Energy Efficiency Best Practice in Housing

Northern Ireland: assessing U-values of existing housing

Energy Saving Trust

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Housing in Northern Ireland

Home energy use is responsible for 28 per cent of UK carbon dioxide emissions which contribute to climate change. By following Best Practice standards, new build and refurbished housing will be more energy efficient and will reduce these emissions, saving energy, money and the environment.

This publication deals with the assessment of U-values in existing dwellings in Northern Ireland and is intended to help designers and energy auditors. Energy certification of buildings will become increasingly prevalent following the implementation of the Energy Performance of Buildings Directive(1).

A U-value is a measure of the rate at which heat is lost through a roof, wall, floor or window. The higher the number, the greater the loss. A dwelling with low U-values can be expected to have less heat loss, lower heating bills and more comfortable indoor temperatures than an equivalent dwelling with high U-values. Age and type of construction affect the U-values of a building and any assessment of an existing dwelling requires some consideration of these factors.

This publication gives typical, as-built U-values for existing housing in Northern Ireland, prior to any retrofit of insulation materials. The U-value depends upon the precise details of a construction, including the thicknesses and properties of the materials. The usual method of calculating a U-value is by using the combined method, described in BS EN ISO 6946(2) and BS EN ISO 13370(3). Should more accurate information on thermal performance be available at the time of the assessment, it should be used in preference to the default U-values given here.

The housing stock

Most housing in Northern Ireland is of traditional construction, although there is a significant quantity of non-traditional stock. Pre-war housing tends to employ solid brick walls with plaster finish. Poured concrete ('no-fines') walls are common in houses built between the wars and shortly after. Since the 1950s, cavity walls have predominated (except for walls within dormers, which tend to be timber-framed). Modern timber-frame accounts for only a small proportion of the housing stock, even post-1999.

Until quite recently, heating in most houses was provided by solid fuel systems (usually with central heating) or oil-fired central heating. Owner-occupied housing favoured oil-fired systems while social housing tended to have solid fuel. In the private rented sector, low maintenance was seen by landlords as a priority and electric heating was common. Since 1991, there has been a dramatic decline in solid fuel heating and a growth in oil – and in the Belfast area, natural gas.

In housing of all ages including the newest, internal wall finishes tend to be plaster rather than dry-lining. Housing built prior to 1920 usually has plaster lath, but from that time onwards the plaster was commonly applied directly to masonry. As a result of the extensive use of plaster, housing is relatively airtight, observed in the low leakage rates in pressurisation tests.

Older construction consists largely of long terraces. From 1950 onwards the housing stock is dominated by semi-detached and detached houses.

Prior to 1973 construction was governed by district council bye-laws and there were no consistent standards applying across Northern Ireland. Consequently levels of insulation varied from district to district. From 1973 onwards levels of insulation and U-values were essentially determined by the Building Regulations in force at the time of construction.

The use of AAC (autoclaved aerated concrete) is very rare in Northern Ireland due to a lack of manufacturers coupled with high transportation costs from the mainland. Lightweight aggregate blockwork is occasionally used but is not nearly as common as dense blockwork.

Of 647,500 dwellings in Northern Ireland, 255,580 have uninsulated walls(4). Some 208,230 (81 per cent) of these are in the private sector (owner-occupied or privately rented). Put another way, 43 per cent of private sector dwellings in Northern Ireland have uninsulated walls compared with just 21 per cent of social housing.

The housing stock in Northern Ireland can be usefully classified according to the following construction periods:

1. pre-1919;
2. 1919-1944;
3. 1945 to the early 1950s;
4. late 1950s and early 1960s;
5. late 1960s and early 1970s;
6. 1978-1984;
7. 1985-1991;
8. 1992-1999;
9. 2000 onwards.

1. Pre-1919

Much of the housing in this period, particularly in Belfast, was built by mill owners or by Belfast Corporation. It was largely for workers needed by labour-intensive heavy engineering and linen manufacture. Many of the dwellings are in long terraces, usually of two or three storeys. Figure 1 shows a pre-1919 three-storey terraced housing block.

