## Energy Efficiency Best Practice in Housing

# Refurbishing cavity-walled dwellings

## A summary of Best Practice

- how to achieve better energy efficiency in existing housing
- measures to improve efficiency, reduce $CO_2$ emissions and cut fuel bills
- a guide for architects, specifiers, installers and others involved in the refurbishment of dwellings

# Cavity walls in dwellings

Masonry cavity walls have been the dominant form of house construction in most parts of the UK since the late 1930s. The technique has been in use, though, for more than 100 years.

Cavity-walled houses are generally amongst the easiest to refurbish in an energy-efficient way as the cavity itself can be filled with insulation. In cases where this may not be appropriate; in very exposed areas or in instances where the cavity is not suitable; they can be treated as though solid-walled (see the relevant document in this series).

| The rise of cavity walls in new housing | | |
|---|---|---|
| **Decade** | **Development** | **Cavity width (mm)** |
| 1920s | Cavity walls start to grow in popularity | variable |
| 1930s | Cavity walls become main form of construction | variable |
| 1940s | Cavity width becomes standardised | 50 |
| 1950s | Concrete blocks are used for inner leaf | 50 |
| 1960s | Lightweight 'aircrete' blocks are introduced | 50 |
| 1970s | Cavity width is increased | 60-70 |
| 1980s | Cavity wall insulation (partial or full-fill) starts to be 'built-in' | 60-70 |

# Refurbishing cavity-walled dwellings

When a dwelling is completely refurbished, all aspects can be tackled at the same time. Such a situation is relatively rare and in most cases different parts of a home are improved at different times, depending largely on when they need repair or replacement. Improvements are, therefore, seldom carried out in order of cost-effectiveness. Each measure outlined in the Best Practice Refurbishment Specification should be carried out as and when the opportunity arises, and not unduly prioritised on cost-effectiveness criteria.

Insulating the cavity and topping up the loft insulation can be carried out at any time and should be undertaken as soon as practical.

### A summary of Best Practice

This document is designed to help anyone specifying refurbishment work on properties with cavity walls. It aims to give architects, specifiers, installers and others sufficient information on Best Practice standards for most typical dwellings in the UK. The main construction elements and building services are covered. However, it is only a summary: a list of more detailed guidance can be found at the end of this publication.

### Using the Best Practice specification

In some situations, it may be possible to exceed Best Practice and achieve even higher levels of energy efficiency – this is to be recommended whenever appropriate. However, in some instances, constraints (such as lack of space in sloping ceilings) may render it impossible to meet Best Practice. In such cases, the highest practical levels of performance should be specified and additional energy efficiency measures applied elsewhere.

Although the specification outlined here is applicable to the vast majority of cavity-walled properties in the UK, other factors may sometimes influence the choice of measures for a refurbishment project: for example, where the dwelling has an unusual form of construction or if it has special historic value.

Table 1 summarises the main points of the Best Practice Refurbishment Specification.

*Table 1: Key points*

| Element | Best Practice Refurbishment Specification |
|---|---|
| **Cavity walls** | Insulate (U-values dependent on type of construction) |
| **Roofs** | |
| - pitched roofs (all types) | Achieve U-value of 0.16 W/m$^2$K |
| - flat roofs (all types) | Achieve U-value of 0.25 W/m$^2$K |
| **Ground floors** | Achieve U-value of 0.20-0.25 W/m$^2$K (depending on floor geometry) |
| **Windows and doors** | Replacement windows and doors to have a maximum U-value of 2.0 W/m$^2$K<br>All doors and windows to be draught-stripped |
| **Heating*** | To meet Central Heating System Specifications (CHeSS) HR4 or HC45<br>Primary hot water pipework to be insulated |
| **Ventilation** | Controlled ventilation to prevent condensation |

* electric heating should only be used where all insulation measures have already been adopted

### Building control

Where building work is subject to the relevant building regulations [1,2,3], the proposals should be agreed with the building control body prior to work being carried out. This is particularly important in Scotland where the Building (Scotland) Act 1959 and the associated Technical Standards may in some cases require more stringent performance levels.

