www.bre.co.uk

BREDEM 2012

A technical description of the BRE Domestic Energy Model
Version 1.1

BREDEM 2012 – A technical description of the BRE Domestic Energy Model

J Henderson and J Hart

Many people have contributed over nearly three decades to the development of BREDEM, too many to list all the authors, but Peter Chapman and Brian Anderson are worthy of special mention for their key roles.

This edition of BREDEM was written by John Henderson and John Hart.

For all related enquiries please contact Henderson J@bre.co.uk

BRE, Garston, Watford, WD25 9XX

Tel: 01923 664000

enquiries@bre.co.uk

www.bre.co.uk

Other BRE publications are available from www.brebookshop.com

July 2013

Version 1.1, with corrections January 2015

BREDEM 2012

The Building Research Establishment Domestic Energy Model (BREDEM) is a calculation methodology to estimate the energy consumption of a dwelling based on its characteristics. This document presents a concise description of the BREDEM 2012 calculation methodology, primarily targeted at readers who have used previous versions of BREDEM and would like to update their models. It will also be accessible to those familiar with recent versions of the Standard Assessment Procedure (SAP). Like SAP, BREDEM complies with the principles in BS EN ISO 13790.

The output of a BREDEM calculation is in the form of estimated fuel requirements for various end uses, which can be converted readily into fuel costs or CO_2 emissions using suitable conversion factors. BREDEM is therefore suited to various energy modelling tasks, such as stock modelling and the assessment of the potential benefits of energy efficiency improvements. It is simple enough to be implemented in a spreadsheet, if required.

In this document the BREDEM 2012 calculation is split in the following sections, each of which is described in a chapter of this document. Taken together these give an overview of the calculation.

1. Calculate the energy consumption for lights, appliances and cooking
2. Calculate the energy requirements for water heating
3. Calculate the dwelling's specific heat loss
4. Calculate the dwelling's thermal mass
5. Calculate the solar heat gain
6. Calculate the internal heat gain
7. Calculate the mean internal temperature
8. Calculate space heating energy consumption
9. Calculate the cooling energy consumption
10. Calculate the amount of electricity generated by photovoltaics and wind turbines

BREDEM 2012 is a monthly calculation methodology. It is therefore important to be clear about which parameters vary with the month of the year (e.g. solar gains) and which have a fixed single value throughout the year (e.g. floor area). Where there is the possibility of confusion a suffix 'm' is added to the symbol representing the variable to denote that it is a monthly figure. For example, $E_{L,m}$ is the monthly energy requirement for lighting, which is different for each month of the year, whereas E_L is the total lighting energy requirement for the year.

Contents

1 Energy required for lights, appliances and cooking 5
2 Energy required to heat water 8
2.1 The volume and energy content of heated water 8
2.2 Water heating system losses 9
2.3 Energy required for electric showers 11
2.4 Hot water from solar water heating systems 12
2.4.1 Calculating the solar energy incident on a solar collector (also used for PV and glazing calculations) 12
2.4.2 Calculating the heat output of a solar water heater 14
2.5 Net water heating energy requirement 15
3 Heat loss 16
4 Thermal mass parameter 20
5 Solar heat gain 21
6 Internal heat gain and total heat gain 22
7 Mean internal temperature 24
8 Space heating energy requirement 27
9 Cooling energy requirement 28
10 Photovoltaics and wind turbines 30
11 Making use of the outputs from a BREDEM calculation 31
Appendix A – External temperature and solar radiation 32
Appendix B – Water heating efficiency, space heating efficiency and heating system responsiveness 34
Appendix C – Values of **Ψ** for different types of junctions for calculating heat losses from thermal bridging 36
Appendix D – Heat capacity of building elements 37

1 Energy required for lights, appliances and cooking

Data item	Symbol	Type	Units	Notes
Number of occupants	N	User input/ calculated	Occupants	Use actual value if known, otherwise see step A.
Total floor area of dwelling	TFA	User input	m^2	All storeys, measured internally
Lighting energy basic requirement	E_B	Calculated	kWh/yr	Step B
Low energy lighting correction factor	C_1	Calculated	Dimensionless	Step C
Proportion of light provided by low energy lamps	$L_{\%}$	User input	Percentage	Low energy lamp means fluorescent, CFL or LED
Daylight availability	G_{DL}	Calculated	Dimensionless	Step D
Total window area	A_W	User input	m^2	Gross area, including frame
Light transmission factor	g_L	User input/ from table	Dimensionless	Proportion of incident light admitted. See Table 1.
Frame factor	Fr	User input/ from table	Dimensionless	Proportion of gross area which is transparent. See Table 2.
Light access factor	Z_L	User input/ from table	Dimensionless	Factor reflecting attenuation due to overshading. See Table 3.
Daylight correction factor	C_2	Calculated	Dimensionless	Step E
Initial annual lighting energy	E_L'	Calculated	kWh/yr	Step F
Lighting energy used each month	$E_{L,m}$	Calculated	kWh/month	Step G
Month number	m	Constants	Dimensionless	Jan=1, Feb=2 … Dec=12
Number of days in month, m	n_m	Constants	Days	Use 28 for February
Final annual lighting energy	E_L	Calculated	kWh/yr	Step H
Initial annual appliance energy	E_A'	Calculated	kWh/yr	Step I
Appliance energy used each month	$E_{A,m}$	Calculated	kWh/month	Step J
Final annual appliance energy	E_A	Calculated	kWh/yr	Step K
Energy for pumps and fans	$E_{p\&f}$	Calculated/ user input	kWh/yr	Step L and Table 4.
Internal volume of dwelling	V_T	User input	m^3	Total internal volume (used in Table 4)
Specific ventilation fan power	SFP	User input	W/(l/s)	If unknown use 1.5 W/(l/s) for warm air systems, 2 W/(l/s) for balanced system or 0.8 W/(l/s) for positive input ventilation (used in Table 4)
In-use factor	IUF	User input	Dimensionless	If unknown use 2.5
Annual cooking energy (fuel 1, 2)	E_{C1}, E_{C2}	Calculated	kWh/yr	Step M
Monthly cooking energy (fuel 1, 2)	E_{C1m}, E_{C2m}	Calculated	kWh/month	Step N
Cooker type coefficients	E_{C1A}, E_{C1B}, E_{C2A}, E_{C2B}	User input/ from table	kWh/yr, kWh/yr p.p.	From Table 5
Monthly cooking consumption	$E_{C,m}$	Calculated	kWh/month	Step O
Additional (non-cooking related) energy consumption for ranges	$E_{R,m}$	Calculated	kWh/month	Step P
Range power consumption	P_R	User input	W	Manufacturer's value in Watts, if known. Otherwise use default of 2000W for a range burning a fossil fuel or 1500W for an electric range
Annual additional consumption for ranges	E_R	Calculated	kWh/yr	Step Q

Lighting energy consumption

A. Number of occupants is either a user input (where known), or is calculated:
   If TFA >13.9, $N = 1 + 1.76 \times [1 - \exp(-0.000349 \times (TFA - 13.9)^2)] + 0.0013 \times (TFA - 13.9)$
   Otherwise, $N = 1$
B. $E_B = 59.73 \times (TFA \times N)^{0.4714}$
C. $C_1 = 1 - 0.5 \times L_{\%}$
D. $G_{DL} = \sum (0.9 \times A_w \times g_L \times Fr \times Z_L) / TFA$ *(summing over all windows)*
E. If $G_{DL} \leq 0.095$, $C_2 = 52.2 \times G_{DL}^2 - 9.94 \times G_{DL} + 1.433$
   If $G_{DL} > 0.095$, $C_2 = 0.96$
F. $E_L' = E_B \times C_1 \times C_2$
G. $E_{L,m} = E_L' \times [1 + 0.5 \times \cos(2\pi(m - 0.2)/12)] \times n_m /365$[i]
H. $E_L = \sum E_{L,m}$ *(summing over all months)*

Appliance, pump and fan energy consumption

I. $E_A' = 184.8 \times (TFA \times N)^{0.4714}$
J. $E_{A,m} = E_A' \times [1 + 0.157 \times \cos(2\pi(m - 1.78)/12] \times n_m/365$[ii]
K. $E_A = \sum E_{A,m}$ (summing over all months)
L. $E_{p\&f} = \sum$applicable items from Table 4

Cooking energy consumption

M. $E_{C1} = E_{C1A} + E_{C1B} \times N$
   $E_{C2} = E_{C2A} + E_{C2B} \times N$
N. $E_{C1,m} = E_{C1} \times n_m/365$
   $E_{C2,m} = E_{C2} \times n_m/365$
O. $E_{C,m} = E_{C1,m} + E_{C2,m}$
P. $E_{R,m} = P_R \times 0.024 \times n_m - E_{C,m}$
   If the range is turned off in summer reset $E_{R,m}$ to zero in June, July, August and September.
Q. $E_R = \sum E_{R,m}$

Table 1: Light transmission factors

Glazing type	Light transmission factor, g_L
Single	0.9
Double	0.8
Triple	0.7

If detailed glazing properties are known, actual figures should be used in preference to those in Table 1. The light transmission factor is the ratio of the amount of visible light admitted through the glazed area of a window to the total incident upon it, assuming normal incidence of light (an adjustment factor of 0.9 is applied to this in the calculation to allow for non-normal incidence).

[i] The formula given above assumes your software requires angles to be entered in radians. If your software requires angles to be entered in degrees use $E_{L,m} = E_L' \times [1 + 0.5 \times \cos(30(m - 0.2))] \times n_m/365$
[ii] If your software requires angles to be entered in degrees use $E_{A,m} = E_A' \times [1 + 0.5 \times \cos(30(m - 1.78))] \times n_m/365$

Table 2: Frame factors

Frame type	Frame factor, Fr_i
Wood	0.7
Metal	0.8
Metal, thermal break	0.8
PVC-U	0.7

If detailed window dimensions are known, actual figures should be used in preference to those in Table 2. The frame factor is the ratio of the glazed (transparent) area of a window to the total area (including frame).

