Energy Efficiency Best Practice in Housing

Effective use of insulation in dwellings

A guide for specifiers and contractors

Introduction

Insulation is a fundamental element of any energy efficiency strategy for dwellings. This guide describes the levels likely to be needed to meet current best practice.

Efficient use of energy helps to reduce fuel bills and thereby tackle fuel poverty. In addition, it cuts atmospheric emissions of gases such as carbon dioxide (CO_2), sulphur dioxide (SO_X) and oxides of nitrogen (NO_X) caused by the burning of fossil fuels. In this way, it helps to combat climate change and improves air quality.

The specification outlined here takes into account the range of heating fuels commonly employed in the UK and also considers the impact of different sizes and configurations of dwellings.

The guide aims to give architects, specifiers, installers and others involved in the design and construction of dwellings sufficient information to specify adequate insulation for most typical dwellings in the UK, in both new build and refurbishment projects. However, it is only a summary: a list of more detailed guidance can be found at the end of this publication.

The Best Practice specifications for dwellings

This guide covers two related insulation specifications:

- the Best Practice specification for new buildings
- the Best Practice refurbishment specification

The level of insulation required to satisfy the specification is expressed in terms of U-values for the main structural elements of the building, such as the walls, roof, etc. U-values measure the rate of energy loss through these elements. This rate can be slowed (and the U-value reduced) by incorporating more insulation within the respective elements.

New Housing

The Best Practice specification for new housing includes Carbon Index (CI) targets. The Index is an indicator of the carbon dioxide emissions associated with space and water heating and is expressed on a scale of 1-10; the higher the number, the better the performance. The CI for a building is obtained from the Government's Standard Assessment Procedure (SAP) which is required for all new dwellings in the UK.

The Carbon Index is determined by a number of factors, including:

- insulation levels
- heating system
- ventilation
- orientation and shading
- the exposed surface area relative to floor area

The greater the exposed surface area compared with floor dimensions, the more insulation will be needed to achieve the same CI. For example, a semi-detached dwelling will require more insulation than a mid-terrace property. The Index can be used to compare performance between dwellings as it is expressed in terms of emissions per square metre of floor area.

Changes to one factor will require alterations to others if the same CI is to be achieved. This gives a certain flexibility to the design process, while the inclusion of maximum acceptable U-values for walls, floors, roofs and glazed areas in the specification ensures that good insulation levels are always achieved. Where wet heating systems are used, minimum boiler efficiencies also have to be achieved. It should be noted that there are limit values: to reach a particular CI value in different dwellings, greater efficiencies and lower energy loss through external surfaces may be required.

The main features of the Best Practice specification are given in Tables 1 and 2. More details can be found in other Energy Efficiency Best Practice in Housing publications: *Energy Efficiency in New Housing: Summary of Specifications for England, Wales and Scotland (CE12) and Energy Efficiency in New Housing: Summary of Specifications for Northern Ireland (CE24).*

Table 1: Carbon Index requirements for various domestic heating fuels

Heating Fuel	Carbon Index
Natural gas, LPG	8.6
Oil	7.4
Electricity	6.8

Table 2: Limit factors for exposed structural elements and for heating boilers

Element	Maximum acceptable U-value (W/m²K)
Roofs	0.13
Walls	0.25
Floors	0.20
Windows, doors, rooflights (area-weighted average)	1.8
Heating Fuel	**Minimum boiler efficiency (%)**
Natural gas	86
LPG	88
Oil	89

What the limits given in Table 2 mean in practice can be seen from the examples on the following page. These give typical figures for three common types of dwelling:

- a flat
- a semi-detached house
- a detached house

In each case, the insulation levels needed to reach the Best Practice CI are given for different heating fuels.

As has been mentioned, a number of factors influence a building's Carbon Index, some of them being site specific and fixed (such as site layout and building orientation). Once these have been determined for a particular building, it may be necessary to adjust the specification in order to achieve the appropriate CI. However, some general conclusions can be drawn from the examples about the relationship between the insulation levels given in the specification and the Carbon Index achieved:

1. For smaller properties such as flats, the Best Practice Carbon Index can usually be met with the insulation levels given in Table 2 and without any further efficiency measures (except in the case of ground floor flats with LPG heating).
2. For semi-detached properties, additional insulation would be required in the case of *electric* or *LPG* heating systems (and in addition a higher efficiency boiler would be required).
3. Additional insulation will be required irrespective of the choice of heating fuel for detached properties. These increases need only be small in houses with *natural gas* or *oil* heating. *Electrically* heated properties will need significantly more insulation. *LPG* heated houses will need further efficiency measures in addition to high insulation levels and a very high efficiency boiler.
4. Additional insulation or other energy efficiency measures will be needed for dwellings where the ratio of the exposed areas, such as walls and roofs, is high compared to the floor area (for example *large bungalows*).