For dwellings in England and Wales, the implications of Approved Document L1 are discussed in Best Practice Publication[4].

# Fuel savings and emissions reductions

Refurbishing to the specifications outlined in this document will result in lower greenhouse gas emissions and, for the occupier, lower fuel bills. Savings that might typically be expected compared with a 'base case' are given in Tables 2 and 3.

The seven most common types of dwelling were assessed (see Table 4). Typical energy use for each was calculated using the BRE Domestic Energy Model (BREDEM-12), not only for the 'base case', but also for fully refurbished properties. The associated fuel costs were calculated from the Standard Assessment Procedure (SAP-2001). SAP is the UK Government's approved procedure for calculating home energy ratings and is a reliable way of determining the energy efficiency of dwellings.

The SAP rating is based on the calculated cost of space and water heating, adjusted according to floor area (which allows properties of different sizes to be compared). This rating is expressed as a number between 1 and 120, with higher numbers reflecting greater efficiency. All new homes in the UK must have a SAP rating to comply with existing building regulations.

SAP also provides a formula for calculating $CO_2$ emissions, and the Carbon Index of a dwelling gives a comparative indicator of these. The Carbon Index (CI) is based on the carbon dioxide emissions associated with space and water heating and, like a SAP rating, is adjusted so as to be independent of floor area. The CI is expressed as a number between 0 and 10, with higher numbers representing fewer emissions.

For simplicity, Tables 2 and 3 illustrate two fuel options. Table 2 relates to gas heated properties and Table 3 applies to electrically heated dwellings.

### The 'base case'

Each of the seven types of dwelling considered is assumed to meet the same insulation standard, regardless of the heating fuel used.

This comprises:

- an uninsulated solid floor (U-value varies depending on dimensions)
- 100mm of loft insulation (U-value of 0.40 W/m$^2$K)
- unfilled cavity walls (U-value 1.44 W/m$^2$K)
- draught-stripped single glazing (U-value 4.7 W/m$^2$K)
- solid wooden floors (U-value 3.0 W/m$^2$K)

It is assumed that the living area of each dwelling is heated to 21°C during the morning and evening of each weekday, and all through the day at weekends.

In the case of *natural gas* heating, the main features of the system are:

- the gas boiler has a SEDBUK efficiency of 67% (69% is the housing stock average and 2% is deducted to represent the proportion of that stock lacking boiler interlock)
- a cylinder thermostat (not applicable for the flat where it is assumed that a 'combi' boiler will be used)
- uninsulated primary pipework (not relevant for the flat with a combi)
- cylinder insulation to the average of the UK stock, equivalent to a 55mm insulating jacket on a 120 litre cylinder (again, not applicable to the flat)
- room thermostat and programmer, but no thermostatic radiator valves (TRVs)

The main features of the *electric heating* system are:

- slimline storage heaters with manual charge control
- secondary heating from on-peak panel radiators
- cylinder insulation equivalent to a 55mm insulating jacket on a 120 litre cylinder (UK stock average)

The impact of changing the insulation and the building services to comply with the Best Practice Refurbishment Specification has been calculated for each dwelling type.

*Table 2: Typical savings in dwellings with natural gas heating*

| | Base case | | | Best Practice | | |
|---|---|---|---|---|---|---|
| **Dwelling type** | **Fuel cost £/yr** | **$CO_2$ (kg/yr)** | **SAP** | **Cost saving £/yr** | **$CO_2$ saving (kg/yr)** | **SAP** |
| Flat * | 333 | 3510 | 70 | 122 | 1590 | 105 |
| Detached bungalow | 462 | 5310 | 52 | 207 | 2800 | 92 |
| Semi-detached bungalow | 420 | 4740 | 56 | 177 | 2370 | 93 |
| Mid-terrace house | 445 | 4670 | 66 | 158 | 2040 | 100 |
| End terrace | 512 | 5630 | 57 | 211 | 2790 | 95 |
| Semi-detached | 565 | 6270 | 55 | 238 | 3160 | 94 |
| Detached | 692 | 7930 | 49 | 316 | 4260 | 90 |