Figure 1: Pre-1919 three-storey terraced housing block.

Approximately 116,400 dwellings were built before 1919. Nine-inch single leaf brickwork is the predominant wall construction for low-rise buildings in urban areas. In the Belfast area the walls usually have facing brickwork, while elsewhere poorer quality brickwork is often rendered. Lath and plaster were generally used internally. In rural areas, construction often used locally-sourced stone or rendered rubble and clay (see Figure 2).

In single-storey and two-storey buildings, walls generally consisted of nine inch (225mm) solid brickwork with a U-value for unimproved walls of around 2.0W/m^2K. In buildings of three or more storeys, lower walls were made of 13.5 inch (340mm) solid brickwork with a U-value for unimproved walls of around 1.6W/m^2K. Some cavity walls exist from this period; typically around 11 inches (280mm) thick with a 2 inch (50mm) cavity. Unimproved cavity walls of this type are likely to have a U-value of around 1.7W/m^2K.

Roofs were usually finished with 'Bangor-blue' slates rather than tiles, and had no sarking felt beneath the slates (although sarking board was very occasionally used). Originally the slates provided a significant amount of ventilation, and eaves ventilation may subsequently have been added.

According to Table A7.12 of the Northern Ireland House Condition Survey 2001[(4)], 73 per cent of pre-1919 dwellings have no wall insulation at all. A principal reason for this is the lack of a cavity in the walls, making insulation more expensive to apply. A proportion of houses in this age band (about 15 per cent) have had internal wall insulation added, which can often be identified by the deep internal reveals at windows and doors.

Figure 2: Pre-1919 rural cottages.

2. 1919-1944

Timber became scarce during the First World War and roof designs changed as a result. It was around this time that the 'Belfast Truss' was developed as a means of using timber in roofs more economically.

After the War, there was a move to cavity walls, leading to a general reduction in wall U-values, typically to about 1.7W/m^2K. Many of these houses have subsequently had cavity wall insulation added, particularly in the case of social housing. Figure 3 shows a two-storey terraced housing block with cavity wall construction from this period.

Figure 3: Two-storey terraced housing block built during the inter-war period.

3. 1945 to the early 1950s

There is an element of 'non-traditional' housing in this period. This used labour systems and materials not previously employed in house building and formed a departure from the traditional solid brick or brick/cavity walls. Most of it has concrete-based walls although there is a small percentage of timber-framed or metal-framed housing. The internal finish is typically plaster applied direct to masonry with no lath. Ceilings from this period are usually plasterboard rather than lath and plaster. U-values of walls in non-traditional housing tend to be around 1.7W/m^2K for concrete-based constructions and around 1.2W/m^2K for framed constructions. Most housing from this period is semi-detached rather than terraced or detached. Non-traditional housing continued until the mid 1950s (or later in the case of no-fines concrete).

Traditionally-built walls of brick/cavity/brick and brick/cavity/block wall constructions (which were also common during this period) have U-values of around 1.7W/m^2K.

Figure 4: Aluminium-framed property with metal cladding, 1947.

Figure 4 shows a non-traditional dwelling with an aluminium frame and metal cladding. There are approximately 1200 dwellings of this type in Northern Ireland, which were all built around 1947. It incorporates some insulation and is thought to have a U-value of around 1.2W/m^{2}K (if unimproved) or 0.5W/m^{2}K (post improvement)([5]).

4. Late 1950s and early 1960s

Cavity walls predominate from the 1950s onwards, consisting of brick/cavity/brick or brick/cavity/block wall. System build is also common.

Figure 5: Rural post World War II property with cavity wall construction.

Figure 5 is an example of a rural post-war dwelling with cavity wall construction and an external render finish.

There is also a significant element of 'no-fines' housing from this period (Figure 6). U-values of 'no-fines' walls vary between 1.0-1.7W/m^{2}K.

Figure 6: No-fines concrete housing, circa 1951.

5. Late 1960s and early 1970s

'No-fines', system-build and other types of non-traditional housing can be found among housing built in the late 1960s and early 1970s.