Table 3: Light access (overshading) factors

Overshading	% of sky blocked	Light access factor, Z_L
Heavy	>80%	0.5
More than average	60-80%	0.67
Average or unknown	20-60%	0.83
Very little	<20%	1

Table 4: Energy requirements of pumps and fans

Equipment	kWh/yr
Heating system	
Standard central heating pump	120
Standard central heating pump (no room 'stat)	156
Low energy central heating pump	30
Low energy central heating pump (no room 'stat)	39
Oil boiler (fan flue and pump supplying oil to boiler)	100
Gas boiler or heat pump flue fan (if fan assisted)	45
Warm air heating system fans (except if balanced whole house MV system)	SFP x 0.4 x V_T
Electric Keep-hot facility of combi boiler	
Keep-hot facility controlled by time-clock	600
Keep-hot facility not controlled by time-clock	900
Ventilation system	
Mechanical extract ventilation fans	IUF x SFP x 1.22 x V_T
Balanced whole-house mechanical ventilation fans	IUF x SFP x 2.44 x n_{mech} x V_T
Positive input ventilation from loft space	0
Positive input ventilation from outside	IUF x SFP x 1.22 x V_T
Intermittent extract fans	28 per fan
Solar water heating pump	
Powered by mains electricity	50
Powered by PV	0

Table 5: Cooking type coefficients

Cooking type	E_{C1A}	E_{C1B}	E_{C2A}	E_{C2B}
Normal size cooker: electric	275	55	0	0
Normal size cooker: gas or LPG	481	96	0	0
Normal size cooker: electric / gas	138	28	241	48
Large cooker (>4 hobs) or range: electric	361	78	0	0
Large cooker (>4 hobs) or range: gas, LPG, oil or solid fuel	631	136	0	0
Large cooker (>4 hobs): electric / gas	181	39	316	68

2 Energy required to heat water

2.1 The volume and energy content of heated water

Data item	Symbol	Type	Units	Notes
Number of showers per day	n_{shower}	User input / calculated	Showers/day	Step A
Number of occupants	N	User input / calculated	Occupants	From §1 A
Daily hot water requirement for showers	$V_{d,shower}$	Calculated	Litres/day	Step B
Hot water use per shower	V_{PS}	User input / from table	Litres	From Table 6
Number of baths per day	n_{bath}	User input / calculated	Baths/day	Step C
Daily hot water requirement for baths	$V_{d,bath}$	Calculated	Litres/day	Step D
Daily hot water requirement for other uses	$V_{d,other}$	Calculated	Litres/day	Step E
Average daily hot water requirement	$V_{d,ave}$	Calculated	Litres/day	Step F
Daily hot water requirement in month m	$V_{d,m}$	Calculated	Litres/day	Step G
Monthly hot water use factor	f_{hw}	Constants / from table	Dimensionless	From Table 7
Monthly rise in temperature required	ΔT_m	Constants / from table	°C	From Table 8
Monthly energy content of heated water	$Q_{HW,m}$	Calculated	kWh/month	Step H
Number of days in month, m	n_m	Constants	Days	Use 28 for February
Annual energy content of heated water	Q_{HW}	Calculated	kWh/yr	Step I

A. If the number of showers taken per day is known use the actual figure, otherwise
$n_{shower} = 0.45\,N + 0.65$

B. $V_{d,shower} = n_{shower} \times V_{PS}$

C. If the number of baths taken per day is known use the actual figure, otherwise
If no shower is present $n_{bath} = 0.35\,N + 0.5$
If a shower is also present $n_{bath} = 0.13\,N + 0.19$

D. $V_{d,bath} = n_{bath} \times 50.8$

E. $V_{d,other} = 9.8N + 14$

F. $V_{d,ave} = V_{d,shower} + V_{d,bath} + V_{d,other}$

G. $V_{d,m} = V_{d,ave} \times f_{hw}$

H. Calculate monthly energy content of the heated water
$Q_{HW,m} = 4.18 \times V_{d,m} \times n_m \times \Delta T_m / 3600$

I. $Q_{HW} = \sum Q_{HW,m}$

Table 6: Hot water use per shower

Shower type	Hot water use per shower, V_{PS} (litres)
None	0
Mixer (not combi)	28.8
Mixer (combi)	44.4
Pumped	43.5
Electric	0
Unknown	18.7

If more than one shower type present, choose the one that is used most often.

Table 7: Monthly hot water use factor

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Month factor, f_{hw}	1.10	1.06	1.02	0.98	0.94	0.90	0.90	0.94	0.98	1.02	1.06	1.10

Table 8: Monthly rise in temperature required

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp rise, ΔT_m (°C)	41.2	41.4	40.1	37.6	36.4	33.9	30.4	33.4	33.5	36.3	39.4	39.9

2.2 Water heating system losses

Data item	Symbol	Type	Units	Notes
Distribution loss of centrally heated water	$Q_{D,m}$	Calculated	kWh/month	Step A
Monthly energy content of heated water	$Q_{HW,m}$	Calculated	kWh/month	From §2.1 H
Manufacturer's declared storage loss	$Q_{st,man}$	User input	kWh/day	If unknown, see step B
Daily storage loss	$Q_{st,d}$	Calculated	kWh/day	Step B
Storage temperature factor	STF	User input / from table	Dimensionless	From Table 9
Volume of hot water storage cylinder or storage combi	V_C	User input	Litres	For use in table 9 and Step B. Use actual value if known, otherwise assume 120l for separate cylinder or 50l for storage combi.
Cylinder heat loss factor	L	User input	kWh/litre/day	Step B
Thickness of hot water cylinder insulation	t	User input	mm	Use average if uneven
Volume factor	V_F	User input	Dimensionless	Step B
Monthly storage loss	$Q_{st,m}$	Calculated	kWh/month	Step C
Monthly primary pipework loss	$Q_{P,m}$	Calculated	kWh/month	Step D
Number of days in month, m	n_m	Constants	Days	Use 28 for February
Fraction of primary pipework insulated	f_{pp}	User input / from table	Dimensionless	From Table 10
Hours per day primary hot	$h_{pp,m}$	User input / from table	Hours / day	From Table 11
Primary circuit adjustment factor for solar water heating	$f_{pa,m}$	User input / from table	Dimensionless	If solar water heating is present, and the cylinder has a thermostat, use values in Table 12; otherwise $f_{pa,m} = 1$.
Monthly loss for a combination boiler	$Q_{com,m}$	Calculated / from table	kWh/month	Zero if no combi. Calculated using formula from Table 13.
Combi loss sizing factor	f_u	Calculated	Dimensionless	See Table 13, note a

a) *Storage losses are only calculated for water heating systems with tanks*
b) *Primary circuit losses apply to water heating systems that aren't immersion, instantaneous or combi boilers*

A. If water is heated centrally, $Q_{D,m} = 0.15 \times Q_{HW,m}$
   If water is heated at point of use, $Q_{D,m} = 0$
B. If $Q_{st,man}$ is known, $Q_{st,d} = Q_{St,man} \times STF$
   If $Q_{st,man}$ is unknown, $Q_{st,d}$ is calculated as follows:
   a. $L = 0.005 + 1.76 / (t + 12.8)$ (if insulated with mineral wool jacket)
      $L = 0.005 + 0.55 / (t + 4.0)$ (if insulated with factory applied foam)
      (The exception is an electric CPSU, where L = 0.022 kWh/litre/day in all cases)
   b. $V_F = (120/V_C)^{1/3}$
   c. $Q_{st,d} = L \times V_C \times V_F \times STF$
C. $Q_{st,m} = Q_{st,d} \times n_m$
D. $Q_{P,m} = n_m \times 14 \times [(0.0091 \times f_{pp} + 0.0245 \times (1 - f_{pp})) \times h_{pp,m} + 0.0263] \times f_{pa,m}$
E. If the water isn't heated by a combination boiler $Q_{com,m} = 0$
   If the water is heated by a combination boiler $Q_{com,m}$ is calculated according to Table 13

Table 9: Storage temperature factor

Type of water storage	Temperature factor, STF	
	For manufacturer's declared loss	For estimated heat loss
Cylinder, electric immersion	0.60	0.60
Cylinder, indirect [a) b)]	0.60	0.60
Storage combi, primary store	N/A	Store volume ≥ 115 litres: 2.54 Store volume < 115 litres: 2.54 + 0.00682 x (115 – Vc)
Storage combi, secondary store	N/A	Store volume ≥ 115 litres: 1.86 Store volume < 115 litres: 1.86 + 0.00496 x (115 – Vc)
Instantaneous combi with close-coupled external store [a) b)]	0.60	0.60
Hot water only thermal store[c) d)]	0.89	1.08
Integrated thermal store and gas-fire CPSU[c) d)]	0.89	1.08
Electric CPSU: for winter operating temp T_w (°C). If unknown, use a default of 85°C.	1.09 + 0.012 x (T_w-85)	1.00
Plate heat exchanger in a community system	1.00	1.00

a) Multiply value by 1.3 if no cylinder thermostat

b) Multiply value by 0.9 if water heating is separately timed from space heating

c) Multiply value by 0.81 if thermal store or CPSU has a separate timer for heating the store

d) Multiply value by 1.1 if the thermal store or CPSU is not in an airing cupboard

Table 10: Fraction of primary pipework insulated

Pipework insulation	Fraction insulated, f_{pp}
Uninsulated primary pipework	0.0
First 1m from cylinder insulated	0.1
All accessible pipework insulated	0.3
Fully insulated primary pipework	1.0

Table 11: Hours per day primary pipework is hot

Hot water controls	Hours per day, $h_{pp,m}$	
	Winter	Summer
No cylinder thermostat	11	3
Cylinder thermostat, water heating not separately timed	5	3
Cylinder thermostat, water separately timed	3	3

- Use summer values for June, July, August and September and winter values for other months.

- For community heating systems use f_{pp}=1 and $h_{pp,m}$ = 3 for all months.

Table 12: Primary circuit loss adjustment factors with solar water heating

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Correction factor, $f_{pa,m}$	1.00	1.00	0.94	0.70	0.45	0.44	0.44	0.48	0.76	0.94	1.00	1.00

But if solar water heating is not present, $f_{pa,m}$ = 1 in all months.

