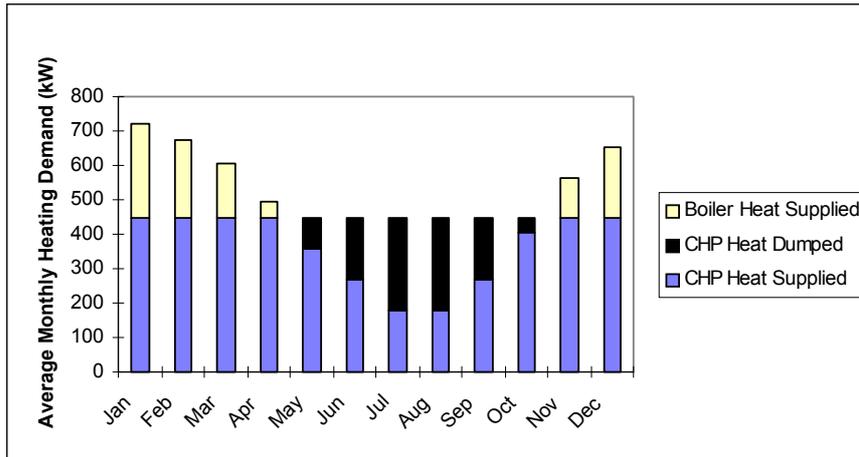


Figure C3 An example of a heat profile chart

The heat required for space and water heating is calculated using an alternative worksheet, designed for calculating SAP when space and water heating is provided by community heating (with or without CHP). The heat price for community heating is taken from Table 12. This price incorporates bulk rates for buying the fuel used in the plant, operating costs, energy used in pumping the hot water and, in the case of CHP, receipts from the sale of the electricity generated. The efficiency to be used in the calculation of the SAP rating is 100% less the adjustment given in Table 4c(3) for controls and charging method.

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

*Note: In the case of community heating with CHP, both heat and electricity are produced and the CO<sub>2</sub> emissions associated with the fuel burnt have to be apportioned to the two forms of energy. In the SAP calculation the electricity generated by CHP is taken as having a CO<sub>2</sub> emissions factor equivalent to that for electricity generated by new gas fired power stations, and the remaining CO<sub>2</sub> is assigned to the heat produced.*

## C2 Community heating schemes 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 community schemes 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 should be estimated, either on the basis of operational records or in the case of a new scheme on the basis of its design specification.

The overall efficiency of the heating plant is 100% minus the amount shown in the "efficiency adjustment" column of Table 4c.

The Dwelling CO<sub>2</sub> Emission Rate is calculated using the following procedure:

- use the worksheet for calculating community heating with CHP or schemes that recover heat from power stations;
- enter "0" in boxes from (101\*) to (106\*);
- enter "0.018" in box (107\*) and complete the calculation as normal.

*Note: 0.018 kg CO<sub>2</sub>/kWh in Table 12 reflects emissions associated with the electricity used for pumping the water from the power station to the dwelling.*

## Appendix D: Method of determining seasonal efficiency values for gas and oil boilers

*Note: The data and equations in this appendix are not to be used by SAP assessors.*

This appendix sets out, in D2 and D4, the method to be used by manufacturers to determine the Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK) for particular gas and oil boilers when test data have been obtained to establish conformity with Council Directive 92/42/EEC\*. This Directive has been implemented in the UK by the Boiler (Efficiency) Regulations\*\*.

Manufacturers' declarations of SEDBUK values so calculated should be accompanied by the form of words in D3, and SAP assessors should look for the same form of words in order to ascertain that the efficiency value referred to is appropriate for SAP calculations.

Range cooker boilers with twin burners are covered by D5 and D6.

### D1 Definitions

#### D1.1 Boiler

A gas or liquid 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 D1.3 to D1.14 inclusive. Boilers not so designed, or without the means to remove the condensate in liquid form, are called 'non-condensing'.

#### D1.3 Regular boiler

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

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

A regular boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing. This includes those with alternative burning rates set once only at time of installation, referred to as range rating.

#### D1.5 Modulating regular boiler

A regular boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.

#### 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.

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\* Council Directive 92/42/EEC on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels. Official Journal of the European Communities No L/167/17. 21 May 1992, p. 92

\*\* The Boiler (Efficiency) Regulations 1993, SI (1993) No 3083, as amended by the Boiler (Efficiency) (Amendment) Regulations 1994, SI (1994) No 3083.

**D1.8 On/off instantaneous combination boiler**

An instantaneous combination boiler that only has a single fuel burning rate for space heating. This includes appliances with alternative burning rates set once only at time of installation, referred to as range rating.

**D1.9 Modulating instantaneous combination boiler**

An instantaneous combination boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.

**D1.10 Storage combination boiler**

A combination boiler with an internal hot water store of capacity at least 15 litres but less than 70 litres, OR

a combination boiler with an internal 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. 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 (D1.13 or D1.14).

**D1.11 On/off storage combination boiler**

A storage combination boiler that only has a single fuel burning rate for space heating. This includes appliances with alternative burning rates set once only at time of installation, referred to as range rating.

**D1.12 Modulating storage combination boiler**

A storage combination boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.

**D1.13 On/off 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. The appliance does not have the capability to vary the fuel burning rate whilst maintaining continuous burner firing. This includes those with alternative burning rates set once only at time of installation, referred to as range rating.

**D1.14 Modulating 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. The appliance has the capability to vary the fuel burning rate whilst maintaining continuous burner firing.

**D1.15 Low temperature boiler**

A non-condensing boiler designed as a low temperature boiler and tested as a low temperature boiler as prescribed by the Boiler Efficiency Directive (ie; the part load test was carried out at average boiler temperature of 40°C).

**D1.16 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 the Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK)**

The method of calculation is applicable only to boilers for which the full load and the 30% part load efficiency values, obtained by the methods deemed to satisfy Council Directive 92/42/EEC, are available. These are net efficiency values. It is essential that both test results are available and that the tests are appropriate to the type of boiler as defined in Council Directive, otherwise the calculation cannot proceed.

In the calculation method the data are first converted to gross efficiency under test conditions, and then converted to a seasonal efficiency value that applies under typical conditions of use in a dwelling, allowing for standing losses.

In this Appendix, efficiencies are expressed in percent. Intermediate calculations should be done to at least four places of decimals of a percentage, and the final result rounded to one decimal place.

The procedure to be adopted by manufacturers is as follows:

**1. Determine fuel for boiler type.**

The fuel for boiler type must be one of natural gas, LPG (butane or propane), or oil (kerosene or gas oil). SEDBUK cannot be calculated for other fuels.

**2. Obtain test data.**

Retrieve the *full-load net efficiency* and *30% part-load net efficiency* test results. Tests must have been carried out using the same fuel as the fuel for boiler type, except as provided in D4.

**3. Reduce to maximum net efficiency values.**

Table D2.1 gives the maximum values of net efficiency for each fuel that may be used for the purposes of the SAP. Reduce any greater test value to the appropriate value given in Table D2.1.

**Table D2.1 : Maximum net efficiency values (in %)**

| Condensing boilers |               | Non-condensing boilers |               |
|--------------------|---------------|------------------------|---------------|
| Full load          | 30% part load | Full load              | 30% part load |
| 101.0              | 107.0         | 92.0                   | 91.0          |

**4. Convert the full and 30% part load efficiencies from net values to gross.**

Use the following equation with the appropriate factor from Table D2.2.

$$E_{\text{gross}} = f \times E_{\text{net}}$$

**Table D2.2 : Efficiency conversion factors**

| Fuel                      | Net-to-gross conversion factor, f |
|---------------------------|-----------------------------------|
| Natural gas               | 0.901                             |
| LPG (propane or butane)   | 0.921                             |
| Oil (kerosene or gas oil) | 0.937                             |

**5. Categorise the boiler.**

- a) Select the appropriate category for the boiler according to the definitions given in D1.
- b) If a gas or LPG boiler, determine whether it has a permanent pilot light:
  - if it has a permanent pilot light, set p = 1
  - if not, set p = 0.
- c) In the case of a storage combination boiler (either on/off or modulating) determine from the test report whether the losses from the store were included in the values reported (this depends on whether the store was connected to the boiler during the tests):
  - if the store loss is included, set b = 1
  - if not, set b = 0.
- d) In the case of a storage combination boiler or a CPSU, obtain the store volume,  $V_{cs}$ , in litres from the specification of the device and the standby loss factor, L, using the following equation:

$$L = 0.584 \times (0.005 + 0.55 / (t + 4.0)) \times (120 / V_{cs})^{1/3}$$

where t is the thickness of the insulation of the store in mm.

### 6. Calculate seasonal efficiency

- a) Use the boiler category and other characteristics as defined in D1 (non-condensing or condensing; gas or LPG or oil; on/off or modulating) to look up the appropriate SEDBUK equation number in Table D2.3. If no equation number is given the calculation cannot proceed. Otherwise, select the appropriate equation from Table D2.4 or Table D2.5.
- b) Substitute the gross full and part load efficiencies (found in step 4) and p, b, V and L (found in step 5). Round the result to one decimal place; ie, to nearest 0.1%. Note the result as [x] for the purpose of the declaration in D3.

**Table D2.3 : Boiler category table**

| SEDBUK Equation numbers<br>for different boiler types | non-condensing (see D1.2)                |  |                                   |                                       | low-temperature<br>(see D1.5) | condensing (see D1.2)                    |  |                                   |                                       |
|---|--|--|-----------------------------------|---------------------------------------|-------------------------------|--|--|-----------------------------------|---------------------------------------|
|   | Gas or LPG                               |  | Oil                               |                                       |                               | Gas or LPG                               |  | Oil                               |                                       |
|   | on/off<br>(see D1.4, D1.8, D1.11, D1.13) | modulating<br>(see D1.5, D1.9, D1.12, D1.14) | on/off<br>(see D1.4, D1.8, D1.11) | modulating<br>(see D1.5, D1.9, D1.12) |                               | on/off<br>(see D1.4, D1.8, D1.11, D1.13) | modulating<br>(see D1.5, D1.9, D1.12, D1.14) | on/off<br>(see D1.4, D1.8, D1.11) | modulating<br>(see D1.5, D1.9, D1.12) |
| regular boiler<br>(see D1.4, D1.5)                    | 101                                      | 102  | 201                               | X                                     | X                             | 101                                      | 102  | 201                               | X                                     |
| instantaneous combi boiler<br>(see D1.7, D1.8, D1.9)  | 103                                      | 104  | 202                               | X                                     | X                             | 103                                      | 104  | 202                               | X                                     |
| storage combi boiler<br>(see D1.10, D1.11, D1.12)     | 105                                      | 106  | 203                               | X                                     | X                             | 105                                      | 106  | 203                               | X                                     |
| combined primary storage unit<br>(see D1.13, D1.14)   | 107                                      | 107  | X                                 | X                                     | X                             | 107                                      | 107  | X                                 | X                                     |

**Table D2.4 : Seasonal efficiency,  $E$ , for natural gas and LPG boilers**

| Gas or LPG boiler type  | Eq. no. | Equation  |
|---|---------|---|
| D1.4 : On/off regular   | 101     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.5 - 4p$   |
| D1.5 : Modulating regular   | 102     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.0 - 4p$   |
| D1.8 : On/off instantaneous combination   | 103     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.8 - 4p$   |
| D1.9 : Modulating instantaneous combination   | 104     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.1 - 4p$   |
| D1.11 : On/off storage combination  | 105     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.8 + (0.209 \times b \times L \times V_{cs}) - 4p$ |
| D1.12 : Modulating storage combination  | 106     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 1.7 + (0.209 \times b \times L \times V_{cs}) - 4p$ |
| D1.13 : On/ off combined primary storage unit (condensing and non-condensing)<br>D1.14 : Modulating combined primary storage unit (condensing and non-condensing) | 107     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - (0.539 \times L \times V_{cs}) - 4p$                |

**Table D2.5 : Seasonal efficiency,  $E$ , for oil boilers**

| Oil boiler type                  | Eq. No. | Equation   |
|----------------------------------|---------|--|
| D1.3 : Regular                   | 201     | $E = 0.5(E_{\text{full}} + E_{\text{part}})$   |
| D1.7 : Instantaneous combination | 202     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.8$   |
| D1.10 : Storage combination      | 203     | $E = 0.5(E_{\text{full}} + E_{\text{part}}) - 2.8 + (0.209 \times b \times L \times V_{cs})$ |

### **D3 Declaring values of seasonal efficiency**

Manufacturers wishing to declare their products' seasonal efficiencies for the specific purposes of calculating SAP ratings can do so provided that:

- a) they use the SEDBUK calculation procedure given in D2 above; and
- b) the necessary boiler test data and the calculations are certified by a Notified Body accredited for the testing of boilers by an EU national accreditation service. The Notified Body must certify that: 'the full load and part load efficiency test results detailed in [*insert reference to report on the efficiency tests*] have been obtained by methods deemed to satisfy the Boiler Efficiency Directive'.

Where a manufacturer declares the SEDBUK, it shall be expressed as:

“Seasonal Efficiency (SEDBUK) = [x]%  
The value is used in the UK Government’s Standard Assessment Procedure (SAP) for energy rating of dwellings. The test data from which it has been calculated have been certified by [*insert name and/or identification of Notified Body*].”

Data for several products may be presented in tabulated form, in which case the second paragraph of the declaration should be incorporated as a note to the table.

### **D4 Method for calculating the SEDBUK for boilers fuelled by LPG but tested with natural gas**

If the fuel for boiler type is LPG but the fuel used to obtain efficiency test results is natural gas then SEDBUK may be calculated subject to certain conditions using the procedure given below. The value of SEDBUK will be lower than if the fuel used to obtain the test results had been LPG.