* top floor flat (see Table 4)

*Table 3: Typical savings in dwellings with electric heating*

| Dwelling type | Base case | | | Best Practice | | |
|---|---|---|---|---|---|---|
| | Fuel cost £/yr | $CO_2$ (kg/yr) | SAP | Cost saving £/yr | $CO_2$ saving (kg/yr) | SAP |
| Flat * | 533 | 5180 | 46 | 192 | 2240 | 76 |
| Detached bungalow | 755 | 7900 | 29 | 337 | 4050 | 69 |
| Semi-detached bungalow | 674 | 6930 | 34 | 280 | 3340 | 71 |
| Mid-terrace house | 673 | 6480 | 46 | 234 | 2710 | 78 |
| End terrace | 810 | 8180 | 34 | 331 | 3920 | 71 |
| Semi-detached | 899 | 9190 | 32 | 377 | 4470 | 69 |
| Detached | 1132 | 11950 | 24 | 525 | 6290 | 63 |

* top floor flat (see Table 4)

*Table 4: Total floor areas of typical dwellings used in the calculations*

| Dwelling type | Floor area ($m^2$) |
|---|---|
| **Flat*** | 61 |
| **Detached bungalow** | 67 |
| **Semi-detached bungalow** | 64 |
| **Mid-terrace house** | 79 |
| **End-terrace** | 79 |
| **Semi-detached** | 89 |
| **Detached** | 104 |

* a top floor flat with two external walls (this has an energy consumption between a ground floor and a mid-floor flat)

# Fabric improvements

The following tables give examples of improvements that will meet the Best Practice Refurbishment Specification, using appropriate levels of insulation.

The amount of insulation actually required in individual cases may be affected by the thermal properties of the original structure, as well as other refurbishment measures being installed in the part of the building under consideration. The insulation requirement will need to be re-calculated if the situation differs from that given in these tables.

### U-values, R-values and conductivities

Best Practice insulation specifications are generally expressed in terms of a **U-value**. This is the overall rate of energy transfer through $1m^2$ of a particular building element when the air temperatures on either side differ by 1°C. It is measured in $W/m^2K$.

For some refurbishment situations, it is more useful to quote thermal resistances, or **R-values**. Thermal resistance depends on **thermal conductivity** ($\lambda$) and thickness (d):

$$R = d/\lambda$$

and is measured in m2K/W. Thermal conductivities of insulating materials are published by manufacturers.

The resistances of each component (as well as the resistances of cavities and surfaces) are used to calculate the overall thermal resistance or R-value for the structural element. The U-value is the reciprocal of this figure.

*Table 5: Insulating cavity walls*

Filling the cavity will improve thermal performance. For example:

**1** A wall consisting of two 105mm brick leaves with a 50mm cavity and plaster facing:

With an unfilled cavity, this has a U-value of 1.44 $W/m^2K$
With a filled cavity, it has a U-value of **0.6 $W/m^2K$**

**2** A wall of 105mm external brick, a 50mm cavity, inner leaf of 100mm dense concrete block ($\lambda$ = 1.130 W/mK) and plaster:

With an unfilled cavity, this has a U-value of 1.67 $W/m^2K$
With a filled cavity, it has a U-value of **0.62 $W/m^2K$**

**3** A wall of 105mm external brick, 65mm cavity, 100mm lightweight block inner leaf ($\lambda$ = 0.18 W/mK) faced with plasterboard:

With an unfilled cavity, this has a U-value of 0.88 $W/m^2K$
With a filled cavity, it has a U-value of **0.41 $W/m^2K$**

*Table 6: Insulation of roofs*

**Pitched roofs**

*Lofts:* An uninsulated loft space would have a U-value in the region of 2.5 W/m$^2$K (with 100mm of insulation ($\lambda$ = 0.040 W/mK) this improves to 0.4 W/m$^2$K).
Two layers of insulation, covering the joists, will achieve a U-value of **0.16 W/m$^2$K.**

| Achieving the required U-value | |
|---|---|
| **Insulation conductivity ($\lambda$) (W/mK)** | **Thickness required (mm)** |
| 0.035 | 100 + 124 |
| 0.040 | 100 + 150 |
| 0.045 | 100 + 180 |

Given that the conductivity of any existing insulation may not be known, thicknesses given above are based on new insulation of known conductivity.