Correction factor does not apply to community heating

Table 13: Combination boiler loss equations

Combi type	$Q_{com,m}$ (kWh/month)
Instantaneous, without keep-hot facility	$600 \times f_u \times n_m / 365$
Instantaneous, with keep-hot facility controlled by time clock	$600 \times n_m / 365$
Instantaneous, with keep-hot facility not controlled by time clock	$900 \times n_m / 365$
Storage combi, store volume, V_C, < 55 litres	$[600 - (V_C - 15) \times 15] \times f_u \times n_m / 365$
Storage combi, store volume ≥ 55 litres	0

a) If daily hot water use, $V_{d,m}$, is less than 100 litres/day, $f_u = 100/V_{d,m}$, otherwise $f_u = 1$
b) If the boiler stores more than 15 litres of water treat is as a storage combi. If not, treat it as an instantaneous combi

2.3 Energy required for electric showers

Data item	Symbol	Type	Units	Notes
Monthly electric shower energy requirement	$E_{shower,m}$	Calculated	kWh/month	Step A
Number of showers per day	n_{shower}	User input / calculated	Dimensionless	From §2.1 A
Electricity consumption per shower	E_{PS}	User input / from table	kWh/shower	From Table 14
Number of days in month, m	n_m	Constants	Days	Use 28 for February
Annual electric shower energy requirement	E_{shower}	Calculated	kWh/yr	Step B

A. $E_{shower,m} = n_{shower} \times E_{PS} \times n_m$
B. $E_{shower} = \sum E_{shower,m}$

Table 14: Electricity consumption per shower

Shower type	Electricity consumption per shower, E_{PS} (kWh)
None	0
Mixer (not combi)	0
Mixer (combi)	0
Pumped	0
Electric	0.93
Unknown	0.45

2.4 Hot water from solar water heating systems

2.4.1 Calculating the solar energy incident on a solar collector (also used for PV and glazing calculations)

Data item	Symbol	Type	Units	Notes
Pitch factor	f_{pitch}	Calculated	Dimensionless	Step A
Pitch (tilt) of the surface	p	User input	Degrees	Degrees from horizontal (e.g. 0° is horizontal, 90° is vertical)
Collector orientation parameters for selected orientation	A, B & C	Calculated	Dimensionless	Steps B, C and D
Collector orientation constants for selected orientation	$k_1, k_2 \ldots k_9$	User input / from table	Dimensionless	From Table 15
Solar height factor	$f_{\phi\delta}$	Calculated	Dimensionless	Step E
Latitude of the site	ϕ	User input / from table	Degrees	Data for site if known. Otherwise from table A1 in Appendix A.
Solar declination for month m	δ_m	Constants / from table	Degrees	From Table 16. Same for all sites/locations.
Ratio to convert horizontal solar flux to that for the selected orientation, pitch and month	$R_{h\text{-}p,m}$	Calculated	Dimensionless	Step F
Incident solar flux for selected orientation, pitch and month	Fx_m	Calculated	W/m^2	Step G
Horizontal solar flux for month m	$Fx_{h,m}$	User input / from table	W/m^2	Use site data if available. Otherwise from table A1 in Appendix A.
Incident solar energy for month m per m^2 of collector	S_m	Calculated	kWh/m^2	Step H
Number of days in month, m	n_m	Constants	Days	Use 28 for February
Annual incident solar energy per m^2 of collector	S	Calculated	$kWh/yr/m^2$	Step I

A. $f_{pitch} = \sin(\pi/180 \times p/2)$ (This assumes software requires angles to be entered in radians[iii])
B. $A = k_1 \times f_{pitch}^3 + k_2 \times f_{pitch}^2 + k_3 \times f_{pitch}$
C. $B = k_4 \times f_{pitch}^3 + k_5 \times f_{pitch}^2 + k_6 \times f_{pitch}$
D. $C = k_7 \times f_{pitch}^3 + k_8 \times f_{pitch}^2 + k_9 \times f_{pitch} + 1$
E. $f_{\phi\delta} = \cos(\pi/180 \times (\phi - \delta_m))$ (This assumes software requires angles to be entered in radians[iv])
F. $R_{h\text{-}p,m} = A \times f_{\phi\delta}^2 + B \times f_{\phi\delta} + C$
G. $Fx_m = Fx_{h,m} \times R_{h\text{-}p,m}$
H. $S_m = Fx_m \times n_m \times 0.024$
I. $S = \sum S_m$

[iii] The formula given assumes your software requires angles to be entered in radians. If your software requires angles to be entered in degrees use $f_{pitch} = \sin(p/2)$
[iv] If your software requires angles to be entered in degrees use $f_{pitch} = \cos(\phi - \delta_m)$

Table 15: Constants for calculation of solar flux on vertical and inclined surfaces

	Orientation				
	North	NE/NW	East/West	SE/SW	South
k_1	26.3	0.165	1.44	-2.95	-0.66
k_2	-38.5	-3.68	-2.36	2.89	-0.106
k_3	14.8	3	1.07	1.17	2.93
k_4	-16.5	6.38	-0.514	5.67	3.63
k_5	27.3	-4.53	1.89	-3.54	-0.374
k_6	-11.9	-0.405	-1.64	-4.28	-7.4
k_7	-1.06	-4.38	-0.542	-2.72	-2.71
k_8	0.0872	4.89	-0.757	-0.25	-0.991
k_9	-0.191	-1.99	0.604	3.07	4.59

If necessary, interpolate k-coefficients for orientations in between the major compass points

Table 16: Solar declination

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Declination, δ_m (^{o})	-20.7	-12.8	-1.8	9.8	18.8	23.1	21.2	13.7	2.9	-8.7	-18.4	-23.0

2.4.2 Calculating the heat output of a solar water heater

Data item	Symbol	Type	Units	Notes
Collector heat loss coefficient	a*	Calculated	Dimensionless	Step A.
First order heat loss coefficient	a_1	User input / from table	Dimensionless	From test certificate, or Table 17
Second order heat loss coefficient	a_2	User input / from table	Dimensionless	From test certificate, or Table 17
Zero loss efficiency of the collector	η_0	User input /from table	Dimensionless	From test certificate, or Table 17
Collector performance factor	f_1	User input / calculated	Dimensionless	Step B
Load ratio	LR	Calculated	Dimensionless	Step C
Aperture area of the collector	A_{ap}	User input	m^2	If gross area, multiply by applicable factor:- Unglazed panel: 1.0 Flat panel, glazed: 0.9 Evacuated tube: 0.7
Annual incident solar energy per m^2 of collector	S	Calculated	kWh/yr/m^2	From §2.4.1 I
Over shading factor	Z_{panel}	User input / from table	Dimensionless	From Table 18
Annual energy content of heated water	Q_{HW}	Calculated	kWh/yr	From §2.1 I
Utilisation factor	UF	Calculated	Dimensionless	Step D
Solar storage volume factor	f_2	Calculated	Dimensionless	Step E
Effective solar volume	V_{eff}	User input	Litres	Volume heated by solar system. See footnote[v].
Average daily hot water requirement	$V_{d,ave}$	Calculated	Litres/day	From §2.1 F
Annual output of solar water heating	Q_{sol}	Calculated	kWh/yr	Step F
Incident solar energy for month m per m^2 of collector	S_m	Calculated	kWh/m^2	From §2.4.1 H
Monthly output of solar water heating	$Q_{sol,m}$	Calculated	kWh/m^2	Step G

A. $a^* = 0.892 \times (a_1 + 45 \times a_2)$
B. f_1 is taken from test results, if available, otherwise:
   If $a^* / \eta_0 < 20$ $\quad f_1 = 0.97 - 0.0367(a^* / \eta_0) + 0.0006(a^* / \eta_0)^2$
   If $a^* / \eta_0 \geq 20$ $\quad f_1 = 0.693 - 0.0108 \times (a^* / \eta_0)$
C. $LR = (A_{ap} \times \eta_0 \times S \times Z_{panel}) / Q_{HW}$
D. $UF = 1 - \exp[-1/LR]$
E. $f_2 = 1.0 + 0.2 \ln(V_{eff} / V_{d,ave})$
   However, if $f_2 > 1$, reset it to 1
F. $Q_{sol} = S \times Z_{panel} \times A_{ap} \times \eta_0 \times UF \times f_1 \times f_2$
G. $Q_{sol,m} = S_m / S \times Q_{sol}$

[v] - In the case of a separate pre-heat tank, V_{eff} is the volume of the pre-heat tank.
- In the case of a combined cylinder (with twin coils), V_{eff} is the volume of the dedicated solar storage (i.e. up to the height of the non-solar coil) plus 0.3 times the volume of the remainder of the cylinder.
- In the case of a thermal store with twin coils, where the solar coil is within the thermal store, V_{eff} is the volume of the dedicated thermal storage (up to the height of the non-solar coil).
- In the case of a direct system where there is no dedicated solar storage, V_{eff} is 0.3 times the volume of the cylinder.

Table 17: Collector efficiency parameters

Collector type	a_1	a_2	η_0
Unglazed panel	15	0	0.9
Flat plate, glazed	4	0.01	0.8
Evacuated tube	1.8	0.005	0.7

Use figures from test results (BS EN 12975-2, Thermal solar systems and components – Solar collectors – Part 2: Test methods) in preference to the above, if available.

Table 18: Overshading factor

Over-shading	% of sky blocked by obstacles	Z_{panel} / Z_{PV}
Heavy	>80%	0.50
More than average	60-80%	0.65
Average or unknown	20-60%	0.80
Very little	<20%	1.00

2.5 Net water heating energy requirement

Data item	Symbol	Type	Units	Notes
Monthly total hot water related energy requirement	$Q_{W,m}$	Calculated	kWh/month	Step A
Monthly energy content of heated water	$Q_{HW,m}$	Calculated	kWh/month	From §2.1 H
Monthly distribution loss for centrally heated water	$Q_{D,m}$	Calculated	kWh/month	From §2.2 A
Monthly storage loss	$Q_{st,m}$	Calculated	kWh/month	From §2.2 C
Monthly primary pipework loss	$Q_{P,m}$	Calculated	kWh/month	From §2.2 D
Monthly loss for a combination boiler	$Q_{com,m}$	Calculated / from table	kWh/month	From §2.2 E
Monthly output of solar water heating	$Q_{sol,m}$	Calculated	kWh/month	From §2.4.2 G
Heat supplied by water heating system 1,2 etc.	$Q_{W1,m}$ $Q_{W2,m}$ etc.	Calculated	kWh/month	Step B
Proportion of water heating by system 1,2 etc.	f_{wh1} f_{wh2} etc.	User input	Dimensionless	Based on volume heated and temperature rise. See footnote[vi].
Monthly fuel requirement for water heating system 1, 2 etc.	$E_{W1,m}$ $E_{W2,m}$ etc.	Calculated	kWh/month	Step C
Efficiency of water heating system 1, 2 etc.	$\varepsilon_1, \varepsilon_2$ etc.	User input	Dimensionless	See Appendix B
Annual fuel requirements for water heating system 1, 2 etc.	E_{W1} E_{W2} etc.	Calculated	kWh/yr	Step D

A. $Q_{W,m} = 0.85 \times Q_{HW,m} + Q_{D,m} + Q_{st,m} + Q_{P,m} + Q_{com,m} - Q_{sol,m}$
If this results in a negative value of $Q_{W,m}$ in any month, it should be reset to zero.

B. $Q_{W1,m} = Q_{W,m} \times f_{wh1}$
$Q_{W2,m} = Q_{W,m} \times f_{wh2}$
...etc.

C. $E_{W1,m} = Q_{W1,m} / \varepsilon_{W1,m}$
$E_{W2,m} = Q_{W2,m} / \varepsilon_{W2,m}$
...etc.

D. $E_{W1} = \sum E_{W1,m}$
$E_{W2} = \sum E_{W2,m}$
...etc.
(Use additional terms if more than 2 water heating systems present)

[vi] e.g. heat pump heats cylinder from 20°C to 40°C, immersion heats from 40°C to 60°C, f_{wh1}=0.5, f_{wh2}=0.5.