Tables 3-5: Typical insulation levels required to satisfy the Best Practice specification

Figures underlined indicate where the required performance is higher than the basic specification. These examples show the levels of insulation and boiler efficiency required to satisfy the Carbon Index targets.

Table 3: Two-bedroom flat – floor area 61m²

Heating Fuel	*Natural Gas*	*Oil*	*LPG*	*Electricity*
Carbon index	***8.6***	***7.4***	***8.6***	***6.8***
U-value (W/m²k)				
- roof*	0.13	0.13	0.13	0.13
- walls	0.25	0.25	0.25	0.25
- floor*	0.20	0.20	<u>0.10</u>	0.20
- windows, doors, rooflights	1.8	1.8	1.8	1.8
Boiler efficiency	86% (combi boiler assumed)	89%	86% (combi boiler assumed)	N/A (storage heaters)

* for ground and top floor flats as applicable

Table 4: Semi-detached house – floor area 89m²

Heating Fuel	*Natural Gas*	*Oil*	*LPG*	*Electricity*
Carbon index	***8.6***	***7.4***	***8.6***	***6.8***
U-value (W/m²k)				
- roof	0.13	0.13	<u>0.08</u>	<u>0.08</u>
- walls	0.25	0.25	<u>0.15</u>	<u>0.20</u>
- floor	0.20	0.20	<u>0.10</u>	<u>0.15</u>
- windows, doors, rooflights	1.8	1.8	<u>1.5</u>	<u>1.5</u>
Boiler efficiency	86%	89%	<u>93.3%</u>	N/A (storage heaters)

Table 5: Detached house – floor area 104m²

Heating Fuel	*Natural Gas*	*Oil*	*LPG**	*Electricity*
Carbon index	***8.6***	***7.4***	***8.6***	***6.8***
U-value (W/m²k)				
- roof	<u>0.1</u>	<u>0.1</u>	<u>0.08</u>	<u>0.08</u>
- walls	<u>0.2</u>	<u>0.22</u>	<u>0.15</u>	<u>0.15</u>
- floor	<u>0.18</u>	<u>0.18</u>	<u>0.10</u>	<u>0.15</u>
- windows, doors, rooflights	1.8	1.8	<u>1.5</u>	<u>1.5</u>
Boiler efficiency	86%	89%	<u>93.3%</u>	N/A (storage heaters)

* mechanical ventilation with heat recovery also assumed here

Existing Housing

Refurbishment work on dwellings tends to focus on particular parts of the structure rather than the building as a whole. For this reason, it is more appropriate to take an elemental approach to energy performance rather than use a whole-building Carbon Index requirement.

The Best Practice refurbishment specification (see Table 6) can be used for most buildings in the UK without undue technical risk. However, there will be instances where, because of the particular design, construction method or indeed a building's historic value, it is not possible to implement all the recommendations in the specification. In such cases the highest practicable levels should be achieved, with additional energy efficiency measures included elsewhere in the refurbishment work. Where it is possible to exceed the levels in the Best Practice specification, this should be done.

Where refurbishment work is subject to the Building Regulations, insulation improvement work should be agreed with the building control body prior to implementation. This is particularly important in Scotland as the application of the Building (Scotland) Act 1959, in association with the Technical Standards, can result in more stringent requirements.

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^{2}K.

For some refurbishment situations, it is more useful to quote thermal resistances, or R-values. Thermal resistance depends on thermal conductivity (λ) 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 6: Best Practice Refurbishment specification – insulation

Element	U-value to be achieved (W/m^{2}K)
Walls	
– cavity walls	install cavity wall insulation
– solid walls (a) internal insulation	0.45
(b) external wall insulation	0.35
Roofs	
– pitched roofs	0.16
– flat roofs	0.25
Ground floors (depending on floor geometry)	0.20-0.25

The following tables give examples of how to achieve Best Practice in refurbishment projects using appropriate levels of insulation.