In 'no-fines' housing, walls are made of concrete cast in-situ with a stone aggregate. The aggregate varies in consistency in different areas. The wall is rendered externally and often lined internally with timber battens and plasterboard. The U-value of 'no-fines' walls varies between 1.0-1.7W/m^{2}K. Information on typical U-values can be found later in this document.

Unimproved roofs are likely to have 25mm of mineral fibre insulation between the joists in the loft, giving a U-value of about 1.3W/m^{2}K. In many cases, additional insulation will have been added later.

Figure 7 shows a terrace of houses of this period with timber infill panels. These usually have structural party end-walls of masonry with timber infill panels to front and rear. The timber panels typically consist of 12-15mm tiles hanging or cedar boarding on battens, with building paper, 25mm EPS insulation between the timber studs and a plasterboard internal finish.

Figure 7: Housing incorporating timber infill panels.

Tower blocks of this period have concrete panels with 25mm of expanded polystyrene sandwiched between them. Some medium rise housing and tower blocks were constructed using no-fines concrete systems. Wall U-values are typically around 1.7W/m^{2}K.

Figure 8: Concrete tower block, typical of the 1960s and early 1970s.

A significant number of system-build houses were constructed around the 1960s with block/cavity/block walls. These have U-values of around 1.7W/m^{2}K.

Prior to 1973, standards were imposed by individual district council bye-laws and there was little consistency from district to district. Cavity walls and roofs with 25mm of insulation were the most common type of construction.

In the mid 1970s, the Northern Ireland Housing Executive built a large number of timber-framed houses with 25mm of insulation and a concrete brick outer skin. In the private sector however timber frames were not popular.

6. 1978-1984

The 1977 revision to the regulations meant that wall U-values of this period were about 1.0W/m^{2}K and roof U-values about 0.6W/m^{2}K (ignoring thermal bridging). The regulations set no requirements for floor insulation. Floor U-values were generally determined by the ratio of the floor perimeter to ground floor area. U-values were still poor by modern standards and therefore thermal bridging had a relatively low impact on overall heat loss.

Roofs were usually insulated with around 50mm of mineral fibre insulation between the joists in the loft, although this was often improved at a later date.

7. 1985-1991

The 1984 revision of the regulations limited thermal bridging, making Northern Ireland the first part of the UK to address this issue. A maximum U-value of 1.2W/m^{2}K was set for windows and doors. An upper limit on wall U-values of 0.60W/m^{2}K and an upper limit on roof U-values of 0.35W/m^{2}K (ignoring the effects of joists, mortar joints and wall ties) was also laid down. 100mm of mineral wool insulation between the ceiling joists in the loft became standard practice.

Figure 9: Traditional-styled house built in the 1980s.

8. 1992-1999

The elemental method was the simplest method of compliance with the requirements of the 1991 regulations, as laid down in Technical Booklet F. This set a maximum U-value of 0.45W/m^{2}K for walls and single glazed windows. Many house builders chose to use an alternative permitted approach, the walls having U-values in the region of 0.60W/m^{2}K, but incorporating better insulated double glazing.

A small amount of timber-frame housing was built with 89mm timber studs and mineral wool quilt insulation. Timber-frame walls from this period are likely to have better U-values than cavity walls.

At this time, it was permissible to ignore the effects of timber joists, timber framing, wall ties, mortar bedding and air gaps between insulation sections. Using today's calculation methods, the U-value of a partially filled cavity wall built to the prevailing standard of 0.45W/m^{2}K might actually achieve a figure of 0.55W/m^{2}K. This is once the effect of steel wall ties and mortar joints have been taken into account(2).

9. 2000 onwards

The 1999 revision of Technical Booklet F kept the elemental U-values nominally the same. However, in practice U-values were tightened up by changes in the method of calculating U-values. U-value calculations now take thermal bridging into account.

Social housing

Table 1 summarises the distribution of housing types in the social housing stock - it is dominated by cavity wall construction.