3 Heat loss

Data item	Symbol	Type	Units	Notes
Thermal bridging loss	H_{TB}	Calculated	W/m²K	Step A
Length of the linear bridge, i	L_{TBi}	User input	m	From plans or survey
Linear thermal transmittance of thermal bridge, i	Ψ_i	User input	W/mK	From table C1, Appendix C
Thermal bridge factor	y	User input	W/K	See footnote[vii]
Total area of external building elements	A_{ext}	User input	m²	Sum of external floor, wall, roof, and window/door areas (excluding party walls).
Fabric heat loss	H_F	Calculated	W/K	Step B
Area of building element, i	A_i	User input	m²	Areas measured internally
U-value of building element, i	U_i	User input	W/m²K	Measured on site, calculated using BS EN ISO 6946, or from SAP Appendix S lookup tables
Air change rate due to chimneys, flues and fans	L_{DV}	Calculated	Air changes per hour	Step C
Rate of deliberate ventilation via to chimneys, flues and fans	F_{DV}	User input / from table	m³/hour	Sum of applicable items from Table 20
Internal volume of dwelling	V_T	User input	m³	Input in §1 (used in Table 4)
Measured air-permeability rate	Q_{50}	User input	m³/hour/m²	If available from test result. If unavailable an alternative method is used – see Step D.
Infiltration rate of the building fabric	L_{fab}	Calculated / from table	Air changes per hour	Step D
Subtotal; fabric & deliberate ventilation	$L_{sub,m}$	Calculated	Air changes per hour	Step E
Site exposure factor	Sh_E	User input / from table	Dimensionless	From Table 21
Dwelling exposure factor	Sh_D	User input / from table	Dimensionless	From Table 22
Monthly average wind speed for region	$v_{reg,m}$	From table	m/s	From table A3, Appendix A
Monthly ventilation rate	$L_{v,m}$	Calculated	Air changes per hour	Step F
Mechanical ventilation heat recovery efficiency	E_{MVHR}	User input	%	From test data if available; otherwise use a default of 60%
Ventilation heat loss	$H_{v,m}$	Calculated	W/K	Step G
Heat transfer coefficient (i.e. total heat loss)	H_m	Calculated	W/K	Step H
Heat loss parameter	HLP_m	Calculated	W/m²/K	Step I
Interzone heat transfer coefficient	H_3	Calculated	W/K	Step J
Floor area of the dwelling's smaller zone	A_L	User input	m²	The lesser of the zone 1 and zone 2 floor areas. See footnote[viii].

[vii] The value of y reflects the level of attention paid to limiting thermal bridge losses. 0.15 would be suitable for most homes built before 2002, when little attention was paid to thermal bridging. For a dwelling complying with the 2002 building regulations for England and Wales, or a similar standard, use 0.11. For a dwelling built after 2006 a suitable value would be 0.08.

[viii] The calculation assumes the dwelling consists of two zones: a living area (zone 1) and a non-living area (zone 2). Zone 1 is assumed to be heated to a higher temperature than zone 2. Typically zone 1 is around 25% of a house or 33% of a flat. Therefore, A_L is usually the area of zone 1.

Fabric heat loss

A. Where details of thermal bridges are known:
   a. $H_{TB} = (\Sigma L_{TBi} \times \Psi_i)$

   Where details of thermal bridges are unknown:
   b. $H_{TB} = y \times A_{ext}$

B. $H_F = (\Sigma A_i \times U_i) + H_{TB}$
   (summed over all external building elements; same for each month of the year)
   The U-values of windows with curtains should be adjusted prior to use in step B using the following equation:

   $U_{adjusted} = 1/(1/U_{unadjusted} + 0.04)$

Ventilation heat loss

C. $L_{DV} = F_{DV}/V_T$
D. If Q_{50} is known, $L_{fab} = Q_{50} / 20$
   Otherwise L_{fab} = ∑ relevant items from Table 19.
E. $L_{sub,m} = (L_{fab} + L_{DV}) \times Sh_E \times Sh_D \times v_{reg,m}/4$
F. For natural ventilation or positive input ventilation from loft space:
   If $L_{sub,m} \geq 1$, $L_{v,m} = L_{sub,m}$; otherwise $L_{v,m} = 0.5 + (L_{sub,m}^2 \times 0.5)$
   For mechanical ventilation (no heat recovery):
   $L_{v,m} = 0.5 + L_{sub,m}$
   For mechanical ventilation with heat recovery:
   $L_{v,m} = 0.5 \times (1 - E_{MVHR}) + L_{sub,m}$
   For mechanical extract ventilation, or positive input ventilation from outside:
   If $L_{sub,m} < 0.25$, $L_{v,m} = 0.5$; otherwise $L_{v,m} = L_{sub,m} + 0.25$
G. $H_{v,m} = 0.33 \times L_{v,m} \times V_T$

Heat transfer coefficients and heat loss parameter

H. $H_m = H_F + H_{V,m}$
I. $HLP_m = H_m / TFA$
J. $H_3 = 0.8 \times A_L + 4.25 \times A_L^{0.5}$ (For single storey dwellings)
   $H_3 = 2.53 \times A_L + 8.5 \times A_L^{0.5}$ (If stairs do not link Z1 and Z2 directly[ix])
   $H_3 = 4.2 \times A_L + 8.5 \times A_L^{0.5}$ (If stairs directly link Z1 to Z2[x] and Z1 is part of one storey)
   $H_3 = 4.2 \times A_L$ (If stairs directly link zone 1 to zone 2 and zone 1 is *all* of one storey)

[ix] e.g. Stairs linking a hallway (not open to the living room) to a landing
[x] e.g. Stairs linking a living room (zone 1) to a landing (zone 2)

Table 19: Infiltration through structural element

Building component	Infiltration contribution (ach)
Structural elements	
Solid walls	0.3
Filled cavity walls	0.3
Partially filled cavity walls	0.3
Unfilled cavity walls	0.35
Timber frame walls	0.25
Stack effect (per storey less one)	0.1
Unsealed suspended timber floor	0.2
Sealed suspended timber floor	0.1
Unsealed loft hatch	0.025
Windows and doors	
Unopenable (except doors)	0.02
Well-fitting, draught sealed	0.05
Poor-fitting, draught sealed	0.1
Well-fitting, not draft sealed	0.15
Loose fitting	0.25
Very loose fitting	0.35
No draught-lobby on main door	0.05

Take an area-weighted average where more than one category applies.
For stack effect infiltration, subtract one from the number of storeys and then multiply by 0.1.

Table 20: Ventilation associated with chimneys, flues and fans

Item	Air flow per item (m^3/hour)
Chimney	40
Open flue	20
Intermittent fan	10
Passive vent	10
Flueless gas fire	40

Table 21: Site exposure factor

Exposure category	Definition	Site exposure factor (Sh_E)
Exposed	Coastal and hill top sites. Any dwelling on the 10th floor or above in a high rise block.	1.1
Above average	Open sites not in the exposed category. Dwellings on the 6th to 9th floor of tower blocks.	1.05
Average	Most rural and sub-urban sites. Dwellings on the 4th and 5th floors, or on the 3rd floor in an urban location. City centre sites close to high rise developments.	1
Below average	Partially sheltered urban and rural sites where there is some geographical reduction in local wind speed. Three storey dwellings on sheltered sites.	0.95
Sheltered	Sites where the local geography provides shelter from prevailing winds (e.g. valley or local hollow). City centre sites that are not close to high rise developments.	0.9

Table 22: Dwelling exposure factor

Definition	Dwelling exposure factor (Sh_D)
Exposed all four sides	1
Exposed three sides	0.925
Exposed two sides	0.85
Exposed one side	0.775
Fully sheltered	0.7

4 Thermal mass parameter

Data item	Symbol	Type	Units	Notes
Thermal mass parameter	TMP	Calculated / user input	kJ/m²K	Step A
Area of building fabric element i	A_i	User input	m²	Includes both internal and external walls, ceilings and floors. (Some will have been entered already in §3 B.)
Heat capacity of building fabric element i	κ_i	User input / from table	kJ/K per m²	See table D1, Appendix D.
Total floor area of dwelling	TFA	User input	m²	Measured internally

A. $TMP = (\sum A_i \times \kappa_i) / TFA$

Alternatively, for generic calculations, the following indicative values can be used:

Low thermal mass	100 kJ/m²K	E.g. timber frame, and lightweight internal walls, ceilings and floors.
Medium thermal mass	250 kJ/m²K	E.g. masonry external walls, lightweight internal walls, timber ground floor.
High thermal mass	450 kJ/m²K	E.g. masonry external walls, masonry internal walls, and concrete ground floor.

5 Solar heat gain

Data item	Symbol	Type	Units	Notes
Monthly average solar gain	$G_{s,m}$	Calculated	W	Step A
Incident solar flux for selected orientation, pitch and month	$Fx_{i,m}$	Calculated	W/m²	Calculated for each element, i (or group of similar elements) as described in §2.4.1, using the actual pitch (usually 90°, except for roof windows).
Area of glazed element i	Aw_i	User input	m²	Gross area of opening (including opaque areas such as frame). Ensure this adds up to the same as the window area used for the U-value calculation.
Solar access (overshading) factor	Ov_i	User input / from table	Dimensionless	From Table 23
Frame factor	Fr_i	User input / from table	Dimensionless	From Table 2 in §1
Transmission factor	Tx_i	User input / from table	Dimensionless	Solar energy transmittance factor of the glazing at normal incidence. Use actual value if known; otherwise take value from Table 24.

A. $G_{s,m} = \sum Fx_{i,m} \times Aw_i \times Ov_i \times Fr_i \times Tx_i \times 0.9$

Similar elements can be grouped, e.g. all windows with similar characteristics on the same face of the dwelling can be treated as one large window.