Table 7: Insulation of walls

(a) **Solid Walls**

For an existing 220mm brick and internal plaster wall (U-value 2.1 W/m^{2}K), either:

- apply external wall insulation with an R-value of 2.3 m^{2}K/W and apply protective render (final U-value of 0.35 W/m^{2}K), or
- apply internal plasterboard/insulation laminate with R-value of 1.8 m^{2}K/W (giving a final U-value of 0.45 W/m^{2}K)

(b) **Cavity Walls**

For a cavity wall with two brick leaves of 105mm, internal plaster and a cavity of 65mm (U-value 1.44 W/m^{2}K):

- fill the cavity with suitable insulation material to give a final U-value of 0.54 W/m^{2}K (based on insulation with a thermal conductivity of 0.040 W/mK)

Achieving the required R-value ($R = d/\lambda$)

Insulation conductivity (λ) (W/mK)	Thickness (d) required (mm)	
	External Wall Insulation	Internal Insulation
0.020	48	35
0.025	60	44
0.030	72	52
0.035	82	61
0.040	95	70

Table 8: Insulation of roofs

(a) **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 (λ = 0.040 W/mK) this improves to 0.4 W/m^{2}K. Insulate (or top up) with two layers, covering the joists, to achieve a U-value of 0.16 W/m^{2}K.

Thickness of loft insulation

Insulation conductivity (λ) (W/mK)	Thickness required (mm)
0.030	100 + 124
0.040	100 + 150
0.045	100 + 180

Thicknesses given 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.

Thickness of sloped ceiling insulation

Rafter depth (mm)	Practically achievable U-value (W/m²K)
Less than 135	0.25
135-185	0.20
Greater than 185	0.16

(b) **Flat roofs**

To improve an uninsulated roof comprising a weatherproof membrane over a timber deck (U-value about 2.57 W/m^{2}K):

- apply insulation with an R-value of 3.7 m2K/W over the deck – this gives a final U-value of 0.25 W/m^{2}K.

Achieving the required R-value (R = d/λ)

Insulation conductivity (λ) (W/mK)	Thickness (d) required (mm)
0.020	74
0.025	93
0.030	111
0.035	130
0.040	148

Table 9: Ground Floors

(a) **Solid floors**

To improve a solid concrete floor slab (U-value between 0.45-0.7 W/m^{2}K):

- apply insulation with an R-value of 2.5 m^{2}K/W under or over new concrete slab, to give a new U-value of 0.20-0.25 W/m^{2}K (depending on floor geometry)

(b) **Suspended floors**

To improve energy performance of a floor composed of timber floorboards on joists (U-value 0.45-0.7 W/m^{2}K):

- apply insulation with an R-value of 3.75 m^{2}K/W between joists tight against the underside of the floor deck. This 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/λ)

Insulation conductivity (λ) (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

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 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 HCFCs and 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.
This definitive guide, developed over 20 years and supported in its current form by the National House-Building Council (NHBC), is predominantly based on life cycle assessment data from the DETR-supported BRE Environmental Profiles scheme. The Guide contains an extensive list of references to all of its sources of data.

Using such materials will help to moderate both embodied and operational environmental impacts.

Relevant Publications

The Energy Efficiency Best Practice in Housing programme

The following publications are available from the Energy Efficiency Best Practice in Housing helpline on 0845 120 7799 or by visiting the website at: www.est.org.uk/bestpractice

Building a sustainable future – homes for an autonomous community (GIR53)

Cavity wall insulation: unlocking the potential in existing dwellings (GIL23)

Cavity wall insulation in existing housing (GPG26)

Domestic Energy Efficiency Primer (GPG171)

Energy efficiency standards for new and existing dwellings (GIL72)

Energy efficient refurbishment of existing housing (GPG155)

Energy efficient refurbishment of existing housing – case studies (GPCS418)

External insulation systems for walls of dwellings (GPG293)

Energy Efficiency in New Housing: Summary of Specifications for England, Wales and Scotland (CE12)

Energy Efficiency in New Housing: Summary of Specifications for Northern Ireland (CE24)

Internal wall insulation in existing housing – a guide for specifiers and contractors (GPG138)

Refurbishment site guidance for solid-walled houses – ground floors (GPG294)

Refurbishment site guidance for solid-walled houses – roofs (GPG296)

Refurbishment site guidance for solid-walled houses – walls (GPG297)

The effect of Building Regulations (Part L1 2002) on existing dwellings – information for installers and builders for extensions and alterations in England and Wales (GIL70)

Other publications

Building Regulations 2000, Approved Document L1 Conservation of Fuel and Power, TSO, London

Building Standards (Scotland) Regulations 1990, 6th amendment, Technical standards to Part J, Conservation of Fuel and Power, TSO, London

Building Regulations (Northern Ireland), 1994 Part F, Technical booklet, Conservation of fuel and power, TSO, London

BR390 The Green Guide to Housing Specification, Anderson and Howard, BRE, 2000

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