*Sloping ceilings:* insulate between and under the rafters to achieve a U-value of **0.16 W/m$^2$K** where possible. If space is limited, particularly where rafters are less than 185mm deep, the best practicable level of insulation should be installed.

| Rafter depth (mm | Practically achievable U-value (W/m$^2$K) |
|---|---|
| Less than 135 | 0.25 |
| 135-185 | 0.20 |
| Greater than 185 | 0.16 |

**Flat roofs**

An uninsulated roof comprising a weatherproof membrane over a timber deck has a U-value of about 2.57 W/m$^2$K).
Applying insulation with an R-value of 3.7 m$^2$K/W over the deck gives a final U-value of **0.25 W/m$^2$K.**

| Achieving the required R-value (R = d/$\lambda$) | |
|---|---|
| **Insulation conductivity ($\lambda$) (W/mK** | **Thickness (d) required (mm)** |
| 0.020 | 74 |
| 0.025 | 93 |
| 0.030 | 111 |
| 0.035 | 130 |
| 0.040 | 148 |

*Table 7: Insulating ground floors*

**Solid floors**

A solid concrete floor slab has a U-value between 0.45-0.7 W/m$^2$K).

Applying insulation with an R-value of 2.5 m$^2$K/W under or over new concrete slab, can improve this to **0.20-0.25 W/m$^2$K** (depending on floor geometry).

**Suspended floors**

A floor composed of timber floorboards on joists will have a U-value between 0.45-0.7 W/m$^2$K).

Insulation with an R-value of 3.75 m$^2$K/W applied between the joists tight against the underside of the floor deck will give a final U-value of **0.20-0.25 W/m$^2$K**, (depending on floor geometry).

| Achieving the required R-value (R = d/$\lambda$) | | |
|---|---|---|
| **Insulation conductivity ($\lambda$) (W/mK)** | **Thickness (d) required (mm)** | |
| | **Solid floors** | **Suspended floors** |
| 0.020 | 50 | 75 |
| 0.025 | 63 | 94 |
| 0.030 | 75 | 115 |
| 0.035 | 88 | 133 |
| 0.040 | 100 | 150 |

*Table 8: Windows and doors*

**Windows**

Single glazed timber or PVC-U windows will have a typical U-value of 4.8 W/m$^2$K, although the figure is 5.7 W/m$^2$K for metal frames with no thermal break. These should be replaced with windows having a U-value of **2.0 W/m$^2$K**, irrespective of frame material. In some situations in Scotland, a U-value of 1.8 W/m$^2$K may be required. If in doubt, seek guidance from building control at the local authority. The frames should also be fully draught-stripped.

**Doors**

A solid timber door will have a U-value of 3.0 W/m$^2$K. A new insulated solid door will improve this to below 1.0 **W/m$^2$K**.

A half-glazed door will typically have a U-value of 3.7 W/m$^2$K. An insulated half glazed door will improve this to below 1.5 **W/m$^2$K**.

**Acceptable glazing systems**

| Frame | Glazing | Coating | Gas fill | Air Gap (mm) | U-value (W/m$^2$k) |
|---|---|---|---|---|---|
| Timber/PVC-U | Double | Low-e, hard (en=0.15) | Air | 16+ | 2.0 |
| Timber/PVC-U | Double | Low-e, hard (en =0.15) | Argon | 12 | 1.9 |
| Timber/PVC-U | Double | Low-e, soft (en =0.1) | Air | 16+ | 1.9 |
| Timber/PVC-U | Double | Low-e, soft (en =0.1) | Argon | 12 | 1.9 |
| Timber/PVC-U | Triple | None | Air | 16+ | 2.0 |
| Timber/PVC-U | Triple | Low-e, hard (en =0.15) | Air | 12 | 1.7 |
| Metal (4mm thermal break) | Triple | Low-e, hard (en =0.15) | Air | 16+ | 2.0 |

# Improvements to building services

While work on building services normally takes place as part of planned maintenance, there are instances (such as boiler breakdown) where immediate action is required. Specifications should be pre-prepared to ensure that such opportunities for improving energy efficiency are not lost.