Table 23: Solar access factors

Over-shading	% of sky blocked by obstacles	Solar access factor, Ov_i
Heavy	>80%	0.3
More than average	60-80%	0.54
Average or unknown	20-60%	0.77
Very little	<20%	1.00

Table 24: Solar gains transmission factors

Glazing type	Transmission factor, Tx_i
Single glazed	0.85
Double glazed (air or argon filled)	0.76
Double glazed (low-E hard coat)	0.72
Double glazed (low-E soft coat)	0.63
Window with secondary glazing	0.76
Triple glazed (air or argon fill)	0.68
Triple glazed (low-E hard coat)	0.64
Triple glazed (low-E soft coat)	0.57

6 Internal heat gain and total heat gain

Data item	Symbol	Type	Units	Notes
Metabolic gain (from body heat)	G_M	Calculated	W	Step A (same each month)
Number of occupants	N	User input / calculated	Occupants	From §1 A
Heat gain from lights	$G_{L,m}$	Calculated	W	Step B
Lighting energy used each month	$E_{L,m}$	Calculated	kWh/month	From §1 G
Number of days in month	n_m	Constants	Days	Use 28 for February
Heat gain from electrical appliances	$G_{A,m}$	Calculated	W	Step C
Appliance energy used each month	$E_{A,m}$	Calculated	kWh/month	From §1 J
Useful heat gain from cooking	$G_{C,m}$	Calculated	W	Step D
Energy for cooking each month	$E_{C,m}$	Calculated	kWh/month	From §1 O
Cooking gain factor	f_{cg}	User input	Dimensionless	From Table 25
Non-cooking related heat gain from always-on ranges	$G_{R,m}$	Calculated	W	Step E
Non-cooking related energy consumption of always-on ranges	$E_{R,m}$	Calculated	kWh/month	From §1 P
Range efficiency, fuel into heat	ε_r	User input	%	Use actual figure if known. Otherwise use defaults of 60% for a range burning fossil fuel, or 100% for an electric range.
Heat loss from internal evaporation	G_{evap}	Calculated	W	Step F (same each month of the year)
Heat gain from pumps and fans	$G_{p\&f,m}$	User input / calculated	W	Step G and Table 26
Heat gain from pumps and fans (cooling)	$G_{p\&fcool,m}$	User input / calculated	W	Step L and Table 26
Internal volume of dwelling	V_T	User input	m³	Input in §1 (used in Table 4)
Specific ventilation fan power	SFP	User input	W/(l/s)	Input in §1 (used in Table 4)
In-use factor	IUF	User input	Dimensionless	Input in §1 (used in Table 4)
Internal monthly storage loss	$Q_{ist,m}$	Calculated	kWh/month	Step H
Monthly storage loss	$Q_{st,m}$	Calculated	kWh/month	From §2.2 C
Heat gains from water heating	$G_{W,m}$	Calculated	W	Step I
Monthly energy content of heated water	$Q_{HW,m}$	Calculated	kWh/month	From §2.1 H
Monthly loss for a combination boiler	$Q_{com,m}$	Calculated	kWh/month	From §2.2 E
Energy for electric shower	$E_{shower,m}$	Calculated	kWh/month	From §2.3 A
Distribution loss centrally heated water	$Q_{D,m}$	Calculated	kWh/month	From §2.2 A
Primary pipework loss	$Q_{P,m}$	Calculated	kWh/month	From §2.2 D
Total internal heat gain in month m	$G_{int,m}$	Calculated	W	Step J
Monthly average solar gain	$G_{s,m}$	Calculated	W	From §5 A
Total heat gain in month m	G_m	Calculated	W	Step K
Total heat gain in month m (cooling)	$G_{cool,m}$	Calculated	W	Step M

A. $G_M = N \times 60$
B. $G_{L,m} = 0.85 \times E_{L,m} / (0.024 \times n_m)$
C. $G_{A,m} = E_{A,m} / (0.024 \times n_m)$
D. $G_{C,m} = E_{C,m} \times f_{cg} / (0.024 \times n_m)$
E. $G_{R,m} = E_{R,m} \times \varepsilon_r \times 0.75 / (0.024 \times n_m)$
F. $G_{evap} = -40 \times N$
G. $G_{p\&f,m} = \sum$(items from Table 26)
H. If cylinder in heated space, $Q_{ist,m} = Q_{st,m}$, otherwise $Q_{ist,m} = 0$.
I. $G_{W,m} = [0.25 \times (0.85 \times Q_{HW,m} + Q_{com,m} + E_{shower,m}) + 0.8 \times (Q_{D,m} + Q_{ist,m} + Q_{P,m})] / (0.024 \times n_m)$
J. $G_{int,m} = G_M + G_{L,m} + G_{A,m} + G_{C,m} + G_{R,m} + G_{p\&f,m} + G_{w,m} + G_{evap}$
K. $G_m = G_{s,m} + G_{int,m}$
L. $G_{p\&fcool,m} = \sum$(items from Table 26 for cooling calculation)
M. $G_{cool,m} = G_{s,m} + G_{L,m} + G_{A,m} + G_{C,m} + G_{R,m} + G_{p\&fcool,m} + G_{w,m} + G_{evap}$

Table 25: Cooking gain factor

Cooking fuel/type	Cooking gain factor (f_{cg})
Gas (incl. LPG)	0.75
Electricity	0.9
Gas/electric	0.825
Range (electric)	0.9
Range (fossil fuel)	0.6

Table 26: Heat gain from pumps and fans

Function	Gain (W)
Central heating pump (if in heated space) (except for communal systems and cooling calculation)	10
Low energy central heating pump (if in heated space) (except for communal systems and cooling calculation)	3
Oil boiler pump (if inside dwelling) (except for cooling calculation)	10
Warm air heating systems fans (except for balanced whole house mechanical ventilation, communal systems and cooling calculation)	SFP x 0.04 x V_T
Fans for positive input ventilation from outside	IUF x SFP x 0.12 x V_T
Fans for balanced whole house mechanical ventilation	IUF x SFP x 0.06 x V_T

Gains from pumps and fans are assumed to be the same in each month.
Gains are not added in for MVHR or MEV systems

7 Mean internal temperature

Data item	Symbol	Type	Units	Notes
Heat loss parameter	HLP_m	Calculated	W/m²K	From §3 I
Demand temperature for an *uncontrolled* zone 2 (rest of dwelling)	$T_{d2,u,m}$	Calculated	°C	Step A
Zone 1 (living room) demand temperature	T_{d1}	User input	°C	Actual temperature achieved in living room. See footnote[xi].
Nominal temperature difference between zones	T_{dif}	User input	°C	Default value is 3°C
Demand temperature for a *controlled* zone 2	$T_{d2,c,m}$	Calculated	°C	Step B
Demand temperature in zone 2 for the selected level of control	$T_{d2,s,m}$	Calculated	°C	Step C
Zone 2 control fraction	f_{z2c}	User input	Dimensionless (0 to 1)	Proportion of the heat emitters in zone 2 which have their own thermostatic control (e.g. TRVs)
Temperature for an unheated zone 2	$T_{d2unhtd,m}$	Calculated	°C	Step D
Interzone heat transfer coefficient	H_3	Calculated	W/K	From §3 J
Average external temperature	$T_{ext,m}$	User input	°C	If data for site is unavailable, use data from table A2, Appendix A
Heat transfer coefficient	H_m	Calculated	W/K	From §3 H
Total gains in month m	G_m	Calculated	W	From §6 K
Zone 2 demand temperature	$T_{d2,m}$	Calculated	°C	Step E
Fraction of zone 2 heated	f_{z2htd}	User input	0 to 1	Often 1 (e.g. full house CH)
The time constant	τ_m	Calculated	Hours	Step F
Thermal mass parameter	TMP	Calculated	kJ/K per m²	From §4 A
Utilisation factor exponent	a_m	Calculated	Dimensionless	Step G
Dwelling's total rate of heat loss (at zone 1 or zone 2 temperature)	$L_{1,m}$, $L_{2,m}$	Calculated	W	Steps H and Q
Ratio of heat gains to losses (at zone 1 or zone 2 temperature)	$\gamma_{1,m}$, $\gamma_{2,m}$	Calculated	Dimensionless	Steps I and R
Gains utilisation factor (at zone 1 or zone 2 temperature)	$\eta_{1,m}$, $\eta_{2,m}$	Calculated	Dimensionless	Steps J and S
Cooling time	$t_{c,m}$	Calculated	Hours	Step K
Background temperature in zone 1 or zone 2	$T_{sc1,m}$, $T_{sc2,m}$	Calculated	°C	Steps L and T
Responsiveness of the main heating system	R	User input	Dimensionless	See Appendix B
Length of heating-off period i	$t_{off,i}$	User input	Hours per day	Input value for each off period. See example in Table 27.
Temperature reduction in zone 1, zone 2, for unheated period i (weekdays and weekends)	$u_{z1,i,wd,m}$, $u_{z1,i,we,m}$, $u_{z2,i,wd,m}$, $u_{z2,i,we,m}$	Calculated	°C	Steps M and U
Average weekday temperature in zone 1 or zone 2 (weekdays and weekends)	$T_{1,wd,m}$, $T_{2,wd,m}$, $T_{1,we,m}$, $T_{2,we,m}$	Calculated	°C	Steps N & O and V & W
Average temperature for zone 1 or zone 2	$T_{1,m}$, $T_{2,m}$	Calculated	°C	Steps P and X
Average temperature for the whole house	T_m	Calculated	°C	Step Y
Floor area of zone 1 or zone 2	A_1, A_2	User input	m²	Measured internally
Total floor area of dwelling	TFA	User input	m²	Measured internally

[xi] Ideally this would be based on temperature measurements taken in the dwelling, in which case it would be the value normally achieved after the heating has been on for long enough to reach a relatively steady temperature. Where actual temperature measurements are not available T_{d1} will usually be based on the thermostat setting. If the thermostat is in the living room, its setting would be the demand temperature. If it is outside the living room (e.g. hall), add 3°C to the thermostat setting to estimate the temperature achieved in the living room.