1. Note the restrictions set out at the start of D2, which still apply.
2. Any differences between the boiler fuelled by natural gas (used to obtain full-load and 30% part-load efficiency test results) and the boiler fuelled by LPG (for which the SEDBUK is required) must be minor. Examples of minor differences are a change of gas injector or adjustment by a single screw on the gas valve.
3. Determine the net heat input on a net calorific value basis for both the natural gas boiler and the LPG boiler. The LPG figure must lie within  $\pm 5\%$  of the natural gas figure.
4. Determine by measurement the percentage dry CO<sub>2</sub> by volume at the maximum heat input for both the natural gas boiler and the LPG boiler. From the results calculate the excess air fractions for both boilers. The calculated excess air fraction for the LPG boiler must not exceed that for the natural gas boiler by more than 5% (of the natural gas excess air fraction).
5. Retrieve the *full-load net efficiency* and *30% part-load net efficiency* test results. If the boiler is a condensing boiler then deduct 2.2 percentage points from the *30% part-load net efficiency* test result.
6. Follow the calculation procedure in D2 from step 3 onwards, taking the fuel for boiler type as LPG.

### **D5 Method for calculating Seasonal Efficiency and Case Emission value of a non-condensing twin-burner range cooker boiler**

1. The method of calculation of the Seasonal Efficiency is applicable only to cooker boilers for which the full load and the 30% part load efficiency values for the boiler function, obtained by the methods deemed to satisfy Council Directive 92/42/EEC, are available.

*Note: A non-condensing range cooker boiler which does not have the capability to provide domestic hot water directly (i.e. is not a combination boiler), but which may nevertheless provide domestic hot water indirectly via a separate hot water storage cylinder exactly matches the definition D1.3 for a Regular Boiler. Consequently the methods deemed to satisfy 92/42/EEC for a Regular Boiler will equally satisfy this requirement for the equivalent type of range cooker boiler.*

These efficiencies are for the heat transferred to water and are carried out with the cooker burner turned off,

When undertaking the efficiency test, record

- input power (net) at full load conditions,  $\Phi_{\text{input,net}}$ , in kW.
- heat transfer to the water under full load conditions,  $\Phi_{\text{water}}$ , in kW
- flue loss (net) under full load conditions,  $\Phi_{\text{flue,net}}$ , in kW according to the method given in EN 304:1992 + Amendment 1: 1998 or other method assured by the independent test laboratory as providing comparable results for the product under test.

*Note: Independent test laboratory is qualified in D6 b).*

2. Calculate the SEDBUK according to D2 using the appropriate equation for a regular boiler.
3. Calculate the case heat emission at full load from

$$\Phi_{\text{case}} = \Phi_{\text{input,net}} - \Phi_{\text{water}} - \Phi_{\text{flue,net}}$$

where  $\Phi_{\text{water}}$  is the heat transferred to water under full load conditions;  
 $\Phi_{\text{flue,net}}$  is the flue gas loss measured according to BS EN 304.

4. If  $\Phi_{\text{case}} < 0.2$  kW and the case temperatures of the range cooker are below 80°C, the case emission may, as an alternative, be derived from measurements of the case temperatures according to Supplement 1 to OFTEC Standard OFS A101, subject to a maximum figure of  $\Phi_{\text{case}} = 0.2$  kW.  
*Note: Supplement 1 to OFTEC Standard OFS A101 (applicable for oil and gas) can be obtained from OFTEC (Oil Firing Technical Association), Tel 0845 6585080, Fax 0845 6585181, e-mail enquiries@oftec.org*
5. If  $\Phi_{\text{case}}$  exceeds either of  $0.05 \times \Phi_{\text{water}}$  or 1 kW, reduce  $\Phi_{\text{case}}$  to  $0.05 \times \Phi_{\text{water}}$  or 1 kW (whichever is the smaller).
6. Provide the values of  $\Phi_{\text{case}}$  and  $\Phi_{\text{water}}$  in kW as part of the test report.

## **D6 Declaring values of seasonal efficiency and heat emission from the case for twin-burner range cooker boilers**

Manufacturers wishing to declare their products' seasonal efficiencies and case emission values for the specific purposes of calculating SAP ratings can do so provided that:

- a) They use the calculation procedure given in D5 above; and
- b) The necessary boiler test data and calculations are certified by an independent Test Laboratory notified under the Council Directive 92/42/EEC on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels (known as a "Notified Body").

Where a manufacturer declares the seasonal efficiency and the case emission value, it shall be expressed as:

Seasonal Efficiency (SEDBUK) = [x]%

Case heat emission at full load = [y] kW

Heat transfer to water at full load = [z] kW

The values are used in the UK Government's Standard Assessment Procedure (SAP) for the energy rating of dwellings. The test data from which they have been calculated has been certified by [insert name and/or identification of Notified Body].

Data for several products may be presented in tabulated form, in which case the last paragraph of the declaration should be incorporated as a note to the table.

## Appendix E: Method of determining seasonal efficiency for gas or oil room heaters

Note: The data and equations in this appendix are not to be used by SAP assessors.

This appendix sets out the method to be used by manufacturers to determine the declared efficiency for gas or oil room heaters.

### E1 Efficiency determination

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

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

|                  |   |
|------------------|---|
| BS EN 613:2001   | Independent gas-fired convection heaters  |
| BS EN 13278:2003 | Open-fronted gas-fired independent space heaters  |
| BS EN 1266:2002  | Independent gas-fired convection heaters incorporating a fan to assist transportation of combustion air and/or flue gases         |
| BS 7977-1:2002   | Specification for safety and rational use of energy of gas domestic appliances. Part 1: Radiant/Convectors                        |
| BS 7977-2:2003   | Specification for safety and rational use of energy of gas domestic appliances. Part 2: Combined appliances: Gas fire/back boiler |

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

|               |  |
|---------------|--|
| OFS A102:1999 | Oil fired room heaters with atomising or vaporising burners with or without boilers, heat output up to 25 kW |
|---------------|--|

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 E3.

**Table E3: 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                          |

### E2 Declaring the efficiency of gas and oil room heaters

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

"The efficiency of this appliance has been measured as specified in [*insert appropriate entry from Table E1 or Table E2*] and the result is [*x*]%. The gross calorific value of the fuel has been used for this efficiency calculation. The test data from which it has been calculated has been certified by [*insert name and/or identification of Notified Body*]. The 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. Not less than 270 litres of primary water, heated mainly during off-peak times to approximately 75°C in summer and between 85 and 95°C in winter, is stored in a thermal store. If the CPSU volume is less than 270 litres, the on-peak fraction becomes high leading to a poor SAP rating.

The procedure in this appendix applies for a 10-hour off-peak tariff providing 3 off-peak periods per day. It is not valid for other tariffs.

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. In the case of an electric CPSU, the on-peak fraction should be calculated (because the procedure is based on a fixed volume). *Note: the treatment of on-peak fraction is different from electric storage heating, because in the case of storage heating the on-peak fraction is fixed (it is achieved by sizing the storage heaters).*

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

### F1 Procedure for electric CPSUs:

The procedure below applies to the worksheet from box (82) onwards.

1. Calculate the on-peak fraction using the following methodology:

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

$$T_{\min} = \frac{[(37) \times (77)] - C_{\max} + [(39) \div 8.76] - (69)}{(37)}$$

$C_{\max}$  is off-peak heat available irrespective of power rating of the heating element, calculated using the formula:

$$C_{\max} = 0.1456 \times V_{cs} \times (T - 48)$$

where:

$V_{cs}$  is the CPSU capacity, litres

$T_w$  is winter operating temperature, °C

b) Find the degree-days (DD) from Table 10 for base temperature  $T_{\min}$  calculated above.

c) Calculate on-peak energy required

$$E_{\text{on-peak}} = 0.024 \times (37) \times \text{DD} \text{ kWh/year}$$

2. Calculate on-peak fraction

$$F = \frac{E_{\text{on-peak}}}{(81) + (39)} \text{ and enter in box (82)}$$

3. Calculate the on-peak percentage:

$$P = 100 \times F, \text{ and enter in box (90)}$$

4. Enter 130 in box (87a) and follow the normal worksheet calculation.

*Note: In the SAP worksheet boxes (82) and (90) are normally used for entry of a fraction from secondary heating but for the purpose of electric CPSU only, these boxes are used for CPSU on-peak fraction.*

## Appendix G: Heat pumps

A heat pump is a device which takes heat energy from a low temperature source and upgrades it to a higher temperature at which it can be usefully employed for heating. There are a number of heat pump techniques by which this can be achieved. The ratio of heat energy released to the energy consumed can be significantly greater than one. Heat pump systems operate most efficiently when the source temperature is as high as possible and the heat distribution temperature is as low as possible.

Heat pump systems are categorised by the low temperature heat source used (e.g. air, water, ground) and the seasonal performance factors (SPF) given in Table 4a under "Efficiency" are assumed to apply for all systems using that source. This is a simplified approach especially for ground source heat pumps where energy may be collected from the ground in a variety of ways, e.g. using surface water from lakes or ponds, using ground water from wells, using fluid (either refrigerant or a water/antifreeze mixture) circulated in closed pipe loops buried horizontally in shallow trenches or vertically in boreholes.

At the time of publication, the SPF to be used for SAP calculations is the appropriate entry in Table 4a. A system of appliance-specific performance factors may be introduced (see Appendix Q).

Heat pumps can also be used in community schemes. That does not affect the calculation of the SAP rating but the SPF of the heat pump should be used in box (104) for the calculation of CO<sub>2</sub> emissions.

### G1 Domestic hot water (DHW)

#### G1.1 DHW heated by heat pump with immersion heater

The heat pump raises the water temperature to a maximum of about 40°C, and an immersion heater is then used to raise the water temperature to the required delivery temperature. For the purpose of the SAP calculation it is assumed that that 50% of domestic hot water heating is by the heat pump and 50% by the immersion heater using off-peak electricity.

The average efficiency for water heating, box (86), is:

$$\frac{100}{[50 \div \text{SPF}] + 0.5}$$

where SPF is the seasonal performance factor for the heat pump, %, given under "Efficiency" in Table 4a. (The SPF is an overall figure, taking account of all the energy required to operate the heat pump, including primary circulation pumps and an auxiliary heater if present). In the case of a ground or water source heat pump the fraction of electricity at the on-peak rate is given in Table 12a with the remainder charged at the off-peak rate.

#### G1.2 DHW heated by heat pump without immersion heater

The heat pump supplies all domestic hot water without supplementary immersion heater.. In the case of a ground or water source heat pump, the on-peak fraction is given in Table 12a. The SPF of the heat pump for water heating is to be multiplied by the factor given in Table 4c.

#### G1.3 DHW heated by immersion only

An immersion heater is used, either standard or off-peak electric tariff.

### G2 Space heating requirement

#### G2.1 Space heating from ground or water source heat pump

A ground source heat pump system (when the main heating system) may consist of either a ground source heat pump sized to meet all space heating requirements, or a combination of a ground source heat pump and a direct acting electric heater (auxiliary heater). A ground source heat pump system which includes an auxiliary heater to help meet the maximum demands has a lower SPF than one without an auxiliary heater. Use the appropriate (SPF given in Table 4a under "Efficiency").

For ground and water source heat pumps using an off-peak tariff, the fraction of the electricity used for space heating at the on-peak rate is given in Table 12a with the remainder charged at off-peak rate.

If the heat pump supplies heat to radiators (as opposed to underfloor heating) the heat pump efficiency for space heating is to be multiplied by the appropriate factor given in Table 4c.

### **G2.2 Direct acting air source heat pump**

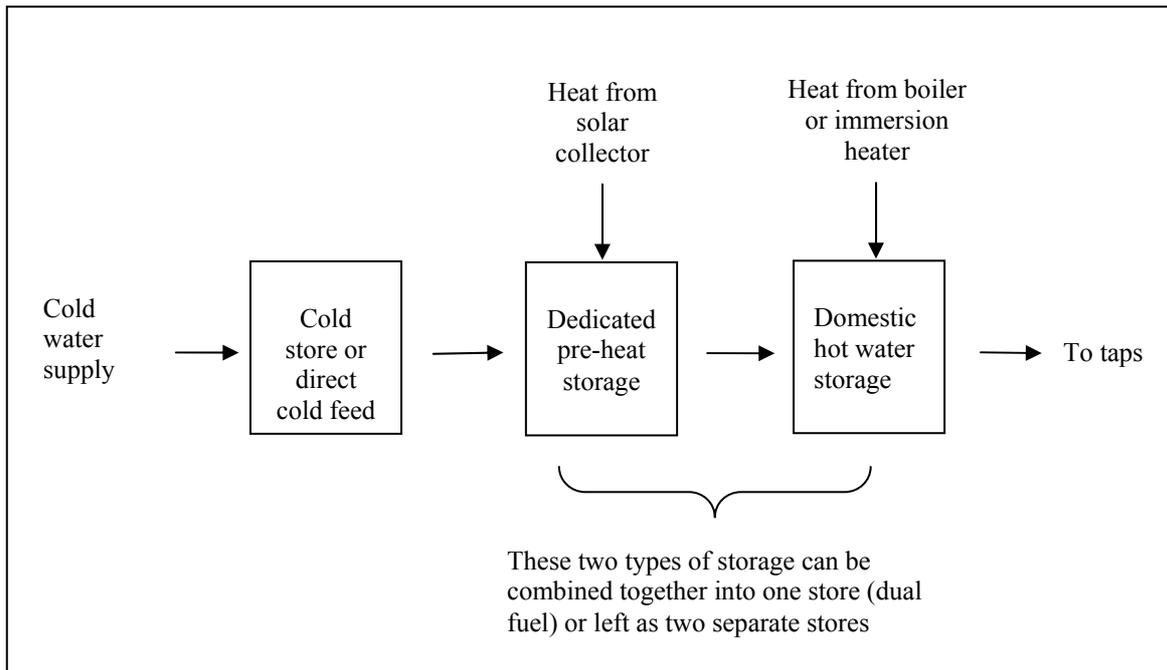
A heat pump using ambient air as the source is subject to frost build up on the external coil and is very likely to have an integral electric heater to provide space heating while the external coil is being defrosted. The use of this heater is allowed for in the SPF. Air source heat pumps use standard electricity tariff.