Table 1: A summary of construction types among the social housing stock*

Type of construction	Year	Number
Masonry with cavity wall insulation (batts)	1981 - 1998	47,874
Cavity wall (pre NIHE)	1945 - 1971	31,000
Masonry without cavity wall insulation (batts)	1971 - 1981	19,769
Cross wall construction	1960 - 1974	17,000
No-fines (various patented systems)	1947 - 1965	11,000
Solid wall construction eg rural cottage type	Pre-1919	5,000
Timber-framed	Post-1972	4,000
Flats, five-storeys and over	1960 - 1970	3,600
Aluminium / Ulster cottages	1947 - 1957	2,000
Two-storey concrete frame	1947 - 1965	670

* For guidance only. Figures in this table are based on recent research(6) and could differ from those published in other statistical surveys.

The above table does not include 7557 dwellings built between 1999 and 2004 by Registered Housing Associations in Northern Ireland(6).

Typical U-values for existing housing

This section gives default U-values for the major building elements of Northern Ireland housing, according to construction method and age. These have been calculated using BS EN ISO 6946 (BS EN ISO 13370 for floors) unless otherwise stated. Due to the greater accuracy of these calculations, U-values stated here may differ from those given in the regulations of the period concerned.

A. Walls

These tables summarise the main types of wall construction and give default U-values. A time lag of one year is assumed between date of regulation and the effect on construction. It should be noted that where insulation is poorly fitted, the true U-value can be significantly higher than the calculated value.

Table 2: Wall types and default U-values

Period of construction	Typical types of wall construction and corresponding U-values *(U-values generally refer to unimproved wall constructions)*	U-value W/m²K
Unknown	• Solid brick walls	2.0
	• Cavity walls.	1.7
	• Timber frame walls.	1.7
Pre-1919	• Traditional 9" (225mm) solid brick walls, internal lath and plaster finish.	2.0
	• Traditional 13.5" (340mm) solid brick walls, internal lath and plaster finish.	1.6
	• Some cavity walls (but rare in this age group).	1.7
1919-1944	• Cavity walls.	1.7
	• Some solid brick walls as above.	-
1945 - mid 1950s	• Cavity walls.	1.7
	• Non-traditional concrete-based constructions.	1.7
	• Non-traditional aluminium-framed constructions.	1.2
	• Non-traditional, aluminium-framed, with subsequent improvements applied.	0.5
	• No-fines concrete, dense aggregate no-fines system with hard plaster finish*.	1.7
	• No-fines concrete, lightweight aggregate no-fines system, hard plaster finish*.	1.3
	• No-fines concrete, dense aggregate no-fines system with plasterboard finish*.	1.3
	• No-fines concrete, dense aggregate no-fines system with 'Paramount' finish*.	1.0
mid 1950s -early 1970s	• No-fines concrete as above.	-
	• Tower blocks. *(Typically 25mm EPS between system build concrete panels. A typical wall design might involve 20mm stone chip finish on 80mm cast concrete, 25mm EPS bridged by metal ties, 80mm cast concrete and 10mm plaster finish. Some thermal bridging is likely at the perimeters of the panels.)*	1.7
	• Cavity walls.	1.7
	• Timber infill panels.	1.7
1974-1977	• System build involving block/cavity/block walls.	1.7
	• Some no-fines housing as above.	-
	• Some timber frame with 25mm of insulation.	1.2
1978-1984	• Mainly brick/block cavity walls.	1.0
	• Other wall types.	1.0
1984 – 1991	• Mainly insulated brick/block cavity walls.	0.6
	• Other wall types.	0.6
1992 – 1999	• Mainly brick/block cavity walls with insulation. *(U-value was nominally 0.45W/m²K but U-value was calculated ignoring thermal bridging The predominant construction type consists of facing brick, partially-filled cavity and inner leaf concrete blockwork.)*	0.55
	• Timber frame walls. *(89mm timber studs and 89mm mineral wool quilt between the studs.)*	0.42
2000 – present	• Mainly brick/block cavity walls with insulation. *(U-value calculated allowing for thermal bridging. The predominant construction type consists of facing brick, partially-filled cavity and inner leaf concrete blockwork)*	0.45
	• Timber frame walls. *(89mm timber studs and 89mm mineral wool quilt between the studs.)*	0.42

* U-values taken from No-fines Concrete Housing in Northern Ireland Report(8)
Note: In cases where the insulation is poorly fitted, the true U-value in practice can be significantly higher than the calculated U-value.
Note: Although there were trade-off options between double glazing and walls with higher U-values, in the 1992-1999 period, these trade-off options were seldom taken.
Non-traditional housing is rare before 1944 and for conciseness has been omitted from this table.