Zone 2 demand temperature

A. If $HLP_m > 6$, $T_{d2,u,m} = T_{d1} - T_{dif}$
   If $HLP_m <= 6$, $T_{d2,u,m} = T_{d1} - T_{dif} \times HLP_m/6$
B. If $HLP_m > 6$, $T_{d2,c,m} = T_{d1} - T_{dif}$
   If $HLP_m <= 6$, $T_{d2,c,m} = T_{d1} - T_{dif} + T_{dif} \times (HLP_m - 6)^2/36$
C. $T_{d2,s,m} = T_{d2,c,m} \times f_{z2c} + T_{d2,u,m} \times (1 - f_{z2c})$
D. $T_{d2unhtd,m} = (T_{d1} \times H_3 + T_{ext,m} \times H_m + G_m)/(H_m + H_3)$
   If $T_{d2unhtd,m} > T_{d1}$, reset $T_{d2unhtd,m}$ to T_{d1}
E. $T_{d2,m} = T_{d2,s,m} \times f_{z2htd} + T_{d2unhtd,m} \times (1 - f_{z2htd})$

Zone 1 mean internal temperature

F. $\tau_m = TMP / (3.6 \times HLP_m)$
G. $a_m = 1 + \tau_m / 15$
H. $L_{1,m} = H_m \times (T_{d1} - T_{ext,m})$
I. $\gamma_{1,m} = G_m / L_{1,m}$
J. If $\gamma_{1,m} <= 0$, $\eta_{1,m} = 1$
   If $\gamma_{1,m} = 1$, $\eta_{1,m} = a_m/(a_m + 1)$
   Otherwise, $\eta_{1,m} = (1 - \gamma_{1,m}^{am})/(1 - \gamma_{1,m}^{(am+1)})$
K. $t_{c,m} = 4 + 0.25 \times \tau_m$
L. $T_{sc1,m} = (1 - R) \times (T_{d1} - 2) + R \times (T_{ext,m} + \eta_{1,m} \times G_m / H_m)$
M. If $t_{off} \le t_{c,m}$, $u_{z1,i,...} = 0.5 \times t_{off}^2 \times (T_{d1} - T_{sc1,m}) / (24 \times t_{c,m})$
   If $t_{off} > t_{c,m}$, $u_{z1,i,...} = (T_{d1} - T_{sc1,m}) \times (t_{off} - 0.5 \times t_{c,m}) / 24$
   Repeat step M for all applicable off periods to generate $u_{z1,1,wd}$, $u_{z1,1,we}$, ..., $u_{z1,2,wd}$, $u_{z1,2,we}$, ... for each month of the year.
N. $T_{1,wd,m} = T_{d1} - u_{z1,1,wd,m} - u_{z1,2,wd,m}$ - ... etc.
O. $T_{1,we,m} = T_{d1} - u_{z1,1,we,m} - u_{z1,2,we,m}$ - ... etc.
   Subtract additional terms, $u_{z1,3,wd,m}$ etc., if more than two heating periods are used.
P. $T_{1,m} = (5 \times T_{1,wd,m} + 2 \times T_{1,we,m}) / 7$

Zone 2 and overall mean internal temperature

Q. $L_{2,m} = H_m \times (T_{d2,m} - T_{ext,m})$
R. $\gamma_{2,m} = G_m / L_{2,m}$
S. If $\gamma_{2,m} <= 0$, $\eta_{2,m} = 1$
   If $\gamma_{2,m} = 1$, $\eta_{2,m} = a_m / (a_m + 1)$
   Otherwise, $\eta_{2,m} = (1 - \gamma_{2,m}^{am}) / (1 - \gamma_{2,m}^{(am+1)})$
T. $T_{sc2,m} = (1 - R) \times (T_{d2,m} - 2) + R \times (T_{ext,m} + \eta_{2,m} \times G_m / H_m)$
U. If $t_{off} \le t_{c,m}$, $u_{z2,i...} = 0.5 \times t_{off}^2 \times (T_{d2,m} - T_{sc2,m}) / (24 \times t_{c,m})$
   If $t_{off} > t_{c,m}$, $u_{z2,i...} = (T_{d2,m} - T_{sc2,m}) \times (t_{off} - 0.5 \times t_{c,m}) / 24$
   Repeat step U for all applicable off periods to generate $u_{z2,1,wd}$, $u_{z2,1,we}$, $u_{z2,2,wd}$, $u_{z2,2,we}$, ... for each month of the year.$T_{2,wd,m} = T_{d2,m} - u_{z2,1wd,m} - u_{z2,2wd,m}$ - ... etc.
V. $T_{2,wd,m} = T_{d2,m} - u_{z2,1,wd,m} - u_{z1,2,wd,m}$ - ... etc.
W. $T_{2,we,m} = T_{d2,m} - u_{z2,1,we,m} - u_{z2,2we,m}$ - ... etc.
X. $T_{2,m} = (5 \times T_{2,wd,m} + 2 \times T_{2,we,m}) / 7$
Y. $T_m = (T_{1,m} \times A_1 + T_{2,m} \times A_2) / TFA$

Table 27: Example heating pattern

	Weekday hours on/off	Weekend hours on/off
On1	2	16
Off1	7	0
On2	7	0
Off2	8	8

For this typical heating pattern, on a weekday the heating is on for 2 hours, off for 7 hours, then on for 7 hours and off for 8 (the total for each day must add up to 24 hours). In other examples there could be more than two heating periods per day (e.g. On3, Off3…etc.). When calculating the temperature reductions for each off period, it is only the *off times* that are used. For example, to calculate $u_{z1,1,wd,m}$ (the zone 1 reduction for the first weekday off period in month m) for this heating pattern, use t_{off} = 7.

8 Space heating energy requirement

Data item	Symbol	Type	Units	Notes
Dwelling's overall rate of heat loss	L_m	Calculated	W	Step A
Heat transfer coefficient	H_m	Calculated	W/K	From §3 H
Average temperature for the whole dwelling	T_m	Calculated	°C	From §7 Y
Average external temperature	$T_{ext,m}$	User input	°C	Input in §7
Ratio of heat gains to losses	γ_m	Calculated	Dimensionless	Step B
Total heat gain in month m	G_m	Calculated	W	From §6 K
Gains utilisation factor for whole dwelling	η_m	Calculated	Dimensionless	Step C
Utilisation factor exponent	a_m	Calculated	Dimensionless	From §7 G
Threshold temperature for heating	T_{thr}	Calculated	°C	Step D
Zone 1 (living room) demand temperature	T_{d1}	User input	°C	Input in §7
Background (unheated) temperature	$T_{sc,m}$	Calculated	°C	Step E
Degree days at threshold temp +0.5	$DD_{+0.5,m}$	Calculated	Degree days	Step F
Degree days at threshold temp -0.5	$DD_{-0.5,m}$	Calculated	Degree days	Step G
Fraction of month that is heated	fr_m	Calculated	Dimensionless	Step H
Energy required for heating in month m	$Q_{heat,m}$	Calculated	kWh/month	Step I
Number of days in month	n_m	Constants	Days	Use 28 for February
Heating energy from system 1, system 2, etc..	$Q_{sys1,m}$, $Q_{sys2,m}$…	Calculated	kWh/month	Step J
Fraction of heat provided by system 1, system 2, etc…	$fr_{sys1,m}$, $fr_{sys2,m}$…	User input	Dimensionless	Base on floor area heated by each system.
Fuel consumed by system 1, system 2, etc…	$E_{sys1,m}$, $E_{sys2,m}$…	Calculated	kWh/month	Step K
Heating efficiency of system 1, system 2, etc…	$\varepsilon_{sys1,m}$, $\varepsilon_{sys2,m}$…	User input	Dimensionless	Data from table B1, Appendix B
Annual fuel consumption of system 1, 2, etc.	E_{sys1}, E_{sys2}…	Calculated	kWh/yr	Step L

A. $L_m = H_m \times (T_m - T_{ext,m})$

B. $\gamma_m = G_m / L_m$

C. If $\gamma_m <= 0$, $\eta_m = 1$

If $\gamma_m = 1$, $\eta_m = a_m / (a_m + 1)$

Otherwise, $\eta = (1 - \gamma_m^{am}) / (1 - \gamma_m^{(am+1)})$

D. $T_{thr} = T_{d1} - 4$

E. $T_{sc,m} = T_{ext,m} + \eta_m G_m / H_m$

F. If $T_{thr} \neq T_{sc,m}$ $DD_{+0.5,m} = (T_{thr} + 0.5 - T_{sc,m}) / (1 - \exp[-5 (T_{thr} + 0.5 - T_{sc,m})])$

If $T_{thr} = T_{sc,m}$ $DD_{+0.5,m} = 0.2$

G. If $T_{thr} \neq T_{sc,m}$ $DD_{-0.5,m} = (T_{thr} - 0.5 - T_{sc,m}) / (1 - \exp[-5 (T_{thr} - 0.5 - T_{sc,m})])$

If $T_{thr} = T_{sc,m}$ $DD_{-0.5,m} = 0.2$

H. $fr_m = DD_{+0.5,m} - DD_{-0.5,m}$

I. $Q_{heat,m} = 0.024 \times (L_m - [1 - fr_m + fr_m \eta_m] \times G_m) \times n_m$

Set $Q_{heat,m}$ to zero if negative or less than 1kWh.

J. $Q_{sys1,m} = fr_{sys1,m} \times Q_{heat,m}$

$Q_{sys2,m} = fr_{sys2,m} \times Q_{heat,m}$

...etc.

K. $E_{sys1,m} = Q_{sys1,m} / \varepsilon_{sys1,m}$

$E_{sys2,m} = Q_{sys2,m} / \varepsilon_{sys2,m}$

...etc.

L. $E_{sys1} = \sum E_{sys1,m}$

$E_{sys2} = \sum E_{sys2,m}$

9 Cooling energy requirement

Data item	Symbol	Type	Units	Notes
Heat loss rate for cooling	$L_{cool,m}$	Calculated	W	Step A
Heat transfer coefficient	H_m	Calculated	W/K	From §3 H
Internal temperature for cooling	T_{cool}	User input	°C	Cooling set point. If unknown use 24°C.
Average external temperature	$T_{ext,m}$	User input	°C	Input in §7
Gain to loss ratio for cooling	$\gamma_{cool,m}$	Calculated	Dimensionless	Step B
Total heat gain in month m	$G_{cool,m}$	Calculated	W	From §6 M
Utilisation factor for cooling	$\eta_{cool,m}$	Calculated	Dimensionless	Step C
Utilisation exponent	a_m	Calculated	Dimensionless	From §7 G
Internal temperature without cooling	$T_{sc,cool,m}$	Calculated	°C	Step D
Degree days at threshold temp +0.5	$DD_{cool,m+0.5}$	Calculated	Degree days	Step E
Degree days at threshold temp -0.5	$DD_{cool,m-0.5}$	Calculated	Degree days	Step F
Fraction of month requiring cooling	$fr_{cool,m}$	Calculated	Dimensionless	Step G
Cooling requirement	$Q_{cool,m}$	Calculated	kWh/month	Step H
Number of days in month m	n_m	Constant	Days	Use 28 for February
Fraction of the TFA cooled	f_{cool}	User input	Dimensionless	Cooled area ÷ total area
Intermittency factor	$f_{intermittent}$	User input	Dimensionless	Hours per day used ÷ 24
Fuel consumption for cooling in month m	$E_{cool,m}$	Calculated	kWh/month	Step I
System Energy Efficiency Ratio	SEER	From table / calculated	Dimensionless	From Table 28
Annual fuel consumption for cooling	E_{cool}	Calculated	kWh/yr	Step J

Cooling utilisation factor

A. $L_{cool,m} = H_m \times (T_{cool} - T_{ext,m})$

B. If $L_{cool,m} = 0$, $\gamma_{cool,m} = 1{,}000{,}000$
otherwise $\gamma_{cool,m} = G_{cool,m} / L_{cool,m}$
Round $\gamma_{cool,m}$ to 8 decimal places to avoid instability when $\gamma_{cool,m}$ is close to 1