### **G2.3 Heating controls**

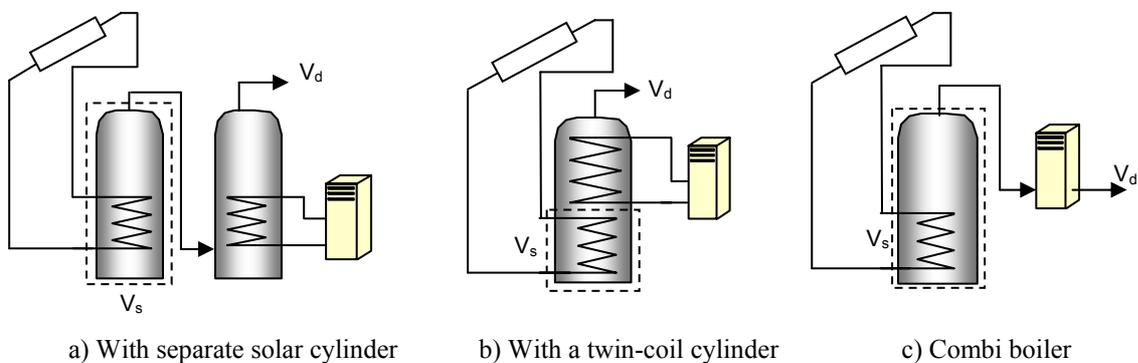
Control options for heat pumps are given in Group 2 of Table 4e. Note that a bypass arrangement is usually necessary with TRVs to ensure sufficient circulating thermal mass while the heat pump is operating. Zoning arrangements or TRVs may not be appropriate for small domestic installations for this reason.

## Appendix H: Solar water heating

The working principle of solar hot water systems is shown in Figure H1: examples of arrangements are given in Figure H2.



**Figure H1: Working principle of solar water heating.**



$V_s$  (indicated by the dashed line) is the dedicated solar storage volume. See text below concerning the effective solar volume.  $V_d$  is the daily hot water demand.

**Figure H2: Schematic examples of arrangements for solar pre-heating**

Water from the cold supply is either fed (directly or via a cold feed cistern) to the preheat zone where it is heated by solar energy. Then the water passes to the domestic hot storage (separate hot water cylinder or upper part of combined cylinder) which is heated to the required temperature by a boiler or an electric immersion.

There are three main types of solar collector:

- unglazed: the overall performance of unglazed collectors is limited by high thermal losses;
- glazed flat plate: a flat plate absorber (which often has a selective coating) is fixed in a frame between a single or double layer of glass and an insulation panel at the back;

- evacuated tube: an absorber with a selective coating is enclosed in a sealed glass vacuum tube.

The performance of a solar collector is represented by its zero-loss efficiency (proportion of incident solar radiation absorbed in the absence of thermal loss) and its heat loss coefficient (heat loss from collector to the environment per unit area and unit temperature difference).

The solar contribution to domestic hot water is given by

$$Q_s = S \times Z_{\text{panel}} \times A_{\text{ap}} \times \eta_0 \times UF \times f(a_1/\eta_0) \times f(V_{\text{eff}}/V_d)$$

where

$Q_s$  = solar input, kWh/year

$S$  = total solar radiation on collector, kWh/m<sup>2</sup>/year

$Z_{\text{panel}}$  = overshadowing factor for the solar panel

$A_{\text{ap}}$  = aperture area of collector, m<sup>2</sup>

$\eta_0$  = zero-loss collector efficiency

$UF$  = utilisation factor

$a_1$  = linear heat loss coefficient of collector, W/m<sup>2</sup>K

$f(a_1/\eta_0)$  = collector performance factor =  $0.87 - 0.034 (a_1/\eta_0) + 0.0006 (a_1/\eta_0)^2$

$V_{\text{eff}}$  = effective solar volume, litres

$V_d$  = daily hot water demand, litres

$f(V_{\text{eff}}/V_d)$  = solar storage volume factor =  $1.0 + 0.2 \ln(V_{\text{eff}}/V_d)$  subject to  $f(V_{\text{eff}}/V_d) \leq 1.0$

The collector's gross area is the projected area of complete collector (excluding any integral means of mounting and pipework). The aperture area is the opening through which solar radiation is admitted.

The preferred source of performance data for solar collectors is from a test on the collector concerned according to BS EN 12975-2, *Thermal solar systems and components – Solar collectors – Part 2: Test methods*. The aperture area, and the performance characteristics  $\eta_0$  and  $a_1$  related to aperture area, are obtained from the test certificate. If test data are not available (e.g. for existing installations), the values in Table H1 may be used.

The effective solar volume is:

- in the case of a separate pre-heat tank (such as arrangements a) or c) in Figure H2), the volume of the pre-heat tank;
- in the case of a combined cylinder (such as arrangement b) in Figure H2), the volume of the dedicated solar storage plus 0.3 times the volume of the remainder of the cylinder;
- in the case of a thermal store (hot-water-only or integrated as defined in Appendix B) where the solar coil is within the thermal store, the volume of the dedicated thermal storage.

## Calculation of solar input for solar water heating

|   |  |                      |       |
|---|--|----------------------|-------|
| Aperture area of solar collector, m <sup>2</sup>  |  | <input type="text"/> | (H1)  |
| <i>If only the gross area can be established reliably, multiply it by ratio in Table H1</i>                     |  |                      |       |
| Zero-loss collector efficiency, $\eta_0$ , from test certificate or Table H1                                    |  | <input type="text"/> | (H2)  |
| Collector heat loss coefficient, $a_1$ , from test certificate or Table H1                                      |  | <input type="text"/> | (H3)  |
| Collector performance ratio $a_1/\eta_0$  | (H3) ÷ (H2) =  | <input type="text"/> | (H4)  |
| Annual solar radiation per m <sup>2</sup> from Table H2   |  | <input type="text"/> | (H5)  |
| Overshading factor from Table H3  |  | <input type="text"/> | (H6)  |
| Solar energy available  | (H1) × (H2) × (H5) × (H6) =  | <input type="text"/> | (H7)  |
| Solar-to-load ratio   | (H7) ÷ [(39) + (40)] =   | <input type="text"/> | (H8)  |
| Utilisation factor  | if (H8) > 0, $1 - \exp[-1/(H8)]$ , otherwise enter "0" in box (H9) | <input type="text"/> | (H9)  |
| <i>if the cylinder is heated by a boiler and there is no cylinderstat, reduce the utilisation factor by 10%</i> |  |                      |       |
| Collector performance factor  | $0.87 - 0.034 \times (H4) + 0.0006 \times (H4)^2 =$                | <input type="text"/> | (H10) |
| Dedicated solar storage volume, $V_s$ , litres  |  | <input type="text"/> | (H11) |
| <i>volume of pre-heat store, or dedicated solar volume of a combined cylinder</i>                               |  |                      |       |
| If combined cylinder, total volume of cylinder, litres  |  | <input type="text"/> | (H12) |
| Effective solar volume, $V_{eff}$   |  | <input type="text"/> | (H13) |
| <i>if separate pre-heat solar storage or a thermal store, (H13) = (H11)</i>                                     |  |                      |       |
| <i>if combined cylinder, (H13) = (H11) + 0.3 × [(H12) – (H11)]</i>  |  |                      |       |
| Daily hot water demand, $V_d$ , (litres) from Table 1   |  | <input type="text"/> | (H14) |
| Volume ratio $V_{eff}/V_d$  | (H13) ÷ (H14) =  | <input type="text"/> | (H15) |
| Solar storage volume factor $f(V_{eff}/V_d)$  | $1 + 0.2 \times \ln(H15) =$  | <input type="text"/> | (H16) |
| Solar input $Q_s$   | (H7) × (H9) × (H10) × (H16) =                                      | <input type="text"/> | (H17) |

*Note: (39) and (40) are box numbers of the main worksheet*

Enter (H17) in (50) of main worksheet. If separate figures for solar input are required for the heating season (8 months) and summer (4 months) take 50% of  $Q_s$  as applying during the heating season and 50% during the summer.

**Table H1 : Default collector parameters**

| Collector type     | $\eta_0$ | $a_1$ | Ratio of aperture area to gross area |
|--------------------|----------|-------|--------------------------------------|
| Evacuated tube     | 0.6      | 3     | 0.72                                 |
| Flat plate, glazed | 0.75     | 6     | 0.90                                 |
| Unglazed           | 0.9      | 20    | 1.00                                 |

**Table H2 : Annual solar radiation, kWh/m<sup>2</sup>**

| Tilt of collector | Orientation of collector |       |     |       |       |
|-------------------|--------------------------|-------|-----|-------|-------|
|                   | South                    | SE/SW | E/W | NE/NW | North |
| Horizontal        | 933                      |       |     |       |       |
| 30°               | 1042                     | 997   | 886 | 762   | 709   |
| 45°               | 1023                     | 968   | 829 | 666   | 621   |

|          |     |     |     |     |     |
|----------|-----|-----|-----|-----|-----|
| 60°      | 960 | 900 | 753 | 580 | 485 |
| Vertical | 724 | 684 | 565 | 427 | 360 |

**Table H3 : Overshading factor**

| <b>Overshading</b>  | <b>% of sky blocked by obstacles.</b> | <b>Overshading factor</b> |
|---|---------------------------------------|---------------------------|
| Heavy   | > 80%                                 | 0.5                       |
| Significant   | > 60% - 80%                           | 0.65                      |
| Modest  | 20% - 60%                             | 0.8                       |
| None or very little   | < 20%                                 | 1.0                       |
| <i>Note: Overshading must be assessed separately for solar panels, taking account of the tilt of the collector. Usually there is less overshading of a solar collector compared to overshading of windows for solar gain (Table 6d)</i> |                                       |                           |

## Appendix J: Seasonal efficiency for solid fuel boilers from test data

This appendix specifies how to obtain a seasonal efficiency from test data on a solid fuel boiler that is provided in the boiler database. A database record for a solid fuel boiler includes:

- SAP seasonal efficiency, %
- Fuel input, heat to water and heat to room from test at full load, kW
- Fuel input, heat to water and heat to room from test at part load, kW

### J1 SAP seasonal efficiency is given

If the SAP seasonal efficiency is given, that value is used for both space and water heating, and the other data is disregarded.

### J2 SAP seasonal efficiency is not given

If the SAP seasonal efficiency is blank, the appropriate efficiency for use in the calculations is obtained as follows.

#### J2.1 Part load data is available

The efficiency at full load is obtained from:

$$E_{\text{full}} = \frac{(\text{heat to water at full load}) + (\text{heat to room at full load})}{\text{fuel input at full load}} \quad (\text{J1})$$

and the efficiency at part load from:

$$E_{\text{part}} = \frac{(\text{heat to water at part load}) + (\text{heat to room at part load})}{\text{fuel input at part load}} \quad (\text{J2})$$

If the boiler is outside the boundary of the dwelling as defined in section 1, "Dwelling dimensions", the heat to room is omitted from (J1) and (J2).

The seasonal efficiency is then:

$$\text{Seasonal efficiency} = 0.5 (E_{\text{full}} + E_{\text{part}}) \quad (\text{J3})$$

#### J2.2. Part load data is not available

If the data for the part load test is blank, the part load efficiency is taken as 95% of the full load efficiency, so that:

$$\text{Seasonal efficiency} = 0.975 E_{\text{full}} \quad (\text{J4})$$

### J3 Heating type and responsiveness

The heating type and responsiveness is that for the applicable type of appliance given in Table 4a.

## Appendix K: Thermal bridging

Thermal bridges that occur at junctions between building elements are now 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.

The transmission heat loss coefficient associated with non-repeating thermal bridges is calculated as:

$$H_{TB} = \sum (L \times \Psi)$$

where L is the length of the thermal bridge over which  $\Psi$  applies.

If details of the thermal bridges are not known, use

$$H_{TB} = y \sum A_{exp}$$

where  $A_{exp}$  is the total area of exposed elements,  $m^2$ .

$y = 0.08$  for new dwellings whose details conform with *Accredited Construction Details* (or are otherwise shown to be equivalent), and a default value of  $y = 0.15$  applies otherwise.

Alternatively values of  $\Psi$  can be determined from the results of numerical modelling, or they can be derived from measurement. If the junction detail is as recommended in *Accredited Construction Details*, the  $\Psi$ -value associated with that junction can be taken from Table K1.

**Table K1 Maximum values of  $\Psi$  from Accredited Construction Details for different types of junctions.**

| Junction detail in external wall                   | $\Psi$ (W/m·K) |
|--|----------------|
| Metal box lintel                                   | 0.30           |
| Other lintels                                      | 0.21           |
| Sill   | 0.04           |
| Jamb   | 0.05           |
| Ground floor                                       | 0.16           |
| Intermediate floor within a dwelling               | 0.07           |
| Intermediate floor between dwellings <sup>a)</sup> | 0.14           |
| Balcony within a dwelling <sup>b)</sup>            | 0.00           |
| Balcony between dwellings <sup>a) b)</sup>         | 0.04           |
| Eaves (insulation at ceiling level)                | 0.06           |
| Eaves (insulation at rafter level)                 | 0.04           |
| Gable (insulation at ceiling level)                | 0.24           |
| Gable (insulation at rafter level)                 | 0.04           |
| Corner (normal)                                    | 0.09           |
| Corner (inverted)                                  | -0.09          |
| Party wall between dwellings <sup>a)</sup>         | 0.06           |

<sup>a)</sup> For these junctions, half the value of  $\Psi$  is applied to each dwelling

<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.

## Appendix L: Energy for lighting

The calculation of lighting use is based on the proportion of fixed low energy lighting outlets installed, and on the contribution of daylight.

### Allowing for fixed low-energy outlets

In UK houses, the average energy consumption for lighting is taken as 9.3 kWh/m<sup>2</sup> annually if no low-energy lighting is used.

$$E_B = 9.3 \text{ kWh/m}^2 \quad (\text{L1})$$

The SAP calculation takes account of fixed lighting outlets with low-energy lamps, by including a correction factor  $C_1$ :

$$C_1 = 1 - 0.50 \times N_{LE}/N \quad (\text{L2})$$

where  $N_{LE}$  is the number of fixed low energy lighting outlets (including sockets or complete luminaires capable of taking only low-energy lamps, and also compact fluorescent lamps that fitted into ordinary lighting sockets) and  $N$  is the total number of fixed lighting outlets (only the ratio  $N_{LE}/N$  is needed).