The heating system is responsible for the greatest energy use in a dwelling. However, the high cost of electricity and its greater contribution to $CO_2$ emissions means that specifying energy efficient lighting and appliances (where fitted) is also increasingly important.

Ventilation is not, in itself, considered an energy efficiency measure. Yet it has an impact on both comfort levels and energy consumption. Too much ventilation, whether from draughts or from uncontrolled vents, will cause discomfort to occupants and excessive energy use. Too little, on the other hand, may lead to a build-up of moisture which can, in turn, result in condensation and mould growth.

The following improvements should be made in order to achieve the standards set by Best Practice Refurbishment Specification.

## 1. Heating systems

### Domestic wet central heating systems

**Boiler**
The boiler should have a minimum SEDBUK rating of:

- 86% if fuelled by natural gas (bands A and B)
- 88% if LPG fuelled (band A and some of B)
- 89% if an oil-fired regular boiler (A and some from B), but 86% for a combi or a combined primary storage unit (CPSU)

These levels can only be achieved with condensing versions.

**Hot water store**
In the case of systems with combi or CPSU boilers, there is no separate store.

Regular boilers will have either a high-performance hot water cylinder exceeding the requirements of BS 1566 and BS 7206 or a high performance thermal (primary) storage system. In the latter case, the insulation properties must exceed the requirements of the Waterheater Manufacturers' Association (WMA) Performance Specification for Thermal Stores[6] by 15% and satisfy its other requirements.

**Controls**
These should comprise:

- a programmable room thermostat. In Scotland these must have a 7-day function
- a boiler interlock
- Thermostatic Radiator Valves (TRVs) on all radiators, except in areas with a room thermostat
- automatic bypass valve

For systems with a separate storage cylinder, a cylinder thermostat is also required. In addition, the programmable room thermostat must have an additional hot water timing capability.

Installation should be carried out to current Best Practice requirements, see CHeSS for full details[5].

### Non-centrally heated systems

Time and temperature controls should be equivalent to CHeSS HC4/HR4.

Off-peak electric storage heaters should have automatic charge control and fan-assisted models are recommended. Heaters using peak-period electricity should have controls for individual room temperature and operating times.

Hot water cylinders should be large enough to supply most of the hot water demand between off-peak charging periods, and they should be insulated to a high performance specification such as 'Maxistore'.

## 2. Lighting

Use dedicated energy efficient lights when replacing fittings. These can have a major impact in high usage areas such as: living rooms, study bedrooms, hallways and landings. They should also be used in communal areas and for security lighting – except where they are push-button operated, or controlled by Passive Infra-Red (PIR) detectors.

## 3. Ventilation

Provide controlled ventilation in order to prevent condensation. Whole-house mechanical ventilation systems should only be considered in conjunction with a package of measures to reduce air leakage.

## 4. Electrical appliances

Electrical appliances, where fitted, should be Energy Efficiency Recommended (EER) models. The EER logo compliments the European Union Energy Label, which shows how much energy an appliance uses on a scale of A to G.

## Environmental considerations

There is a growing urgency to reduce the environmental impact of human activities.

Energy efficiency initiatives over the last 30 years have reduced the energy consumption of new dwellings considerably, but action to minimise the impact from construction materials has been relatively slow.

The Green Guide to Housing Specification[7] provides a useful reference work, giving environmental rating to over 250 construction products. Developed over 20 years and currently supported by the National House Building Council (NHBC), the ratings are based on life cycle assessment data from the Government-supported BRE Environmental Profiles Scheme. The Guide contains an extensive list of references to all its data sources.