C. Calculate utilisation factor for cooling:

if $\gamma_{cool,m} > 0$ and $\neq 1$: $\eta_{cool,m} = (1 - \gamma_{cool,m}^{-am}) / (1 - \gamma_{cool,m}^{(-(am+1))})$

if $\gamma_{cool,m} = 1$: $\eta_{cool,m} = a_m / (a_m + 1)$

If $\gamma_{cool,m} \leq 0$: $\eta_{cool,m} = 1$

Cooling season length

D. $T_{sc,cool,m} = T_{ext,m} + G_{cool,m} / H_m$

E. If $T_{cool} \neq T_{sc,cool,m}$ $DD_{cool,m+0.5} = (T_{cool} + 0.5 - T_{sc,cool,m}) / (1 - \exp[-5 (T_{cool} + 0.5 - T_{sc,cool,m})]$
If $T_{cool} = T_{sc,cool,m}$ $DD_{cool,m+0.5} = 0.2$

F. If $T_{cool} \neq T_{sc,cool,m}$ $DD_{cool,m-0.5} = (T_{cool} - 0.5 - T_{sc,cool,m}) / (1 - \exp[-5 (T_{cool} - 0.5 - T_{sc,cool,m})]$
If $T_{cool} = T_{sc,cool,m}$ $DD_{cool,m-0.5} = 0.2$

G. $fr_{cool,m} = 1 - DD_{cool,m+0.5} + DD_{cool,m-0.5}$

Cooling energy requirement

H. $Q_{cool,m} = 0.024 \times (G_{cool,m} - \eta_{cool,m} \times L_{cool,m}) \times n_m \times fr_{cool,m} \times f_{cool} \times f_{intermittent}$
Set $Q_{cool,m}$ to zero if negative or less than 1 kWh

I. $E_{cool,m} = Q_{cool,m} / SEER$

J. $E_{cool} = \sum E_{cool,m}$

Table 28: Energy Efficiency Ratio (EER) and System Energy Efficiency Ratio (SEER)

Energy label class	Default EER (electrically driven)	
	Split and Multi-split systems	Packaged systems
A	3.2	3.0
B	3.0	2.8
C	2.8	2.6
D	2.6	2.4
E	2.4	2.2
F	2.2	2.0
G	2.0	1.8
The SEER is: for systems with on/off control SEER = 1.25 × EER for systems with variable speed compressors SEER = 1.35 × EER		

10 Photovoltaics and wind turbines

Data item	Symbol	Type	Units	Notes
Amount of electricity generated by a PV system	E_{PV}	Calculated	kW	Step A
Peak power of the installation	kWp	User input	kW	Manufacture's figure. Measure of its output under ideal conditions.
Annual solar radiation	S	Calculated	kWh/yr per m^2	Calculate according to §2.4.1
Overshading factor	Z_{PV}	User input / from table	Dimensionless	From Table 18 in §2.4.2
Swept area of the turbine	A_{swept}	Calculated	m^2	Step B
Rotor diameter	D_{rot}	User input	m	Diameter of circle made by rotor tips
Amount of electricity generated by wind turbine	E_{wind}	Calculated	kWh/yr	Step C
Wind speed correction factor	C_{ws}	From table	Dimensionless	From Table 29

A. $E_{PV} = 0.8 \times kWp \times S \times Z_{PV}$
(Where more than one panel with different levels of shading or orientations, calculate separately and sum to give total output.)

B. $A_{swept} = 0.25 \times \pi \times D_{rot}^2$

C. $E_{wind} = 2.448 \times A_{swept} \times (5 \times C_{ws})^3$
(Where more than one turbine, calculate separately and sum to give total output.)

Table 29: Wind turbine terrain correction factor

Terrain type	Height of hub above ground or roof ridge (m)*	Correction factor
Dense Urban	10	0.56
	5	0.51
	2	0.40
	0	0.28
Low rise urban / suburban	6	0.67
	4	0.61
	2	0.53
	0	0.39
Rural	12	1.00
	7	0.94
	2	0.86
	0	0.82

* Hub height must be at least half the rotor diameter

11 Making use of the outputs from a BREDEM calculation

In previous sections methodology has been provided to estimate the energy required for various energy end-uses in dwellings. For most purposes the results will need to be further combined and processed to arrive at quantities of interest, for example:

- Delivered energy consumption
- Primary energy consumption
- CO_2 emissions
- Fuel costs

The exact nature of this will depend on the task being undertaken but generally this will involve summing the energy consumption for each fuel type, to which a fuel-specific factor can be applied.

<u>Example – estimating dwelling CO_2 emissions</u>

A BREDEM calculation has provided estimates of energy consumption for the following end-uses:

Energy used by heating system 1 (gas boiler): 13,500 kWh/yr
Energy used by heating system 2 (electric fire): 1,500 kWh/yr
Energy used by water heating system (in cylinder from gas boiler): 2,600 kWh/yr
Instantaneous electric shower: 450 kWh/yr
Lights and appliances: 3,100 kWh/yr

From this we can calculate:

Total gas use = 13,500 + 2,600 = 16,100 kWh/yr
Total electricity use = 1,500 + 450 + 3,100 = 5,050 kWh/yr
CO_2 factor for gas = 0.2 kgCO_2/kWh *(note this is just an indicative figure)*
CO_2 associated with gas use = 0.2 x 16,100 = 3,220 kgCO_2/yr
CO_2 factor for electricity = 0.5 kgCO_2/kWh *(note this is just an indicative figure)*
CO_2 associated with electricity use = 0.5 x 5,050 = 2,525 kgCO_2/yr
Total CO_2 emissions for this dwelling = 3,220 + 2,525 = 5,745 kgCO_2/yr

Generally applicable CO_2 factors, fuel prices and primary energy factors suitable for this kind of analysis can be taken from the current SAP specification found at http://www.bre.co.uk/sap2012, but site (or project) specific factors should be used where known.

Appendix A – External temperature and solar radiation

Table A1: Mean global solar irradiance (W/m²) on a horizontal plane, and latitude (° North)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Latitude*
UK average	26	54	96	150	192	200	189	157	115	66	33	21	*53.4*
Thames	30	56	98	157	195	217	203	173	127	73	39	24	*51.5*
South East	32	59	104	170	208	231	216	182	133	77	41	25	*51.0*
South	35	62	109	172	209	235	217	185	138	80	44	27	*50.8*
South West	36	63	111	174	210	233	204	182	136	78	44	28	*50.6*
Severn	32	59	105	167	201	226	206	175	130	74	40	25	*51.5*
Midland	28	55	97	153	191	208	194	163	121	69	35	23	*52.7*
West Pennines	24	51	95	152	191	203	186	152	115	65	31	20	*53.4*
North West	23	51	95	157	200	203	194	156	113	62	30	19	*54.8*
Borders	23	50	92	151	200	196	187	153	111	61	30	18	*55.5*
North East	25	51	95	152	196	198	190	156	115	64	32	20	*54.5*
East Pennines	26	54	96	150	192	200	189	157	115	66	33	21	*53.4*
East Anglia	30	58	101	165	203	220	206	173	128	74	39	24	*52.3*
Wales	29	57	104	164	205	220	199	167	120	68	35	22	*52.5*
W Scotland	19	46	88	148	196	193	185	150	101	55	25	15	*55.8*
E Scotland	21	46	89	146	198	191	183	150	106	57	27	15	*56.4*
NE Scotland	19	45	89	143	194	188	177	144	101	54	25	14	*57.2*
Highland	17	43	85	145	189	185	170	139	98	51	22	12	*57.5*
Western Isles	16	41	87	155	205	206	185	148	101	51	21	11	*58.0*
Orkney	14	39	84	143	205	201	178	145	100	50	19	9	*59.0*
Shetland	12	34	79	135	196	190	168	144	90	46	16	7	*60.2*
N Ireland	24	52	96	155	201	198	183	150	107	61	30	18	*54.7*

Table A2: Mean external temperature (°C) at typical height above sea level for region

Region	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
UK average	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
Thames	5.1	5.6	7.4	9.9	13.0	16.0	17.9	17.8	15.2	11.6	8.0	5.1
South East	5.0	5.4	7.1	9.5	12.6	15.4	17.4	17.5	15.0	11.7	8.1	5.2
South	5.4	5.7	7.3	9.6	12.6	15.4	17.3	17.3	15.0	11.8	8.4	5.5
South West	6.1	6.4	7.5	9.3	11.9	14.5	16.2	16.3	14.6	11.8	9.0	6.4
Severn	4.9	5.3	7.0	9.3	12.2	15.0	16.7	16.7	14.4	11.1	7.8	4.9
Midland	4.3	4.8	6.6	9.0	11.8	14.8	16.6	16.5	14.0	10.5	7.1	4.2
West Pennines	4.7	5.2	6.7	9.1	12.0	14.7	16.4	16.3	14.1	10.7	7.5	4.6
North West	3.9	4.3	5.6	7.9	10.7	13.2	14.9	14.8	12.8	9.7	6.6	3.7
Borders	4.0	4.5	5.8	7.9	10.4	13.3	15.2	15.1	13.1	9.7	6.6	3.7
North East	4.0	4.6	6.1	8.3	10.9	13.8	15.8	15.6	13.5	10.1	6.7	3.8
East Pennines	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
East Anglia	4.7	5.2	7.0	9.5	12.5	15.4	17.6	17.6	15.0	11.4	7.7	4.7
Wales	5.0	5.3	6.5	8.5	11.2	13.7	15.3	15.3	13.5	10.7	7.8	5.2
W Scotland	4.0	4.4	5.6	7.9	10.4	13.0	14.5	14.4	12.5	9.3	6.5	3.8
E Scotland	3.6	4.0	5.4	7.7	10.1	12.9	14.6	14.5	12.5	9.2	6.1	3.2
NE Scotland	3.3	3.6	5.0	7.1	9.3	12.2	14.0	13.9	12.0	8.8	5.7	2.9
Highland	3.1	3.2	4.4	6.6	8.9	11.4	13.2	13.1	11.3	8.2	5.4	2.7
Western Isles	5.2	5.0	5.8	7.6	9.7	11.8	13.4	13.6	12.1	9.6	7.3	5.2
Orkney	4.4	4.2	5.0	7.0	8.9	11.2	13.1	13.2	11.7	9.1	6.6	4.3
Shetland	4.6	4.1	4.7	6.5	8.3	10.5	12.4	12.8	11.4	8.8	6.5	4.6
N Ireland	4.8	5.2	6.4	8.4	10.9	13.5	15.0	14.9	13.1	10.0	7.2	4.7

Table A3: Mean monthly wind-speed (m/s)