*Note: In Equation (L2), only fixed lighting outlets are included in  $N_{LE}$  and  $N$ . Movable lamps, which plug into a mains socket, are disregarded. The equation is based on two-thirds of the lighting energy consumption being via fixed lighting points, and each fixed low energy lighting point achieving a saving of 75% over a point with a non low energy lamp ( $2/3 \times 3/4 = 0.50$ ).*

### Daylighting

Analysis of typical house types gives the following approximate correction factor,  $C_2$ , for lighting energy use depending on the ratio of glass area to floor area, glass transmittance and light access factor.

$$C_2 = 52.2 G_L^2 - 9.94 G_L + 1.433 \quad \text{if } G_L \leq 0.095 \quad (\text{L3})$$

$$C_2 = 0.96 \quad \text{if } G_L > 0.095 \quad (\text{L4})$$

$$G_L = \frac{\sum 0.9 \times A_w \times g_L \times FF \times Z_L}{\text{TFA}} \quad (\text{L5})$$

where:  $FF$  is the frame factor from Table 6c  
 $A_w$  is the area of a window, m<sup>2</sup>  
 $TFA$  is the total floor area, m<sup>2</sup>  
 $g_L$  is the light transmittance factor from Table 6b  
 $Z_L$  is the light access factor from Table 6d

The summation allows for different window and rooflight types (the light access factor is different for windows and rooflights).

The annual energy used for lighting in the house,  $E_L$ , is then

$$E_L = E_B \times TFA \times C_1 \times C_2 \text{ kWh/year} \quad (\text{L6})$$

where:

$E_B = 9.3 \text{ kWh/m}^2$   
 $TFA$  is the total floor area, m<sup>2</sup>  
 $C_1$  and  $C_2$  are defined above

### Gains from lighting

The reduction in lighting energy use due to low energy lights is:

$$\Delta E_L = E_B \times TFA \times (1 - C_1) \times C_2 \text{ (kWh/year)} \quad (\text{L7})$$

To allow for this the quantity

$$\Delta \text{gains} = 0.15 \Delta E_L \quad (\text{L8})$$

should be deducted from the internal heat gains obtained from Table 5. The factor 0.15 in equation (L8) is based on 75% of the annual lighting energy being used during the months October to April when there is a significant heating need.

## Appendix M: Energy from Photovoltaic (PV) technology

Photovoltaic technology converts sunlight 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 (the range for currently available types is from about 30 to 120 watts peak per m<sup>2</sup>), 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 produces about 750 kWh of electricity per year (at favourable orientation and not overshadowed).

The procedure for PV is as follows.

- 1) Establish the installed peak power of the PV unit (kWp).
- 2) The electricity produced by the PV module in kWh/year is
$$0.75 \times \text{kWp} \times S \times Z_{PV}$$
where S is the annual solar radiation from Table H2 (depending on orientation and pitch), and  $Z_{PV}$  is the overshadowing factor from Table H3.

In the worksheet enter the calculated energy produced by PV in box (95).
- 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 (usually the standard tariff, or the day rate 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. At present the value of  $\beta = 0.30$  should be used for SAP calculations: this will be reviewed in future if relevant data becomes available. The fuel price used in the calculation of box (95a) is:

$$\beta \times \text{normal electricity price} + (1 - \beta) \times \text{exported electricity price}.$$
- 4) For calculation of CO<sub>2</sub> emissions, the emissions factor for grid-displaced electricity from Table 12 is used in the calculation of box (110). The same factor is used for all electricity generated, whether used within the dwelling or exported.

## **Appendix N: Micro-cogeneration (also known as micro-CHP)**

### **N1 Overview**

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. It provides space heating throughout the heating season, and hot water service for either (a) the whole of the year, or (b) none of the year.

The characteristics of micro-cogeneration are described by data derived from laboratory tests. The test data is used to calculate parameters related to the annual energy performance of the micro-cogeneration package. Results (known as “intermediate results”) from the annual energy performance method are used for SAP as described in N2.

Any space heating requirements not met by the micro-cogeneration package are assumed to be provided by secondary heating appliances (if provided) or by electric room heaters. If the package provides domestic hot water it is assumed to provide all water heating needs.

The heat produced by the package and the electrical energy consumed/generated are based on operation during an average year, taking account of the output rating of the appliance and the design heat loss for the dwelling into 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 0.5 then the package cannot be regarded as the primary heating system, and the performance data are not valid for SAP.

The electricity consumed/generated will normally be negative, and then represents the net electricity provided 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, if supplied by the micro-cogeneration package, water heating. The electricity consumed (or the net electricity generation) is scaled according to the net energy use as obtained in the SAP calculation.

### **N2 Interpolation of result sets**

The intermediate results from the annual energy performance method are produced in sets, with each set calculated for a different plant size ratio (e.g. 0.5, 1.0, 1.5 and 4.0). The plant size ratio is defined as the maximum heat output of the micro-cogeneration package divided by the design heat loss of the dwelling. Each set of results contains the data in Table N1. The data to be used for SAP calculations are provided by way of the boiler database, each database record for a micro-cogeneration package containing the output power of the package and a number of sets of intermediate results.

**Table N1: Set of intermediate results from the annual energy performance method**

| Data item  | Symbol       | Unit |
|--|--------------|------|
| Plant size ratio for which data apply  | PSR          | -    |
| Annual heat generated for space heating  | $Q_{sp}$     | kWh  |
| Annual heat generated for domestic hot water, if any   | $Q_{hw}$     | kWh  |
| Annual auxiliary heating requirement   | $Q_{aux}$    | kWh  |
| Heating season * thermal efficiency  | $\eta_{hs}$  | -    |
| Summer season thermal efficiency   | $\eta_{sum}$ | -    |
| The electricity consumed or, if negative, net electricity generated, during the heating season | $E_{mc,hs}$  | kWh  |
| The electricity consumed or, if negative, net electricity generated, during the summer season  | $E_{mc,sum}$ | kWh  |
| Number of days operating for 16 hours instead of 9   | $N_{16,9}$   | days |
| Number of days operating for 24 hours instead of 9   | $N_{24,9}$   | days |
| Number of days operating for 24 hours instead of 16  | $N_{24,16}$  | days |

The plant size ratio (PSR) for the dwelling is calculated using the maximum output of the micro-cogeneration package and the design heat loss of the dwelling taken as the heat loss coefficient, box (37) of the worksheet, multiplied by a temperature difference of 20 K. 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. The intermediate results applicable to the dwelling are then obtained by linear interpolation between the intermediate results<sup>†</sup> for the two sets of data whose PSRs enclose that of the actual dwelling. The dwelling-specific result sets are used in equations (N1) to (N4) to calculate the parameters used in the SAP calculation.

### N3 Calculation of space and water heating, and electricity produced

The electricity used by any fans within the package is included in  $E_{mc,hs}$  and  $E_{mc,sum}$  and is not included separately in the SAP calculation, thus box (87b) is zero.

If the micro-cogeneration package includes a central heating system pump to circulate water through the heat emitters the electricity for it is included in  $E_{mc,hs}$  and the heat gain from it is allowed for in  $\eta_{sp}$ . In that case no allowance for a central heating pump is included in box (53b) and box (87a) is zero. If the package does not include a central heating pump, it is provided separately outside the package, and the gain from Table 5a is included in box (53b) and electricity use from Table 4f is included in box (87a).

#### Mean internal temperature

The micro-cogeneration package, when undersized in relation to the dwelling's design heat loss, can provide space heating needs on more days of the heating season if it operates for 16 hours per day or continuously. The seasonal thermal efficiency and electricity generated in the intermediate results are based on the hours of operation indicated by the parameters  $N_{16,9}$ ,  $N_{24,9}$  and  $N_{24,16}$  for a total heating season length of 238 days (34 weeks). For the normal SAP heating schedule, this would comprise 78 weekend days with

\* The heating season and summer season together comprise a whole year.

† For the efficiency values, the interpolated efficiency is the reciprocal of linear interpolation between the reciprocals of the efficiencies.

16 hours of heating and 170 weekdays with 9 hours of heating (2 hours in the morning and 7 hours in the evening). The mean internal temperature in the living area for the heating season is

$$MIT = [ (N_{24,16} + N_{24,9}) T_{24} + (78 - N_{24,16} + N_{16,9}) T_{16} + (170 - N_{16,9} - N_{24,9}) T_9 ] / 238 \quad (N1)$$

where  $T_{24}$ ,  $T_{16}$  and  $T_9$  are the mean temperatures for 24, 16 and 9 hours of heating, given in Table N2. MIT from equation (N1) is used instead of a value obtained from the data in Table 8.

**Table N2: Internal temperature of living area for different hours of operation**  
*HLP is item (38) in the worksheet*

| <b>HLP</b>      | <b>T<sub>24</sub><br/>continuous</b> | <b>T<sub>16</sub><br/>16 hours/day</b> | <b>T<sub>9</sub><br/>9 hours/day</b> |
|-----------------|--------------------------------------|--|--------------------------------------|
| 1.0 (or lower)  | 21.00                                | 19.63                                  | 18.58                                |
| 1.5             | 21.00                                | 19.63                                  | 18.58                                |
| 2.0             | 21.00                                | 19.61                                  | 18.55                                |
| 2.5             | 21.00                                | 19.58                                  | 18.50                                |
| 3.0             | 21.00                                | 19.53                                  | 18.40                                |
| 3.5             | 21.00                                | 19.45                                  | 18.26                                |
| 4.0             | 21.00                                | 19.36                                  | 18.11                                |
| 4.5             | 21.00                                | 19.27                                  | 17.94                                |
| 5.0             | 21.00                                | 19.16                                  | 17.75                                |
| 5.5             | 21.00                                | 19.04                                  | 17.54                                |
| 6.0 (or higher) | 21.00                                | 18.93                                  | 17.32                                |

#### Efficiency

If the micro-cogeneration package provides both space and hot water heating, use the heat efficiency  $\eta_{hs}$  and  $\eta_{sum}$  in boxes (83) and (86) respectively.

If the package only provides space heating use the seasonal heat efficiency  $\eta_{hs}$  for space heating only in box (83) and specify a separate hot water system such as an electric immersion heater.

If the package is a condensing type, the efficiency adjustments in Table 4c(1) apply where relevant.

#### Hot water storage losses

If the micro-cogeneration package contains within it a storage vessel for domestic hot water that was included in the energy performance tests, heat losses associated with hot water storage are included in the intermediate results and zero is entered for the cylinder loss (46) and the primary loss (48). The distribution loss (40) is included as normal.

If the package does not contain a storage vessel for domestic hot water, a cylinder is specified separately and the cylinder loss and primary loss are included in the SAP calculation.

#### Secondary heating

The auxiliary heating requirement  $Q_{aux}$  is provided by a secondary heating system (any system from the room heater section of Table 4a). The secondary fraction is calculated from

$$SF = \frac{Q_{aux}}{Q_{sp} + Q_{aux}} \quad (N2)$$

#### Electricity

If the package provides both space and hot water heating, the electricity consumed or generated is scaled to the actual heat requirement of the dwelling for both heating and hot water:

$$E^* = \frac{[\text{box (81)}] \times (1 - SF) + [0.66 \times \text{box (51)}]}{Q_{sp} + 0.66 \times Q_{hw}} \times E_{mc,hs} + \frac{\text{box(51)}}{Q_{hw}} \times E_{mc,sum} \quad (N3)$$

(0.66 is the heating season as a fraction of a year).

If the package provides space heating only, the electricity consumed or generated is scaled to the actual space heating requirement of the dwelling:

$$E^* = \frac{\text{box(81)} \times (1 - SF)}{Q_{sp}} \times E_{mc,hs} \quad (N4)$$

If  $E^*$  is positive, enter  $E^*$  in box (96) and use the unit price for standard tariff electricity in the calculation of box (96a).

If  $E^*$  is negative, enter  $E^*$  in box (95). 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 day rate 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 box (95a) is then:

$$\beta \times \text{normal electricity price} + (1 - \beta) \times \text{exported electricity price}.$$

If  $E^*$  is positive, the emission factor used in the calculation of box (111) is that for grid-supplied electricity from Table 12.

If  $E^*$  is negative, the emission factor used in the calculation of box (110) is that for grid-displaced electricity from Table 12.

## Appendix P: Assessment of internal temperature in summer

This appendix provides a method for assessing the propensity of a house to have high internal temperature in hot weather. 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 CO<sub>2</sub> emissions.

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 'Reducing overheating – a designer's guide', CE 129, Energy Efficiency Best Practice in Housing, Energy Saving Trust, London (2005).

### P1 Assessment procedure

1. Obtain a value for the effective air change rate during hot weather. Indicative values based on the procedure in BS 5925\* are given in Table P1.

**Table P1: Effective air change rate**

| Window opening  | Effective air change rate in ach |                               |                    |
|---|----------------------------------|-------------------------------|--------------------|
|   | Trickle vents only               | Windows slightly open (50 mm) | Windows fully open |
| Single storey dwelling (bungalow, flat)<br>Cross ventilation possible                         | 0.1                              | 0.8                           | 6                  |
| Single storey dwelling (bungalow, flat)<br>Cross ventilation not possible                     | 0.1                              | 0.5                           | 4                  |
| Two storey dwelling<br>windows open upstairs and downstairs<br>Cross ventilation possible     | 0.2                              | 1                             | 8                  |
| Two storey dwelling<br>windows open upstairs and downstairs<br>Cross ventilation not possible | 0.1                              | 0.6                           | 5                  |

If there is a mechanical ventilation system providing a specified air change rate, that rate can be used instead.

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, m<sup>3</sup>

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 (box (35) of the worksheet).

\* BS 5925:1991, Code of practice for ventilation principles and design for natural ventilation

4. Calculate the total solar gains for the summer period,  $G_{\text{solar}}^{\text{summer}}$ , using the solar flux for the summer period from Table 6a.

$$G_{\text{solar}}^{\text{summer}} = \sum (0.9 \times A_w \times S \times g_{\perp} \times FF \times Z_{\text{summer}}) \quad (\text{P3})$$

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 or a glazed door),  $\text{m}^2$

$S$  is the solar flux on a surface during the summer period from Table 6a,  $\text{W}/\text{m}^2$

$g_{\perp}$  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 summer solar access factor from Table 6d (usually for average overshading)

Solar gains should be calculated separately for each orientation and for rooflights, and totalled according to equation (P3).