Table 3 gives the elemental wall U-values prescribed in each revision of Technical Booklet F of the Northern Ireland Building Regulations, together with the implementation dates.

Table 3: Elemental Wall U-values for compliance with Technical Booklet F

Wall U-value, W/m²K	Date of implementation
1.7	1973
1.0	1977
0.60 (thermal bridging ignored)	1984
0.45 (thermal bridging ignored)	1991
0.45 (taking thermal bridging into account)	1999

Once granted, Building Control Approval lasts for three years. Consequently it may be difficult to determine which standard was used if a house was built within three years of a change. This is a particular issue on larger sites where it may take a number of years to complete all the properties. To allow for the time lag between an application and actual construction, an average time lag of one year should be assumed.

Table 4 shows typical U-values for a fully-filled cavity wall with various insulation thicknesses and thermal conductivities (λ). The wall consists of an outer leaf of brick and an inner leaf of concrete blockwork with a fully insulated cavity between, as shown in Figure 10. The internal finish is dense plaster.

Table 4: U-values for various insulation thicknesses and thermal conductivities

Thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)			
	0.02	0.03	0.04	0.05
	U-value (W/m²K)			
30	0.54	0.73	0.88	1.01
40	0.43	0.59	0.73	0.84
50	0.36	0.50	0.62	0.73
60	0.31	0.43	0.54	0.64
70	0.27	0.38	0.48	0.57
80	0.24	0.34	0.43	0.51
90	0.22	0.31	0.39	0.47
100	0.20	0.28	0.36	0.43

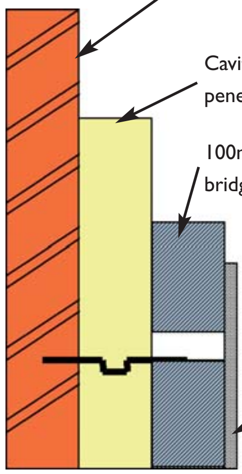

Figure 10: Typical full-fill cavity wall construction

Table 5 shows how alterations to this type of construction (Figure 10) can affect U-values.

Table 5: Adjustments to wall U-value for different levels of thermal resistance of insulation

Additional measure	Thermal resistance* of insulation (m²K/W)			
	0.5	1.0	2.0	5.0
	Adjustment to U-value			
Exterior render (20mm)	-0.02	-0.01	-0.01	0.00
12.5 mm of plasterboard on plaster dabs (15mm air gap)	-0.21	-0.1	-0.04	-0.01
Lightweight aggregate blocks (in lieu of dense concrete blocks)	-0.15	-0.07	-0.02	0.00
Unventilated cavity (50mm air space)	-0.18	-0.08	-0.03	-0.01

* The thermal resistance is equal to the thicknesses (in metres) of insulation divided by the thermal conductivity (in W/mK).

For example, a cavity wall with 60mm of insulation of conductivity 0.03W/mK with lightweight aggregate blockwork to inner leaf would give a U-value of 0.43 (Table 4) minus 0.02 (Table 2) = 0.41W/m²K.

Retrofit measures

This guide does not cover any upgrade measures made to buildings that have undergone refurbishment or had energy efficiency improvements. However, there are ways to identify whether improvements have been made which would alter the U-value of the wall. These include the following.

- A regular drill hole pattern in the outer leaf may indicate the addition of cavity wall insulation.
- Window sill extensions are common when external wall insulation has been added.
- Deep internal window reveals often signal the presence of internal wall insulation.