Region	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
UK average	5.1	5.0	4.9	4.4	4.3	3.8	3.8	3.7	4.0	4.3	4.5	4.7
Thames	4.2	4.0	4.0	3.7	3.7	3.3	3.4	3.2	3.3	3.5	3.5	3.8
South East	4.8	4.5	4.4	3.9	3.9	3.6	3.7	3.5	3.7	4.0	4.1	4.4
South	5.1	4.7	4.6	4.3	4.3	4.0	4.0	3.9	4.0	4.5	4.4	4.7
South West	6.0	5.6	5.6	5.0	5.0	4.4	4.4	4.3	4.7	5.4	5.5	5.9
Severn	4.9	4.6	4.7	4.3	4.3	3.8	3.8	3.7	3.8	4.3	4.3	4.6
Midland	4.5	4.5	4.4	3.9	3.8	3.4	3.3	3.3	3.5	3.8	3.9	4.1
West Pennines	4.8	4.7	4.6	4.2	4.1	3.7	3.7	3.7	3.7	4.2	4.3	4.5
North West	5.2	5.2	5.0	4.4	4.3	3.9	3.7	3.7	4.1	4.6	4.8	4.7
Borders	5.2	5.2	5.0	4.4	4.1	3.8	3.5	3.5	3.9	4.2	4.6	4.7
North East	5.3	5.2	5.0	4.3	4.2	3.9	3.6	3.6	4.1	4.3	4.6	4.8
East Pennines	5.1	5.0	4.9	4.4	4.3	3.8	3.8	3.7	4.0	4.3	4.5	4.7
East Anglia	4.9	4.8	4.7	4.2	4.2	3.7	3.8	3.8	4.0	4.2	4.3	4.5
Wales	6.5	6.2	5.9	5.2	5.1	4.7	4.5	4.5	5.0	5.7	6.0	6.0
W Scotland	6.2	6.2	5.9	5.2	4.9	4.7	4.3	4.3	4.9	5.4	5.7	5.4
E Scotland	5.7	5.8	5.7	5.0	4.8	4.6	4.1	4.1	4.7	5.0	5.2	5.0
NE Scotland	5.7	5.8	5.7	5.0	4.6	4.4	4.0	4.1	4.6	5.2	5.3	5.1
Highland	6.5	6.8	6.4	5.7	5.1	5.1	4.6	4.5	5.3	5.8	6.1	5.7
Western Isles	8.3	8.4	7.9	6.6	6.1	6.1	5.6	5.6	6.3	7.3	7.7	7.5
Orkney	7.9	8.3	7.9	7.1	6.2	6.1	5.5	5.6	6.4	7.3	7.8	7.3
Shetland	9.5	9.4	8.7	7.5	6.6	6.4	5.7	6.0	7.2	8.5	8.9	8.5
N Ireland	5.4	5.3	5.0	4.7	4.5	4.1	3.9	3.7	4.2	4.6	5.0	5.0

Appendix B – Water heating efficiency, space heating efficiency and heating system responsiveness

The following table contains some typical figures for common system types for convenience. A more comprehensive list can be found SAP tables 4a to 4d. However, values based on official test data should be used where known, as these will be more accurate.

Table B1: Efficiencies for common heating system types

Space heating systems	Winter efficiency, η_{winter}	Summer (water heating) efficiency, η_{summer}	Responsiveness
Old gas/LPG boiler	70%	60%	From table B2
Typical gas/LPG boiler	80%	70%	From table B2
New gas/LPG boiler	90%	80%	From table B2
Old oil boiler	66%	54%	From table B2
Typical oil boiler	80%	68%	From table B2
New oil boiler	92%	82%	From table B2
Old electric storage heaters	100%	n/a	0
Typical electric storage heaters	100%	n/a	0.2
New electric storage heaters	100%	n/a	0.5
Electric ground to water heat pump	230%	170%	From table B2
Electric air to water heat pump	170%	170%	From table B2
Direct acting electric heaters	100%	100%	1
Decorative fuel effect gas/LPG fires	20%	n/a	1
Old gas/LPG fires	50%	n/a	1
New gas/LPG fires	63%	n/a	1
Open fires burning solid fuel	37%	n/a	0.5
Closed fires burning solid fuel	65%	n/a	0.5
Old solid fuel boiler	65%	n/a	0.75
New solid fuel boiler	70%	n/a	0.75
Old gas/LPG/oil fired warm air system	70%	n/a	1
New gas/LPG/oil fired warm air system	78%	n/a	1
Hot water only systems			
Electric immersion system (water only)	100%	100%	-
Single-point gas water heater (instantaneous at point of use)	70%	70%	-
Multi-point gas water heater (instantaneous serving several taps)	65%	65%	-
Range cooker with boiler for water heating only	50%	50%	-

Space heating is always at the 'winter' efficiency value. If heating system 1 also provides hot water (water heating system 1), the water heating efficiency depends on how great the demand is for heat in each month:

Water heating efficiency in month m = $(Q_{sys1,m} + Q_{w1,m}) / [(Q_{sys1,m} / \eta_{winter}) + (Q_{w1,m} / \eta_{summer})]$

Table B2: Responsiveness of boilers and heat pumps

System type	Responsiveness
Boiler or heat pump systems with radiators	1
Boiler or heat pump systems with underfloor heating or mixture of underfloor heating and radiators:	
pipes in insulated timber floor	1
pipes in screed above insulation	0.75
pipes in concrete slab	0.25

Appendix C – Values of Ψ for different types of junctions for calculating heat losses from thermal bridging

Table C1: Ψ value for various junctions

Junction type	Junction detail	Ψ (W/m·K)	
		Approved	Default
Junctions with an external wall	Steel lintel with perforated steel base plate	0.50	1.00
	Other lintels (including other steel lintels)	0.30	1.00
	Sill	0.04	0.08
	Jamb	0.05	0.10
	Ground floor (normal)	0.16	0.32
	Ground floor (inverted)		0.07
	Exposed floor (normal)		0.32
	Exposed floor (inverted)		0.32
	Basement floor		0.07
	Intermediate floor within dwelling	0.07	0.14
	Intermediate floor within dwelling (block of flats)	0.07	0.14
	Balcony within a dwelling, wall insulation continuous	0.00	0.00
	Balcony between dwellings, wall insulation continuous	0.02	0.04
	Balcony within or between dwellings, balcony support penetrates wall insulation		1.00
	Eaves (insulation at ceiling level)	0.06	0.12
	Eaves (insulation at ceiling level - inverted)		0.24
	Eaves (insulation at rafter level)	0.04	0.08
	Gable (insulation at ceiling level)	0.24	0.48
	Gable (insulation at rafter level)	0.04	0.08
	Flat roof		0.08
	Flat roof with parapet		0.56
	Corner (normal)	0.09	0.18
	Corner (inverted - internal area greater than external)	-0.09	0.00
	Party wall between dwellings	0.03	0.06
	Staggered party wall between dwellings		0.06
Junctions with a party wall	Ground floor		0.16
	Ground floor (inverted)		0.07
	Intermediate floor within a dwelling		0.00
	Intermediate floor within dwelling (block of flats)		0.00
	Exposed floor (normal)		0.16
	Exposed floor (inverted)		0.24
	Roof (insulation at ceiling level)		0.24
	Roof (insulation at rafter level)		0.04
Junctions within a roof or with a room-in-roof	Head		0.08
	Sill		0.06
	Jamb		0.08
	Ridge (vaulted ceiling)		0.08
	Ridge (inverted)		0.04
	Flat ceiling		0.06
	Flat ceiling (inverted)		0.04
	Roof wall (rafter)		0.06
	Roof wall (flat ceiling)		0.04

Appendix D – Heat capacity of building elements

Table D1: Heat capacity of building elements

Construction	Heat Capacity, κ_i (kJ/m^{2}K)
Ground floors	
Suspended timber, insulation between joists	20
Slab on ground, screed over insulation	110
Suspended concrete floor, carpeted	75
Exposed floors	
Timber exposed floor, insulation between joists	20
External walls – masonry, solid external insulation	
Solid wall: dense plaster, 200mm dense block, insulated externally	190
Solid wall: plasterboard on dabs or battens, 200mm dense block, insulated externally	150
Solid wall: dense plaster, 210 brick, insulated externally	135
Solid wall: plasterboard on dabs or battens, 210mm brick, insulated cavity	110
External walls – masonry, solid internal insulation	
Solid wall: dense plaster, insulation, any outside structure	17
Solid wall: plasterboard on dabs or battens, insulation, any outside structure	9
External walls – cavity masonry, full or partial cavity fill	
Cavity wall: dense plaster, dense block, filled cavity, any outside structure	190
Cavity wall: dense plaster, AAC block, filled cavity, any outside structure	70
Cavity wall: plasterboard on dabs or battens, dense block, filled cavity, any outside structure	150
Cavity wall: plasterboard on dabs or battens, AAC block, filled cavity, any outside structure	60
External walls – timber or steel frame	
Timber framed wall, one layer of plasterboard	9
Timber framed wall, two layers of plasterboard	18
Steel framed wall, warm frame or hybrid construction	14
Roofs	
Plasterboard, insulated at ceiling level	9
Plasterboard, insulated slope	9
Plasterboard, insulated flat roof	9
Party walls	
Dense plaster both sides, dense blocks, cavity	180
Single plasterboard on dabs on both sides, dense blocks, cavity	70
Plaster on dabs and single plasterboard on both sides, dense cellular blocks, cavity	70
Plasterboard on dabs mounted on cement render on both sides, AAC blocks, cavity	45
Double plasterboard on both sides, twin timber frame with/without sheathing board	20
Steel framed	20
Party floors	
Precast concrete plank floor, screed, carpeted (from above / from below)	40/30
Concrete floor slab, carpeted (from above / from below)	80/100
Precast concrete plank floor, (screed laid on insulation), carpeted (from above / from below)	40/30
Precast concrete plank floor, (screed laid on rubber), carpeted (from above / from below)	70/30
In-situ concrete slab supported by profiled metal deck, carpeted (from above / from below)	64/90
Timber I-joists, carpeted (from above / from below)	30/20
Internal partitions	
Plasterboard on timber frame	9
Dense block, dense plaster	100
Dense block, plasterboard on dabs	75
Ceiling/floor	
Plasterboard ceiling, carpeted chipboard floor (from above / from below)	18/9

The values of κ_i are not necessarily based on the entire depth of the layer. Starting from the inner surface of the thermal mass layer, only the heat capacity of the first 100mm of thickness of material should be included, and no more than half the total width of the layer, whichever is less. When an insulation layer (thermal conductivity of <0.08W/mK) is reached, no further depth of material is included. Windows and doors are assumed to have negligible heat capacity and are therefore ignored.