For data to calculate  $Z_{\text{summer}}$  see section 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), so that the total gains are:

$$G = G_{\text{solar}}^{\text{summer}} + G_i \quad (\text{P4})$$

5. Calculate the summer Gain/Loss ratio:

$$\text{Summer Gain/Loss ratio} = \frac{G}{H} \quad (\text{P5})$$

6. Obtain the summer mean external temperature,  $T_e^{\text{summer}}$ , from Table P2.

**Table P2: Summer mean external temperature**

| Region   | Mean external temperature, $T_e^{\text{summer}}$ , used for estimating mean internal temperature in summer |
|--|--|
| Thames valley  | 17   |
| Severn valley; South, South East, South West England | 16   |
| Midlands; East Anglia; East Pennines; West Pennines  | 15.5   |
| North West, North East England; Borders              | 14   |
| Wales, Northern Ireland, East, West Scotland         | 14   |
| North East Scotland; Highland; Western Isles         | 13   |
| Orkney   | 12   |
| Shetland   | 11   |

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.

$$T_{\text{threshold}} = T_e^{\text{summer}} + \frac{G}{H} + \Delta T_{\text{mass}} \quad (\text{P6})$$

where

$$\Delta T_{\text{mass}} = 2.0 - 0.2 \times \text{TMP} \quad \text{if } \text{TMP} < 10$$

$$\Delta T_{\text{mass}} = 0 \quad \text{if } \text{TMP} \geq 10$$

TMP typically varies between 5 for lightweight construction to 20 for heavy construction. For further details see section P4.

8. Use Table P3 to estimate tendency to high internal temperature in hot weather.

**Table P3: 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°C               | Not significant  |
| ≥ 20.5°C and < 22.0°C  | Slight   |
| ≥ 22.0°C and < 23.5°C  | Medium   |
| ≥ 23.5°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 P3 for stated assumptions on occupant-determined factors (usage of blinds/curtains and window opening).

If the orientation of the dwelling is not known, the assessment should be for the orientation giving the greatest tendency to high internal temperature.

## P3 Solar shading

$Z_{\text{summer}}$  is given by

$$Z_{\text{summer}} = Z_{\text{blinds}} (Z + Z_{\text{overhangs}} - 1) \quad (\text{P7})$$

subject to

$$Z_{\text{summer}} \geq 0.1 Z_{\text{blinds}} \quad (\text{P8})$$

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 P4 gives values for  $Z_{\text{blinds}}$ , and Tables P5 and P6 give values for  $Z_{\text{overhangs}}$ . If there are no overhangs,  $Z_{\text{overhangs}} = 1$ .

### P3.1 Curtains and blinds

**Table P4 : Shading factors for blinds, curtains or external shutters**

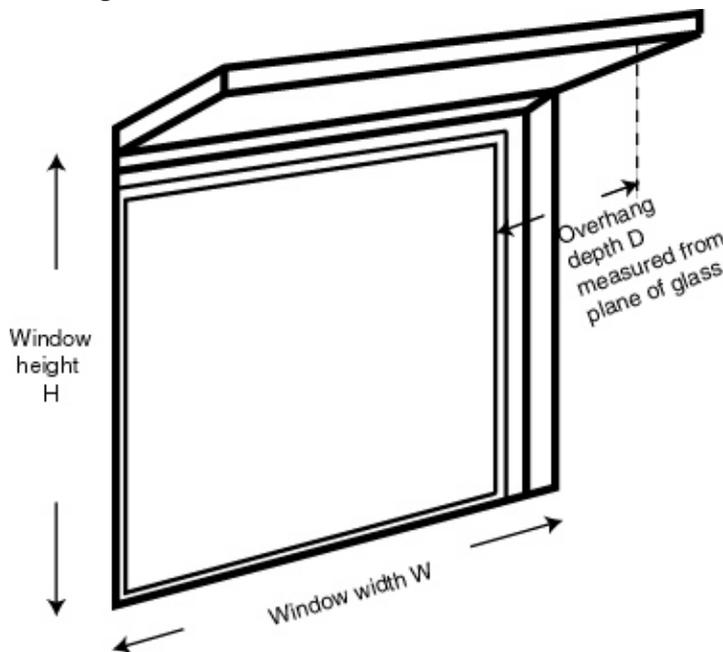
| Blind or curtain type                           | $Z_{\text{blind}}$ |
|---|--------------------|
| Net curtain (covering whole window)             | 0.80               |
| Net curtain (covering half window)              | 0.90               |
| Dark-coloured curtain or roller blind (note 1)  | 0.85               |
| Light-coloured curtain or roller blind (note 1) | 0.60               |
| Dark-coloured venetian blind (note 2)           | 0.88               |
| Light-coloured venetian blind (note 2)          | 0.70               |

|   |      |
|---|------|
| Dark-coloured external shutter, window closed     | 0.24 |
| White external shutter, window closed             | 0.27 |
| Dark-coloured external shutter, window fully open | 0.85 |
| White external shutter, window fully open         | 0.65 |

Notes to Table P4

1. Factor applies when fully closed. If closed only for a fraction  $f$  of the daylight hours use  $f \times Z_{\text{blind}} + (1 - f)$ .
2. 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 use  $f \times Z_{\text{blind}} + (1 - f)$ .

**P3.2 Overhangs**



Where the overhang is at least twice as wide as the window (e.g. balconies on blocks of flats) use Table P5. In other cases use Table P6. Interpolation may be used between rows of these tables. Usually the same value of  $Z_{\text{overhangs}}$  can be applied to all the windows on a given façade on the basis of an average depth-to-height ratio.

**Table P5:  $Z_{\text{overhangs}}$  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 P6:  $Z_{\text{overhangs}}$  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

#### P4 Thermal mass

The thermal mass of a building is represented by the thermal mass parameter (TMP). Table P7 gives some indicative values of TMP based on the characteristics of the construction elements. For this purpose the mass of an element is low for admittance less than 2 W/m<sup>2</sup>K, medium 2 to 3.5 W/m<sup>2</sup>K and high over 3.5 W/m<sup>2</sup>K (see Table P8). Note that the threshold temperature is not affected by any increase in TMP above 10.

**Table P7: Indicative values of thermal mass parameter**

| Mass of construction elements |                |                  |                     | Illustrative construction   | TMP<br>W/m <sup>2</sup> K |
|-------------------------------|----------------|------------------|---------------------|---|---------------------------|
| Ground floor                  | External walls | Separating walls | Internal partitions |   |                           |
| low                           | low            | low              | low                 | suspended timber floor, timber/steel frame walls, plasterboard on timber/steel stud internal partitions   | 5                         |
| medium                        | low            | low              | low                 | solid floor, timber/steel frame walls, plasterboard on timber/steel stud internal partitions  | 6                         |
| medium                        | low            | medium           | low                 | solid floor, masonry external walls (internal insulation), masonry separating walls with plasterboard on dabs, plasterboard on timber/steel stud internal partitions  | 7                         |
| medium                        | medium         | medium           | low                 | solid floor, masonry external walls (cavity fill or external insulation) with plasterboard on dabs, masonry separating walls with plasterboard on dabs, plasterboard on timber/steel stud internal partitions | 8                         |
| medium                        | medium         | high             | low                 | solid floor, masonry external walls (cavity fill or external insulation) with plasterboard on dabs, masonry separating walls dense plaster, plasterboard on timber/steel stud internal partitions             | 9                         |
| medium                        | high           | medium           | low                 | solid floor, masonry external walls (cavity fill or external insulation) with dense plaster, masonry separating walls with plasterboard on dabs, plasterboard on timber/steel stud internal partitions        | 10                        |

|        |        |        |        |  |    |
|--------|--------|--------|--------|--|----|
| medium | low    | medium | medium | solid floor, masonry external walls (internal insulation), masonry separating walls with plasterboard on dabs, masonry internal partitions with plasterboard on dabs                                     | 11 |
| medium | high   | high   | low    | solid floor, masonry external walls (cavity fill or external insulation) with dense plaster, masonry separating walls with dense plaster, plasterboard on timber/steel stud internal partitions          | 11 |
| medium | medium | medium | medium | solid floor, masonry external walls (cavity fill or external insulation) with plasterboard on dabs, masonry separating walls plasterboard on dabs, masonry internal partitions with plasterboard on dabs | 12 |
| medium | medium | high   | high   | solid floor, masonry external walls (cavity fill or external insulation) with plasterboard on dabs, masonry separating walls dense plaster, masonry internal walls with dense plaster                    | 17 |
| medium | high   | high   | high   | solid floor, masonry external walls (cavity fill or external insulation) with dense plaster, masonry separating walls with dense plaster, masonry internal walls with dense plaster                      | 19 |

Alternatively, TMP can be calculated from the admittances of the elements comprising the structure of the dwelling. It is defined as

$$TMP = \frac{\sum AY}{TFA} \quad (P9)$$

where A and Y are the areas and admittance of each element of the construction and TFA is the total floor area of the dwelling.

Thin elements like windows and doors are omitted from the calculation of  $\sum AY$  but, unlike the calculation of  $\sum AU$  for heat loss calculations, the sum includes all internal partitions, intermediate floors and party walls and floors. The area of an internal partition includes both sides of the partition. The admittance of a building element is determined primarily by the properties of the layers adjacent to the room. Values for some common constructions are given in Table P8.

**Table P8: Y-values for common constructions**

| <b>Construction</b><br>(external elements insulated to typical new-build levels) | <b>Admittance Y (W/m<sup>2</sup>K)</b> |
|--|--|
| <b>Ground floors</b>   |  |
| Suspended timber, carpeted   | 1.4                                    |
| Suspended timber, laminated  | 1.7                                    |
| Slab on ground (insulation above or below slab, screed on top, carpeted)         | 3.2                                    |
| Slab on ground (insulation above or below slab, screed on top, laminated)        | 3.4                                    |
| Suspended concrete floor, carpeted   | 3.0                                    |
| Suspended concrete floor, laminated  | 3.2                                    |
| <b>Exposed floors</b>  |  |
| Timber exposed floor, carpeted   | 1.2                                    |
| Timber exposed floor, laminated  | 1.5                                    |
| <b>External walls - masonry, solid, external insulation</b>                      |  |
| Solid wall: dense plaster, 200 mm dense block, insulated externally              | 4.8                                    |

|  |         |
|--|---------|
| Solid wall: plasterboard on dabs, 200 mm dense block, insulated externally                               | 2.5     |
| Solid wall: dense plaster, 210 mm brick, insulated externally  | 4.1     |
| Solid wall: plasterboard on dabs, 210 mm brick, insulated externally                                     | 2.3     |
| <b>External walls - masonry, solid, internal insulation</b>  |         |
| Solid wall: dense plaster, insulation, dense block or brick, rendered                                    | 1.3     |
| Solid wall: plasterboard on dabs, insulation, dense block or brick, rendered                             | 0.7     |
| <b>External walls - cavity masonry walls, full or partial cavity fill</b>                                |         |
| Cavity wall: dense plaster, dense block, filled cavity, dense block or brick                             | 5.2     |
| Cavity wall: dense plaster, AAC block, filled cavity, AAC block  | 3.0     |
| Cavity wall: plasterboard on dabs, dense block, filled cavity, dense block or brick                      | 2.6     |
| Cavity wall: plasterboard on dabs, AAC block, filled cavity, AAC block                                   | 2.0     |
| <b>External walls – concrete panel construction (precast or in-situ)</b>                                 |         |
| Plasterboard directly fixed, concrete panel construction   | 4.5     |
| Plasterboard directly fixed with 5 mm air gap, concrete panel construction                               | 3.1     |
| Plasterboard, internal insulation board, concrete panel construction                                     | 0.9     |
| <b>External walls – timber or steel frame</b>  |         |
| Timber framed wall (one layer of plasterboard)   | 0.8     |
| Timber framed wall (two layers of plasterboard)  | 1.3     |
| Steel frame wall (warm frame construction)   | 2.0     |
| Steel frame wall (hybrid construction)   | 1.1     |
| <b>Roofs</b>   |         |
| Insulated at ceiling level   | 0.7     |
| Insulated slope  | 0.7     |
| Insulated flat roof  | 0.7     |
| <b>Separating walls</b>  |         |
| Dense plaster both sides, dense blocks, cavity<br>(E-WM-1 or E-WM-2)*                                    | 5.0     |
| Single plasterboard on dabs on both sides, dense blocks, cavity<br>(E-WM-3 or E-WM-4)*                   | 2.5     |
| Plaster on dabs and single plasterboard on both sides, dense cellular blocks, cavity<br>(E-WM-5)*        | 2.5     |
| Plasterboard on dabs mounted on cement render on both sides, AAC blocks, cavity<br>(E-WM-6 or E-WM-7)*   | 2.2     |
| Double plasterboard on both sides, twin timber frame with/without sheathing board<br>(E-WT-1 or E-WT-2)* | 1.4     |
| Steel frame (E-WS-1 to E-WS-3)*  | 1.4     |
| <b>Separating floors (Y from above /Y from below)</b>  |         |
| Precast concrete planks floor, screed, carpeted (E-FC-1)*  | 1.9/1.9 |
| Concrete floor slab, carpeted (E-FC-2)*  | 2.0/2.7 |
| Precast concrete plank floor (screed laid on insulation), carpeted (E-FC-3)*                             | 2.3/1.9 |
| Precast concrete plank floor (screed laid on rubber), carpeted (E-FC-4)*                                 | 2.7/1.9 |
| In-situ concrete slab supported by profiled metal deck, carpeted (E-FS-1)*                               | 1.9/2.7 |
| Timber I-joists, carpeted (E-FT-1)*  | 1.7/1.4 |
| <b>Internal partitions</b>   |         |
| Plasterboard on timber frame   | 0.8     |
| Dense block, dense plaster   | 4.6     |
| Dense block, plasterboard on dabs  | 2.6     |
| <b>Ceiling/floor between floors in a house (Y from above/Y from below)</b>                               |         |
| Plasterboard ceiling, carpeted chipboard floor   | 0.9/1.0 |

\* Reference in the Robust Details for Part E “Resistance to the passage of sound”

## Appendix Q: Special features and specific data

### Q1 Special features

This section provides a method to allow for the benefits of new energy-saving 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 recognised as part of SAP by being described on the web page [www.bre.co.uk/sap2005](http://www.bre.co.uk/sap2005) (or a web page linked to it). For recognised systems, this web page will contain details for calculating the data to be entered into the worksheet.