**Insulation**
The use of insulation in the building fabric will significantly reduce the operational environmental impact of the structure over its lifetime. This benefit will outweigh the embodied environmental impact from its use in the first place.

To minimise this embodied impact too, specifiers should avoid foam insulation materials that use blowing agents associated with ozone depletion or global warming, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Alternative agents such as carbon dioxide or pentane are less environmentally damaging.

Renewable and recycled materials such as cork, recycled cellulose, flax and sheep's wool, foams using alternative blowing agents, low density mineral and glass wool: all of these have high ratings in the Green Guide to Housing Specification. Using them will help to moderate both embodied and operational environmental impacts. (Lower density glass and mineral wools should be used in preference to denser versions wherever possible as their environmental impact increases with weight.)

**Windows and doors**
Windows and doors contribute between 5-10% of the embodied environmental impact of a house.

*PVC-U* has a poor environmental rating in the Green Guide to Housing Specification due to the high energy intensity of manufacture and the lack of any recycled material input (although the industry is taking steps to encourage more general recycling of PVC-U).

Primary *aluminium* manufacture is also highly energy intensive. Although aluminium extrusions used for windows and doors contain around 30% recycled metal (which requires significantly less energy to process), the high energy input to primary and secondary manufacturing processes still results in high overall environmental impact for aluminium windows.

*Timber* windows are made from a renewable material and softwood window – which do not require much energy in manufacture – score particularly well. As with all timber products, specifiers should ensure that the timber is sustainably grown; this is particularly relevant for tropical hardwood which will also entail more transport-related energy input. Locally grown hardwoods will have similar impacts to softwood. Information on sustainably-sourced timber is available from the Forest Stewardship Council (www.fsc-uk.org - Tel: 01686 413916).

## References


1. Building Regulations 2000, Approved Document L1 Conservation of Fuel and Power
2. Building Standards (Scotland) Regulations 1990, 6th amendment, Technical standards to Part J, Conservation of Fuel and Power
3. Building Regulations (Northern Ireland) Part F Conservation of Fuel and Power
4. The effect of Building Regulations (Part L1 2002) on existing dwellings - Information for installers and builders for extensions and alterations in England and Wales (CE53)
5. Central Heating System Specifications (CHeSS) (CE51)
6. Waterheater Manufacturers' Association Performance Specification for Thermal Stores, 1999
7. BR390 The Green Guide to Housing Specification, Anderson and Howard, BRE, 2000

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## Further reading

**Energy Efficiency Best Practice in Housing publications**
These publications can be obtained free of charge by telephoning the Helpline on: **0845 120 7799** or by visiting the website at: **www.est.org.uk/bestpractice**

**General**
Domestic Energy Efficiency Primer (GPG 171)

Energy efficiency standards - for new and existing dwellings (GIL 72)

Energy efficient refurbishment of existing housing (GPG 155)

Energy efficient refurbishment of existing housing - case studies (GPCS 418)

Refurbishing dwellings with solid walls (CE58)

Refurbishing timber-framed dwellings (CE59)

The effect of Building Regulations (Part L1 2002) on existing dwellings - Information for installers and builders for extensions and alterations in England and Wales (CE53)

**Insulation**
Cavity wall insulation in existing housing (GPG 26)

Cavity wall insulation: unlocking potential in existing dwellings (GIL 23)

Effective use of insulation in dwellings (CE23)

**Services**
Central Heating System Specifications (CHeSS) (CE51)

Controls for domestic central heating & hot water – guidance for specifiers and installers (CE50)

Domestic central heating and hot water: systems with gas and oil-fired boilers – guidance for installers and specifiers (CE48)

Domestic heating & hot water – choice of fuel & system type (CE49)

Energy efficient lighting – a guide for installers and specifiers (CE61)

Energy efficient ventilation in housing - a guide for specifiers on the requirements and options for ventilation (GPG 268)

Low energy domestic lighting - a summary guide (GIL 20)

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