B. Roofs

Most dwellings of all ages have a pitched roof with a tile or slate covering. The following tables give guidance on typical roof U-values. Table 6 lists U-values where the level of insulation is known and Table 7 where it is not.

Table 6: Default roof U-values with insulation between joists

Insulation thickness (mm)	Typical roof U-value (W/m²K), no sarking felt (R of roof space 0.06m²K/W) – Allowing for bridging by joists	Typical roof U-value (W/m²K), no sarking felt (R of roof space 0.06m²K/W) – Not including bridging by joists	Typical roof U-value (W/m²K), with sarking felt (R of roof space 0.2m²K/W) – Allowing for bridging by joists	Typical roof U-value (W/m²K), with sarking felt (R of roof space 0.2m²K/W) – Not including bridging by joists
None	3.85	3.85	2.5	2.5
12	1.92	1.79	1.51	1.43
25	1.26	1.13	1.06	0.98
50	0.76	0.66	0.68	0.61
75	0.54	0.47	0.50	0.44
100	0.42	0.36	0.40	0.35
150	0.27	0.25	0.26	0.24
200	0.21	0.19	0.20	0.19
250	0.16	0.16	0.16	0.15
≥ 300	0.14	0.13	0.14	0.13

Table 7: Default U-values where thickness of roof insulation is not known

Period	Default roof U-value (W/m²K)		
	Pitched roof, insulation between joists	Pitched roof, insulation between rafters	Flat roof
Mid 1950s-1977	0.68 (50mm, sarking felt)	1.5	1.5
1978-1984	0.68 (50mm, sarking felt)	0.68	0.68
1985-1991	0.40 (100mm, sarking felt)	0.40	0.40
1992-1999	0.29 (150mm, sarking felt)	0.35	0.35
2000-present	0.25 (150mm, sarking felt)	0.35	0.35

C. Ground floors

Table 8 gives typical U-values for solid and suspended ground floors. The figures may be used in the absence of specific information.

Table 8: Default U-values for solid and suspended floors

Period	Default floor U-value
Until early 1990s	No U-value requirement in the regulations, so the figure is simply calculated from perimeter-to-area ratio. A typical U-value may be in the region of 0.60W/m²K, but this will tend to be higher for detached dwellings and lower for mid-terrace dwellings.
1992-1999	0.45W/m²K
2000-present	0.45W/m²K

D. Windows

Table 9: Default U-values of windows

Period	Predominant types of window construction	Default U-value (W/m²K)
Up to 1991	Single glazed, wooden frame	4.8
1992-1999	Single glazed windows Double glazed windows	4.8 3.1
2000-present	Double glazing without low-e coating	3.1

References

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8. No-fines Concrete Housing in Northern Ireland. The Queen's University of Belfast. Dr J M Trewsdale. May 1990.

Further reading

Energy Efficiency Best Practice in Housing publications

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

Assessing U-values of housing in Scotland (CE84)
Cavity wall insulation in existing housing (CE16)
Domestic Energy Efficiency Primer (GPG 171)
Effective use of insulation in dwellings (CE23)
Energy efficiency in new housing: Summary of specification for Northern Ireland (CE24)
Energy efficient refurbishment of existing housing (GPG 155)
Energy efficient refurbishment of existing housing - case studies (GPCS 418)
External insulation systems for walls of dwellings (GPG 293)
Internal wall insulation in existing housing - a guide for specifiers and contractors (CE17)
Post-construction testing – a professional's guide to testing housing for energy efficiency (GIR 64)
Refurbishing cavity-walled dwellings: A summary of Best Practice (CE57)
Refurbishing dwellings with solid walls: A summary of Best Practice (CE58)
Refurbishing timber-framed dwellings: A summary of Best Practice (CE59)
Refurbishment site guidance for solid-walled houses - ground floors (GPG 294)
Refurbishment site guidance for solid-walled houses - windows and doors (GPG 295)
Refurbishment site guidance for solid-walled houses - roofs (GPG 296)
Refurbishment site guidance for solid-walled houses - walls (GPG 297)

Other publications

Non-traditional housing CD. A collection of BRE publications. BRE. 2002

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