In general, a technology may use one form of energy to achieve savings in another form of energy.

*Example. If whole-house mechanical ventilation with heat recovery were to be assessed in this way for a oil-heated house:*

- *the web page would contain the routine for calculating the heat recovered (and so the energy saved), together with a routine to calculate the energy used by fans;*
- *the energy saved would be applied with the cost and CO<sub>2</sub> emission factors for oil;*
- *the electricity used for fans would be applied with the cost and CO<sub>2</sub> factors for electricity.*

In the worksheet:

SAP rating:

1. include the amount of energy saved by the technology (kWh/year) in box (94);
2. multiply the amount of saved energy by the unit price of the fuel concerned and enter the result in box (94a);
3. include the amount of energy used by the technology in box (95);
4. multiply the energy used by the unit price of the fuel concerned and enter the result in box (95a);
5. include both these items in the calculation of the total energy cost in box (97).

CO<sub>2</sub> Emissions:

1. the amount of energy saved by the technology (kWh/year) in box (94) is multiplied by the appropriate emission factor and subtracted from the total CO<sub>2</sub> emissions;
2. the amount of energy used by the technology (kWh/year) in box (95) is multiplied by the appropriate emission factor and added to the total CO<sub>2</sub> emissions.

### Q2 Specific data

A similar mechanism will be used, if appropriate, to permit the use of data specific to a technology instead of the data provided in the SAP tables. For recognised data types, the web page mentioned above will give details of the conditions for accepting the data and its applicability within the SAP calculation.

## Appendix R: Reference values

This appendix provides a set of reference values for the parameters of a SAP calculation, which are used in connection with establishing a target CO<sub>2</sub> emissions rate for the purposes of demonstrating compliance with regulations for new dwellings. Table R1 is used to define a notional dwelling of the same size and shape as the actual dwelling.

The CO<sub>2</sub> emissions per unit floor area from the notional dwelling are adjusted as specified in the applicable regulatory document to form the target CO<sub>2</sub> emission rate for the actual dwelling.

CO<sub>2</sub> emissions associated with internal lighting should be recorded separately. CO<sub>2</sub> emissions associated with electricity consumption for pumps and fans are included with those for heating and hot water.

**Table R1 : Reference values**

| Element or system                      | Value  |
|--|--|
| Size and shape                         | Same as actual dwelling  |
| Opening areas (windows and doors)      | 25% of total floor area<br>(or, if total exposed façade area is less than 25% of the total floor area, the total exposed façade area)<br>The above includes one opaque door of area 1.85 m <sup>2</sup> , any other doors are fully glazed |
| Walls                                  | U = 0.35 W/m <sup>2</sup> K  |
| Floors                                 | U = 0.25 W/m <sup>2</sup> K  |
| Roofs                                  | U = 0.16 W/m <sup>2</sup> K  |
| Opaque door                            | U = 2.0 W/m <sup>2</sup> K   |
| Windows and glazed doors               | U = 2.0 W/m <sup>2</sup> K<br>Double glazed, low-E hard coat<br>Frame factor 0.7<br>Solar energy transmittance 0.72<br>Light transmittance 0.80  |
| Living area fraction                   | Same as actual dwelling  |
| Shading and orientation                | All glazing orientated E/W;<br>average overshading   |
| Number of sheltered sides              | 2  |
| Allowance for thermal bridging         | 0.11 x total exposed surface area (W/K)  |
| Ventilation system                     | Natural ventilation with intermittent extract fans   |
| Air permeability                       | 10 m <sup>3</sup> /m <sup>2</sup> ·h at 50 Pa  |
| Chimneys                               | None   |
| Open flues                             | None   |
| Extract fans                           | 3 for dwellings with floor area greater than 80 m <sup>2</sup> ,<br>2 for smaller dwellings  |
| Primary heating fuel (space and water) | Mains gas  |
| Heating system                         | Boiler and radiators<br>water pump in heated space   |
| Boiler                                 | SEDBUK 78%<br>room-sealed<br>fanned flue   |
| Heating system controls                | Programmer + room thermostat + TRVs<br>boiler interlock  |

|   |   |
|---|---|
| Hot water system  | Stored hot water, heated by boiler<br>separate time control for space and water heating |
| Hot water cylinder  | 150 litre cylinder insulated with 35 mm of factory applied foam                         |
| Primary water heating losses  | Primary pipework not insulated<br>cylinder temperature controlled by thermostat         |
| Secondary space heating   | 10% electric  |
| Low energy light fittings   | 30% of fixed outlets  |
| <p><i>Note: Building regulations can vary between England &amp; Wales, Scotland and Northern Ireland.<br/>The data in the table should only be used subject to any qualifications or amendments given in the<br/>regulatory documents that apply in the Administration where the dwelling(s) will be constructed.</i></p> |   |

## Appendix S : Reduced Data SAP for existing dwellings

Reduced Data SAP has been developed by government for use in existing dwellings based on a site survey of the property, when the complete data set for a SAP calculation is not available. It consists of a system of data collection (defined in Table S19) together with defaults and inference procedures, as defined by the rules given in this Appendix, that generate a complete set of input data for the SAP calculation. For any item not mentioned in this Appendix, the procedures and data given elsewhere in this document apply.

This Appendix forms part of SAP 2005 and provides a methodology for existing dwellings that is compliant with the Energy Performance of Buildings Directive. It is not appropriate for new dwellings for which all data for the calculation should be acquired related to the dwelling concerned.

### S1 Dwelling types

Dwellings are classified as one of

- house
- bungalow
- flat
- maisonette

and one of

- detached
- semi-detached
- mid-terrace
- end-terrace
- enclosed mid-terrace
- enclosed end-terrace

A house or bungalow has a completely exposed ground floor and a completely exposed roof. A flat or maisonette does not have both.

"Enclosed" is typically applicable for "back-to-back" terraces and has the following meaning:

- mid-terrace has external walls on two opposite sides;
- enclosed mid terrace has an external wall on one side only;
- end-terrace has three external walls;
- enclosed end-terrace has two adjacent external walls.

Many dwellings have an extension either added onto the main part, or built at the same time but of different construction or insulation. In these cases, dimensions and constructional details of the main part of the dwelling and the extension are recorded separately, to allow the assignment of different U-values to the original and to the extension. Occasionally there may be two extensions whose details need each to be recorded separately. In addition, dwellings can have a different construction for some parts of the walls (for example, a timber framed bay window in otherwise masonry construction). These are recorded as a separate constructional element, termed "alternative wall".

## S2 Age bands

A set of age bands is defined according to Table S1 for the purposes of assigning U-values and other data.

**Table S1 : Age bands**

| Age band | Years of construction |              |                  |
|----------|-----------------------|--------------|------------------|
|          | England & Wales       | Scotland     | Northern Ireland |
| A        | before 1900           | before 1919  | before 1919      |
| B        | 1900-1929             | 1919-1929    | 1919-1929        |
| C        | 1930-1949             | 1930-1949    | 1930-1949        |
| D        | 1950-1966             | 1950-1964    | 1950-1973        |
| E        | 1967-1975             | 1965-1975    | 1974-1977        |
| F        | 1976-1982             | 1976-1983    | 1978-1985        |
| G        | 1983-1990             | 1984-1991    | 1986-1991        |
| H        | 1991-1995             | 1992-1998    | 1992-1999        |
| I        | 1996-2002             | 1999-2002    | 2000-2006        |
| J        | 2003-2006             | 2003-2007    | (not applicable) |
| K        | 2007 onwards          | 2008 onwards | 2007 onwards     |

*Note. From the 1960s, constructional changes have been caused primarily by amendments to building regulations for the conservation of fuel and power, which have called for increasing levels of thermal insulation. The dates in Table S1 are generally one year after a change in regulations, to allow for completion of dwellings approved under the previous regulations.*

## S3 Heat loss areas

Heat loss areas are determined separately for the main part of the dwelling and any extension.

### S3.1 Conversion to internal dimensions

If horizontal dimensions are measured externally, they are converted to overall internal dimensions for use in SAP calculations by application of the appropriate equations in Table S2, using the appropriate wall thickness from Table S3. External dimensions should be measured to the mid-point of party walls dividing two dwellings. The equations are applied on a storey-by-storey basis, for the whole dwelling (i.e. inclusive of any extension).

**Table S2 : Conversion of dimensions**

| Dwelling type                | Equations   |
|------------------------------|---|
| Detached                     | $P_{\text{int}} = P_{\text{ext}} - 8 w$ $A_{\text{int}} = A_{\text{ext}} - w (P_{\text{int}} - 4 w^2)$  |
| Semi-detached or End-terrace | $P_{\text{int}} = P_{\text{ext}} - 5 w$ $a = 0.25 \left( P_{\text{ext}} + \sqrt{P_{\text{ext}}^2 - 8 A_{\text{ext}}} \right)$ $A_{\text{int}} = A_{\text{ext}} - w (P_{\text{int}} + 0.5 A_{\text{ext}}/a) - 2 w^2$ |
| Mid-terrace                  | $P_{\text{int}} = P_{\text{ext}} - 2 w$ $A_{\text{int}} = A_{\text{ext}} - w (P_{\text{ext}} + 2 A_{\text{ext}}/P_{\text{ext}}) + 2 w^2$  |

|  |  |
|--|--|
| Enclosed end-terrace   | $P_{int} = P_{ext} - 3 w$<br>$A_{int} = A_{ext} - 1.5 w P_{ext} + 2.25 w^2$                  |
| Enclosed mid-terrace   | $P_{int} = P_{ext} - w$<br>$A_{int} = A_{ext} - w (A_{ext}/P_{ext} + 1.5 P_{ext}) + 1.5 w^2$ |
| All types  | Perimeter ratio = $P_{int}/P_{ext}$<br>Area ratio = $A_{int}/P_{ext}$                        |
| <p><math>P_{ext}</math> and <math>A_{ext}</math> are the measured external perimeter and area (of whole dwelling)<br/> <math>P_{int}</math> and <math>A_{int}</math> are the calculated internal perimeter and area<br/> <math>w</math> is the wall thickness<br/> After obtaining the perimeter ratio and area ratio for the whole dwelling, multiply separately the measured perimeters and areas of (a) the main part of the dwelling and (b) any extension, by these ratios.</p> |  |

**Table S3 : Wall thickness (m)**

| Age band                                       | A    | B    | C    | D    | E    | F    | G    | H    | I, J, K |
|--|------|------|------|------|------|------|------|------|---------|
| <b>Wall type</b>                               |      |      |      |      |      |      |      |      |         |
| Stone as built*                                | 0.50 | 0.50 | 0.50 | 0.50 | 0.45 | 0.42 | 0.42 | 0.42 | 0.45    |
| Stone + internal or external insulation*       | 0.57 | 0.57 | 0.57 | 0.57 | 0.52 | 0.49 | 0.49 | 0.49 | 0.52    |
| Solid Brick as built                           | 0.22 | 0.22 | 0.22 | 0.22 | 0.24 | 0.25 | 0.27 | 0.27 | 0.30    |
| Solid brick + internal or external insulation  | 0.29 | 0.29 | 0.29 | 0.29 | 0.31 | 0.32 | 0.34 | 0.34 | 0.37    |
| Cavity**                                       | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.26 | 0.27 | 0.27 | 0.30    |
| Timber Frame                                   | 0.15 | 0.15 | 0.15 | 0.25 | 0.27 | 0.27 | 0.27 | 0.27 | 0.30    |
| System Build                                   | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.30 | 0.30 | 0.30 | 0.30    |
| System build + internal or external insulation | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.37 | 0.37 | 0.37 | 0.37    |

\* If in Scotland add 0.20 m for bands A and B, and 0.10 for other bands

\*\* If in Scotland add 0.05 m

### S3.2 Heights and exposed wall areas

Heights are measured internally within each room, and 0.25 m is added to each room height except for the lowest storey of the dwelling, to obtain the storey height. Façade areas are obtained from the product of heat loss perimeter (after conversion to internal dimensions if relevant) and storey height, summed over all storeys. For the main house and any extension(s), window and door areas are deducted from the façade areas to obtain the net wall areas for the heat loss calculations. If an alternative wall is present, the area of the alternative wall is recorded net of any openings in it and identified as part of the main wall or extension wall, so that it may be subtracted from that wall area prior to the calculation of wall heat losses.

### S3.3 Door and window areas

The area of external doors is taken as 1.85 m<sup>2</sup>. The number of external doors is:

- flat/maisonette with heated corridor: 0
- flat/maisonette with unheated corridor or no corridor: 1
- house/bungalow: 2

Window areas are obtained by application of the appropriate equation from Table S4. The equation used is chosen according to the age band of the main part of the dwelling, with the resulting total window area apportioned between main part and extension pro rata to their wall areas.

**Table S4 : Window area (m<sup>2</sup>)**

| Age band  | House or Bungalow       | Flat or Maisonette      |
|---|-------------------------|-------------------------|
| A, B ,C   | WA = 0.1220 TFA + 6.875 | WA = 0.0801 TFA + 5.580 |
| D   | WA = 0.1294 TFA + 5.515 | WA = 0.0341 TFA + 8.562 |
| E   | WA = 0.1239 TFA + 7.332 | WA = 0.0717 TFA + 6.560 |
| F   | WA = 0.1252 TFA + 5.520 | WA = 0.1199 TFA + 1.975 |
| G   | WA = 0.1356 TFA + 5.242 | WA = 0.0510 TFA + 4.554 |
| H   | WA = 0.0948 TFA + 6.534 | WA = 0.0813 TFA + 3.744 |
| I   | WA = 0.1382 TFA – 0.027 | WA = 0.1148 TFA + 0.392 |
| J, K  | WA = 0.1435 TFA – 0.403 | WA = 0.1747 TFA – 2.834 |
| WA = window area for main part or extension<br>TFA = total floor area of main part or extension |                         |                         |

The window areas calculated using Table S4 should be reduced by 25% if it is assessed as being less than typical for the age and type of property, and increased by 25% if assessed as being more than typical for the age and type of property.

If assessed as much greater than typical, or for an atypical property e.g. a dwelling created by a change of use, the total window area should be obtained from measurements of each individual window. In this case the window areas in the main part of the dwelling and in any extension are recorded separately (along with whether single glazed, or double glazed before or during/after 2002) and Table S4 is not used.

### S3.4 Roof area

Roof area is the greatest of the floor areas on each level.

### S3.5 Room in roof

If there are roof rooms, with a total floor area of  $F_{rr}$  (measured internally), then:

- (1) Area  $F_{rr}$  is deducted from the roof area determined at S3.4.
- (2) A separate heat-loss roof area  $A_{rr}$  is defined, where

$$A_{rr} = F_{rr} + 11.0\sqrt{F_{rr}} / 1.5$$

$A_{rr}$  has a U-value for the appropriate age band for the construction of the roof rooms (see Table S10). The formula is based on a rectangular room-in-roof area of average height 2.2 m, and  $A_{rr}$  includes the walls of the roof rooms as well as their roof.

### S3.6 Heat loss floor area

The lowest floor of a dwelling can be a basement, a ground floor, an exposed floor (e.g. over a passageway) or a semi-exposed floor (e.g. over an integral garage) or not a heat loss floor (flats/maisonettes).

If it is a basement it is treated as if it were a ground floor for heat loss purposes.

### S3.7 Heat loss floor area for houses and bungalows

The area of the lowest occupied floor is a ground floor. If the area of an upper floor is greater than that of the floor below, the difference in these areas is an exposed or semi-exposed floor. Semi exposed floors are treated as if they were fully exposed.

The ground floor area of the main dwelling and that of any extension are treated separately as they can have different U-values.

### S3.8 Heat loss floor area for flats and maisonettes

There is no heat loss through the floor if below it there is another dwelling or other premises that are normally heated. The floor area of the flat, or the lower floor of the maisonette, is an exposed or semi-

exposed floor if there is an open space or unheated premises below it. Semi exposed floors are treated as if they were fully exposed.

### S3.9 Semi-exposed walls for flats and maisonettes

If the flat or maisonette is adjacent to an unheated corridor or stairwell, the area of wall between the dwelling and the corridor or stairwell is treated as a semi-exposed wall. Semi exposed walls in houses and bungalows are treated as if they were fully exposed.

## S4 Parameters for ventilation rate

The parameters for calculation of the ventilation rate are obtained from Table S5.

**Table S5 : Ventilation parameters**

| Parameter  | Value  |
|--|--|
| Chimneys   | Number of open fireplaces  |
| Flues  | Number of open flues (main and secondary heating systems)                              |
| Ventilation system   | Natural with intermittent extract fans, unless mechanical system clearly identified    |
| Extract fans   | Age bands A to E all cases 0   |
|  | Age bands F to G all cases 1   |
|  | Age bands H to K up to 2 rooms 1   |
|  | " 3 to 5 rooms 2   |
|  | " 6 to 8 rooms 3   |
| " more than 8 rooms 4  |  |
| Wall infiltration  | According to wall type, system build treated as masonry                                |
| Floor infiltration (suspended timber floor only)   | Age bands A to E: unsealed<br>Age bands F to K: sealed                                 |
| Draught lobby  | House or bungalow: no<br>Flat or maisonette: yes if heated or unheated corridor        |
| Percent of doors and windows draughtstripped   | Percentage of double glazing (Doors not draughtstripped)                               |
| Number of storeys  | Greater of the number of storeys in the main part of the dwelling and in any extension |
| Sheltered sides  | 4 for flat/maisonette up to third storey above ground level<br>2 in other cases        |
| Age bands in this table relate to the age of the main dwelling and not to any extension<br>The number of rooms is as defined in S9 |  |

## S5 Constructional types and U-values

U-values of construction elements are determined from the constructional type and date of construction. U-values are assessed separately for the main part of the dwelling and for any extension. If the insulation status is unknown, the relevant value for "as built" is used.

### S5.1 U-values of walls

**Table S6 : Wall U-values – England and Wales**

| Age band                                | A    | B    | C    | D    | E    | F     | G     | H     | I                 | J                 | K                 |
|---|------|------|------|------|------|-------|-------|-------|-------------------|-------------------|-------------------|
| Wall type                               |      |      |      |      |      |       |       |       |                   |                   |                   |
| Stone: granite or whin (as built)       | 2.4  | 2.4  | 2.4  | 2.4  | 1.7  | 1.0   | 0.60  | 0.60  | 0.45              | 0.35              | 0.30              |
| Stone: sandstone (as built)             | 2.1  | 2.1  | 2.1  | 2.1  | 1.7  | 1.0   | 0.60  | 0.60  | 0.45              | 0.35              | 0.30              |
| Solid brick (as built)                  | 2.1  | 2.1  | 2.1  | 2.1  | 1.7  | 1.0   | 0.60  | 0.60  | 0.45              | 0.35              | 0.30              |
| Stone/solid brick (external insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.35* | 0.30*             | 0.25*             | 0.21*             |
| Stone/solid brick (internal insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.35* | 0.30*             | 0.25*             | 0.21*             |
| Cavity (as built)                       | 2.1  | 1.6  | 1.6  | 1.6  | 1.6  | 1.0   | 0.60  | 0.60  | 0.45              | 0.35              | 0.30              |
| Filled cavity                           | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.40  | 0.35  | 0.35  | 0.45 <sup>†</sup> | 0.35 <sup>†</sup> | 0.30 <sup>†</sup> |
| Timber frame                            | 2.5  | 1.9  | 1.9  | 1.0  | 0.80 | 0.45  | 0.40  | 0.40  | 0.40              | 0.35              | 0.30              |
| System build (as built)                 | 2.0  | 2.0  | 2.0  | 2.0  | 1.7  | 1.0   | 0.60  | 0.60  | 0.45              | 0.35              | 0.30              |
| System build (external insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.35* | 0.30*             | 0.25*             | 0.21*             |
| System build (internal insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.35* | 0.30*             | 0.25*             | 0.21*             |

\* wall may have had internal or external insulation when originally built; this applies only if insulation is known to have been increased subsequently (otherwise “as built” applies)

<sup>†</sup> assumed as built

**Table S7 : Wall U-values – Scotland**

| Age band                                | A    | B    | C    | D    | E    | F     | G     | H                 | I                 | J                 | K                 |
|---|------|------|------|------|------|-------|-------|-------------------|-------------------|-------------------|-------------------|
| Wall type                               |      |      |      |      |      |       |       |                   |                   |                   |                   |
| Stone: granite or whin (as built)       | 1.7  | 1.7  | 1.7  | 1.7  | 1.7  | 1.0   | 0.60  | 0.45              | 0.45              | 0.30              | 0.27              |
| Stone: sandstone (as built)             | 1.5  | 1.5  | 1.5  | 1.5  | 1.5  | 1.0   | 0.60  | 0.45              | 0.45              | 0.30              | 0.27              |
| Solid brick (as built)                  | 2.1  | 2.1  | 2.1  | 2.1  | 1.7  | 1.0   | 0.60  | 0.45              | 0.45              | 0.30              | 0.27              |
| Stone/solid brick (external insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.30*             | 0.30*             | 0.21*             | 0.20*             |
| Stone/solid brick (internal insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.30*             | 0.30*             | 0.21*             | 0.20*             |
| Cavity (as built)                       | 2.1  | 1.6  | 1.6  | 1.6  | 1.6  | 1.0   | 0.60  | 0.45              | 0.45              | 0.30              | 0.27              |
| Filled cavity                           | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.40  | 0.35  | 0.45 <sup>†</sup> | 0.45 <sup>†</sup> | 0.30 <sup>†</sup> | 0.27 <sup>†</sup> |
| Timber frame                            | 2.5  | 1.9  | 1.9  | 1.0  | 0.80 | 0.45  | 0.40  | 0.40              | 0.40              | 0.30              | 0.27              |
| System build (as built)                 | 2.0  | 2.0  | 2.0  | 2.0  | 1.7  | 1.0   | 0.60  | 0.45              | 0.45              | 0.30              | 0.27              |
| System build (external insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.30*             | 0.30*             | 0.21*             | 0.20*             |
| System build (internal insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.30*             | 0.30*             | 0.21*             | 0.20*             |

\* wall may have had internal or external insulation when originally built; this applies only if insulation is known to have been increased subsequently (otherwise “as built” applies)

<sup>†</sup> assumed as built

**Table S8 : Wall U-values – Northern Ireland**

| Age band                          | A   | B   | C   | D   | E   | F   | G    | H    | I    | J | K    |
|-----------------------------------|-----|-----|-----|-----|-----|-----|------|------|------|---|------|
| Wall type                         |     |     |     |     |     |     |      |      |      |   |      |
| Stone: granite or whin (as built) | 2.4 | 2.4 | 2.4 | 2.4 | 1.7 | 1.0 | 0.60 | 0.45 | 0.45 | - | 0.30 |
| Stone: sandstone (as built)       | 2.1 | 2.1 | 2.1 | 2.1 | 1.7 | 1.0 | 0.60 | 0.45 | 0.45 | - | 0.30 |
| Solid brick (as built)            | 2.1 | 2.1 | 2.1 | 2.1 | 1.7 | 1.0 | 0.60 | 0.45 | 0.45 | - | 0.30 |

|   |      |      |      |      |      |       |       |                   |                   |   |                   |
|---|------|------|------|------|------|-------|-------|-------------------|-------------------|---|-------------------|
| Stone/solid brick (external insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.30*             | 0.30*             | - | 0.21*             |
| Stone/solid brick (internal insulation) | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45* | 0.35* | 0.30*             | 0.30*             | - | 0.21*             |
| Cavity (as built)                       | 2.1  | 1.6  | 1.6  | 1.6  | 1.5  | 1.0   | 0.60  | 0.45              | 0.45              | - | 0.30              |
| Filled cavity                           | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.40  | 0.35  | 0.45 <sup>†</sup> | 0.45 <sup>†</sup> | - | 0.30 <sup>†</sup> |
| Timber frame (as built)                 | 2.5  | 1.9  | 1.9  | 1.0  | 0.80 | 0.45  | 0.40  | 0.40              | 0.40              | - | 0.30              |
| System build (as built)                 | 2.0  | 2.0  | 2.0  | 2.0  | 1.7  | 1.0   | 0.60  | 0.45              | 0.45              | - | 0.30              |
| System build (external insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.30*             | 0.30*             | - | 0.21*             |
| System build (internal insulation)      | 0.60 | 0.60 | 0.60 | 0.60 | 0.55 | 0.45  | 0.35* | 0.30*             | 0.30*             | - | 0.21*             |

\* wall may have had internal or external insulation when originally built; this applies only if insulation is known to have been increased subsequently (otherwise “as built” applies)

<sup>†</sup> assumed as built

### S5.2 U-values of semi-exposed walls

For semi-exposed walls of flats and maisonettes, the U-value for the applicable wall area is taken as that of the external walls of the dwelling adjusted as described in Section 3.3 using  $R_u = 0.4 \text{ m}^2\text{K/W}$ .

### S5.3 U-values of roofs

The U-value assumed for a pitched roof with an insulated ceiling should, where possible, be based on the observed thickness of the loft insulation according to Table S9.

**Table S9 : Roof U-values when loft insulation thickness is known**

| Insulation thickness (mm) | Assumed roof U-value (W/m <sup>2</sup> K) |
|---------------------------|---|
| None                      | 2.3                                       |
| 12                        | 1.5                                       |
| 25                        | 1.0                                       |
| 50                        | 0.68                                      |
| 75                        | 0.50                                      |
| 100                       | 0.40                                      |
| 150                       | 0.29                                      |
| 200                       | 0.20                                      |
| 250                       | 0.16                                      |
| >= 300                    | 0.13                                      |

*Note: These U-values take account of joists. The insulation is taken as being between joists only up to 150 mm, and between and over joists for 200 mm or more.*

If the insulation thickness is not known, the U-value should be taken from Table S10.

**Table S10 : Assumed U-values when the roof insulation thickness is unknown**

| Age band   | Assumed Roof U-value (W/m <sup>2</sup> K) |                                     |           |              |
|------------|---|-------------------------------------|-----------|--------------|
|            | Pitched, insulation between joists        | Pitched, insulation between rafters | Flat roof | Room-in-roof |
| A, B, C, D | 2.3 (none)                                | 2.3                                 | 2.3       | 2.3          |
| E          | 1.5 (12 mm)                               | 1.5                                 | 1.5       | 1.5          |

|   |               |      |      |      |
|---|---------------|------|------|------|
| F | 0.68 (50 mm)  | 0.68 | 0.68 | 0.80 |
| G | 0.40 (100 mm) | 0.40 | 0.40 | 0.50 |
| H | 0.29 (150 mm) | 0.35 | 0.35 | 0.35 |
| I | 0.26 (150 mm) | 0.35 | 0.35 | 0.35 |
| J | 0.16 (250 mm) | 0.20 | 0.25 | 0.30 |
| K | 0.16 (250 mm) | 0.20 | 0.25 | 0.25 |

Note: These U-values take account of joists. They may differ from Elemental U-values in regulations applicable at the time of construction, where the Elemental U-values were set on the basis of ignoring joists in U-value calculations.

#### S5.4 U-values of floors next to the ground

The floor U-value is calculated according to BS EN ISO 13370 using its area and exposed perimeter, and rounded to two decimal places. The following parameters are used:

- wall thickness from Table S3
- soil type clay (thermal conductivity 1.5 W/m·K)
- $R_{si} = 0.17 \text{ m}^2\text{K/W}$
- $R_{se} = 0.04 \text{ m}^2\text{K/W}$
- floor type from Table S11
- all-over floor insulation of thickness from Table S11 with thermal conductivity 0.035 W/m·K

For suspended floors:

- height above external ground level 0.3 m
- average wind speed at 10 m height 5 m/s
- wind shielding factor 0.05
- ventilation openings per m exposed perimeter 0.003 m<sup>2</sup>/m
- U-value of walls to underfloor space 1.5 W/m<sup>2</sup>K

A non-separated conservatory has an uninsulated solid ground floor.

**Table S11 : Basis for floor U-value calculation**

| Age band | Floor type          | All-over floor insulation |          |                  |
|----------|---------------------|---------------------------|----------|------------------|
|          |                     | England & Wales           | Scotland | Northern Ireland |
| A, B     | suspended, unsealed | none                      | none     | none             |
| C to G   | solid               | none                      | none     | none             |
| H        | solid               | none                      | 25 mm    | 25 mm            |
| I        | solid               | 25 mm                     | 50 mm    | 50 mm            |
| J        | solid               | 75 mm                     | 75 mm    | -                |
| K        | solid               | 100 mm                    | 100 mm   | 100 mm           |

#### S5.5 U-values of exposed and semi-exposed upper floors

To simplify data collection no distinction is made in terms of U-value between an exposed floor (to outside air below) and a semi-exposed floor (to an enclosed but unheated space below) and the U-values in Table S12 are used.

**Table S12 : Exposed/Semi-exposed floor U-values**

| Age band | U-value (W/m <sup>2</sup> K) |
|----------|------------------------------|
| A to G   | 1.20                         |
| H or I   | 0.51                         |
| J        | 0.25                         |

|   |      |
|---|------|
| K | 0.22 |
|---|------|

### S5.6 U-value of floor above a partially heated space

The U-value of a floor above partially heated premises is taken as 1.0 W/m<sup>2</sup>K. This applies typically for a flat above non-domestic premises that are not heated to the same extent or duration as the flat.

### S5.7 Allowance for thermal bridging

The thermal bridging factor,  $y$ , as defined in Appendix K is taken from Table S13.

**Table S13 : Thermal bridging**

| Age band | Thermal bridging factor $y$ (W/m <sup>2</sup> K) |
|----------|--|
| A to I   | 0.15   |
| J        | 0.11   |
| K        | 0.08   |

## S6 Non-separated conservatory

The floor area and volume of a non-separated conservatory are added to the total floor area and volume of the dwelling. Its roof area is taken as the same as its floor area, and wall area is taken as the product of its exposed perimeter and its height. Its height can be estimated from the equivalent number of storey heights of the dwelling to the nearest half storey. The conservatory walls and roof are taken as fully glazed (and this glazed area applied in addition to that from Table S4). Glazed walls are taken as windows, glazed roof as rooflight.

## S7 Solar gains

Solar gains are calculated for average overshadowing (Table 6d) and for East/West orientation of all windows. A conservatory roof is taken as horizontal for the purposes of Table 6a.

## S8 Window U-values and g-values

The U-value of windows and the solar transmittance of glazing is taken from Table S14.

**Table S14 : Window characteristics**

| Glazing | Installed   | Frame (for Table 6c) | U-value | g-value |
|---------|---|----------------------|---------|---------|
| Single  | any   | wood frame           | 4.8     | 0.85    |
| Double  | England & Wales: before 2002,<br>Scotland: before 2003<br>N. Ireland: before 2006       | PVC frame            | 3.1     | 0.76    |
| Double  | England & Wales: 2002 or later,<br>Scotland: 2003 or later<br>N. Ireland: 2006 or later | PVC frame            | 2.0     | 0.72    |

Table S15 applies to a non-separated conservatory.

**Table S15 : Non-separated conservatory**

| Glazing | Age | Frame (for | Window | Roof | g-value |
|---------|-----|------------|--------|------|---------|
|---------|-----|------------|--------|------|---------|

|        |             |                  |                |                |      |
|--------|-------------|------------------|----------------|----------------|------|
|        | <b>band</b> | <b>Table 6c)</b> | <b>U-value</b> | <b>U-value</b> |      |
| Single | any         | wood frame       | 4.8            | 5.1            | 0.85 |
| Double | any         | PVC frame        | 3.1            | 3.3            | 0.76 |

### S9 Room count and living area fraction

The room count is based on the number of habitable rooms, which include any living room, sitting room, dining room, bedroom, study and similar; and also a non-separated conservatory.

Excluded from the room count are any kitchen, utility room, bathroom, cloakroom, en-suite accommodation and similar; any hallway, stairs or landing; and also any room not having a window.

For open plan dwellings count all spaces thermally connected to the main living area (e.g. a living/dining room) as one room.

The living area fraction is determined from the number of habitable rooms.

**Table S16 : Living area fraction**

|                              |          |           |           |           |           |           |            |          |
|------------------------------|----------|-----------|-----------|-----------|-----------|-----------|------------|----------|
| <b>Number of rooms:</b>      | <b>1</b> | <b>2</b>  | <b>3</b>  | <b>4</b>  | <b>5</b>  | <b>6</b>  | <b>7</b>   | <b>8</b> |
| <b>Living area fraction:</b> | 0.75     | 0.50      | 0.30      | 0.25      | 0.21      | 0.18      | 0.16       | 0.14     |
|                              |          |           |           |           |           |           |            |          |
| <b>Number of rooms:</b>      | <b>9</b> | <b>10</b> | <b>11</b> | <b>12</b> | <b>13</b> | <b>14</b> | <b>15+</b> |          |
| <b>Living area fraction:</b> | 0.13     | 0.12      | 0.11      | 0.10      | 0.10      | 0.09      | 0.09       |          |

### S10 Space and water heating

Space and water heating systems and their controls are those defined in Tables 4a, 4b and 4e (less some specific systems which will be defined separately). Parameters not included in the data collection (Table S19) are defined in Table S17 and Table S18.

**Table S17 : Cylinder size**

| <b>Descriptor</b> | <b>Indicative size range</b> | <b>Size to be used in SAP calculation</b>   |
|-------------------|------------------------------|---|
| Inaccessible      |                              | Off-peak electric dual immersion: 210 litres<br>From solid fuel boiler: 160 litres<br>Otherwise: 110 litres |
| Normal            | 90 – 130 litres              | 110 litres  |
| Medium            | 131 – 170 litres             | 160 litres  |
| Large             | > 170 litres                 | 210 litres  |

**Table S18 : Heating and hot water parameters**

| <b>Parameter</b>                                | <b>Value</b>   |
|---|--|
| Hot water cylinder insulation if not accessible | Age bands A to F: none<br>Age bands G, H: 25 mm foam<br>Age bands J, K: 35 mm foam |
| Insulation of primary pipework                  | No   |

|  |  |
|--|--|
| Space heating circulation pump for wet systems | Within heated space  |
| Hot water separately timed                     | Age bands A to I: no<br>Age bands J, K: yes  |
| Hot water cylinder in heated space             | Yes  |
| Boiler interlock                               | Assumed present if there is a room thermostat and (for stored hot water systems) a cylinder thermostat. Otherwise not present  |
| Solar panel                                    | If present, the parameters for the calculation are:<br>- panel aperture area 3 m <sup>2</sup><br>- flat panel, $\eta_0 = 0.75$ , $a_1 = 6.0$<br>- facing South, pitch 30°, modest overshading<br>- combined cylinder, solar part one-third of total, or if a combi boiler the cylinder identified is a dedicated solar cylinder<br>- pump is not solar powered |
| Photovoltaics                                  | If present, the parameters for the calculation are:<br>- PV area is roof area for heat loss, times percent of roof area covered by PVs, and if pitched roof divided by $\cos(35^\circ)$<br>- kWp is 0.06 x PV area.<br>- facing South, pitch 30°, modest overshading   |
| Community heating scheme                       | If details cannot be ascertained they are defaulted to:<br>system based on mains gas-fired boiler, efficiency 80%<br>piping installed before 1990, pre-insulated<br>flat-rate charging<br><br>If CHP and details cannot be ascertained they are defaulted to:<br>fraction of heat from CHP = 0.30<br>CHP overall efficiency 75%<br>heat to power ratio = 2.0   |

## S11 Improvement measures

The effect of improvement measures can be assessed by amending the data for the existing dwelling according to the improvement measure being considered. When a number of measures are being considered, the effect of any one of them on the SAP and Environmental Impact ratings depends, in general, on the order in which they are introduced. A standard list of improvement measures and how their effect on energy performance is to be assessed will be published separately.

In most cases, an improvement measure is assessed by adjusting the values within the reduced data set. For increased loft insulation, for example, the calculation would be re-done with a different roof U-value taken from Table S9 according to the proposed new thickness of the loft insulation. For some cases involving new technology, appropriate data may be added in future via the Appendix Q procedure.

## S12 Minimum data to be collected

**Table S19 : Data to be collected**

| Item                      | Data                            | Comment                      |
|---------------------------|---------------------------------|------------------------------|
| Built form and detachment | Classification according to S1. |                              |
| Age band                  | According to S2.                | Identify age band separately |

| Item                        | Data  | Comment   |
|-----------------------------|---|---|
|                             |   | for:<br>– main property<br>– age extension<br>– any rooms in roof   |
| Number of rooms             | Number of habitable rooms<br><br>If half or more of those rooms are not heated, the number of heated habitable rooms                          | Total as defined in S9, inclusive of main property and any extension.<br><br>A heated room is one with a heat emitter in the room.  |
| Dimension type              | Measured internally or externally   | Applies to areas and perimeters. Room heights always measured internally within the room. See S3.   |
| Dimensions                  | Area, average room height and exposed perimeter for each floor  | Measured separately for main property and any extension<br><br>For rooms-in-roof, measure floor area only, inside the dwelling  |
| Non-separated conservatory. | Floor area<br>Glazed perimeter<br>Double glazed (yes/no)<br>Height (number of half storeys of main dwelling)                                  | See section 3.3.3. A separated conservatory is to be disregarded.   |
| Flats and maisonettes       | Corridor, one of:<br>- no corridor<br>- heated corridor<br>- unheated corridor  | Refers to entrance to the flat  |
|                             | If unheated corridor, length of sheltered wall  | The length of wall between flat and corridor  |
|                             | Floor level (0 for ground floor) and number of floors in block  | The lowest floor level of a maisonette  |
|                             | Floor is one of:<br>- above heated space<br>- above partially heated space<br>- above unheated space or fully exposed                         | A heated space below applies when it is above another flat. A partially heated space below applies when it is above non-domestic premises.<br>An unheated space below applies when it is above a space not used for habitation. Where the flat is above more than one type, it is classified according to the largest floor area concerned. |
| Wall construction           | One of:<br>- stone (granite or whin)<br>- stone (sandstone)<br>- solid brick<br>- cavity<br>- timber frame<br>- system build (i.e. any other) | Recorded separately for main dwelling and any extension.  |

| Item   | Data   | Comment   |
|--|--|---|
| Wall insulation  | One of:<br>- external<br>- filled cavity<br>- internal<br>- as built<br>- unknown                                      | Recorded separately for main dwelling and any extension.<br><br>External, cavity or internal insulation to be indicated only if added subsequent to original construction. If it has only the insulation that was part of the original construction it is "as built". |
| Alternative wall construction (if present)                     | - Location<br>- construction (as preceding item)<br>- insulation (as preceding item)<br>- net area of alternative wall | Location identifies whether part of main wall or an extension wall  |
| Roof construction  | One of:<br>- pitched<br>- flat<br>- another dwelling above   | Recorded separately for main dwelling and any extension   |
| Roof insulation (if not another dwelling above)                | One of:<br>- rafters<br>- joists<br>- no access  | Recorded separately for main dwelling and any extension   |
| Roof insulation thickness                                      | One of:<br>- none, 12, 25, 50, 75, 100, 150, 200, 250, ≥300 mm,<br>don't know  | For roof insulation at joist level and where can be accessed. Recorded separately for main dwelling and any extension   |
| Windows (of the dwelling only, not including any conservatory) | Area: one of<br>– typical<br>– less than typical<br>– more than typical<br>– much more than typical                    | "Typical" refers to normal construction for the property type and age band concerned. If assessed as much more than typical the area of each window should be measured.   |
|  | Proportion double glazed   | As percentage   |
|  | Double glazing installed, one of:<br>- pre year xxxx<br>- during or post year xxxx<br>- don't know                     | xxxx is:<br>- 2002 in England & Wales<br>- 2003 in Scotland<br>- 2006 in Northern Ireland   |
| Fireplaces   | Number of open fireplaces  |   |
| Main heating system  | Fuel for main heating  |   |
|  | Boiler identification if possible, otherwise system according to Table 4a/4b <sup>(a)</sup>                            | If boiler can be identified, its characteristics are obtained via the SEDBUK system   |
|  | Heat emitter type, one of<br>- radiators<br>- underfloor<br>- other  |   |
| Main heating controls  | Item from Table 4e <sup>(a)</sup> according to main system type  |   |

| Item   | Data  | Comment  |
|--|---|--|
| Secondary heating system   | Fuel for secondary heating, and system from room heater section of Table 4a <sup>(a)</sup>  | "None" if no secondary heating system  |
| Water heating  | Either<br>- from main heating system, or<br>- from secondary system, or<br>- item from hot-water-only section of Table 4a <sup>(a)</sup>  |  |
|  | Cylinder size, one of:<br>- no cylinder<br>- no access<br>- normal (90-130 litres)<br>- medium (131-170 litres)<br>- large (> 170 litres) |  |
|  | Cylinder insulation type, one of<br>- no access<br>- none<br>- jacket<br>- spray foam   |  |
|  | Cylinder insulation thickness, one of:<br>0, 12, 25, 38, 50, 80, 100, 150 mm  |  |
|  | If immersion, whether single or dual  |  |
|  | Cylinderstat (yes/no)   |  |
| Mechanical ventilation   | yes/no, and if yes whether heat recovery  | Applies to whole house balanced ventilation system only. Otherwise natural ventilation is assumed. Intermittent extract fans (kitchen and bathrooms) are not a mechanical ventilation system for SAP calculations. |
| Mains gas available  | yes/no  | Can be relevant to improvement recommendations   |
| Solar water heating  | Solar panel (yes/no)  |  |
| Photovoltaic array   | yes/no, and if yes the % of external roof area with PVs   |  |
| Low energy lighting  | Percentage of fixed outlets   |  |
| <sup>(a)</sup> A few heating systems and controls will be omitted, this will be published separately |   |  |