Windows for new and existing housing

A summary of Best Practice

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

High performance windows

Double-glazed windows offer many benefits over single glazing and in recent years have become a standard part of any housing specification in the UK. Recent changes in building regulations in England, Wales and Scotland have raised the minimum legal standards required – basic double glazing is no longer sufficient. Even so, most installed windows merely comply with the minimum requirements: there is considerable scope for further improvement.

There are around two million window installations (both new and replacement) every year in the UK, so the potential aggregate energy savings from choosing higher performance windows are substantial. While the savings from installing new windows are not as high as, for example, cavity wall insulation, it is important to recognise that they are replaced very infrequently and the occasion to install high performance glazing may not re-occur for a number of years. For this reason, it may be necessary to specify them ahead of other measures when the opportunity arises. The timing of other energy efficiency measures can be altered much more easily.

A summary of Best Practice

This document is aimed at architects, specifiers, installers and others involved in specifying energy efficient windows for new and refurbishment projects. It is designed to help them achieve Best Practice, outlining some of the technical options available. However, it is only a summary: a list of more detailed guidance can be found at the end of this publication.

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.

In England & Wales, an alternative and more common route for replacement windows is to use a Fenestration Self-Assessment Scheme (FENSA) registered company (www.fensa.org.uk).

Measuring window performance

A window's energy performance is generally specified by its U-value. However, specifiers should be aware that quoted values may not always be comparable between products: manufacturers may quote the U-value of the frame, the sealed unit or the whole window. Whole window calculations are complex as they must take into account the thermal performance of a number of components.

The building regulations include look-up tables for window performance as well as setting minimum standards of performance. The U-values in these tables are slightly conservative and manufacturers are permitted to quote actual values for their products instead. However, these must either have been calculated in accordance with international standards (BS EN ISO 10077-1 or EN ISO 10077-2), or alternatively measured in a 'hot box' test (to BS EN ISO 12567-1).

While the U-value is an indication of heat loss through a properly functioning window, poorly sealed opening casements and sashes can result in further losses. These can be significant in windows being replaced, although they are generally small in new windows.

Heat losses may be offset by energy entering through the window in the form of solar gains. The exact contribution of these gains will depend on a number of factors, including location and orientation, the ratio of frame to glass area, and the properties of the glass itself.

Work by the British Fenestration Rating Council (BFRC) has led to the development of a European energy rating system, known in the UK as the BFRC Rating. This takes into account heat losses and gains, with a single number indicating the window's overall energy performance.

The BFRC Rating

In collaboration with European partners, the British Fenestration Rating Council has developed a system for comparing the overall energy performance of windows. The rating system is based on the total annual energy flow through the window (kWh/m^2/yr).

Most windows will have a negative rating: this indicates a net heat loss over the year. However, some very high performance types can achieve a positive figure, indicating a net inflow of heat.

The ratings are classified into bands A-G to make the system more consumer-friendly. It is anticipated that the BFRC Rating will eventually replace U-values as the main UK method for specifying windows.

More information on the BFRC Rating can be found at: www.bfrc.org

Energy Label	BFRC Rating kWh/m^2/yr
A	> 0.0
B	0.0 to -10.0
C	-10.0 to -20.0
D	-20.0 to -30.0
E	-30.0 to -50.0
F	-50.0 to -70.0
G	< -70.0

Apparently similar windows can have quite different energy ratings (see Table 2). This is because the rating system takes into account a number of factors such as the design of the frame and also the materials used (compare for example the values for softwood and hardwood windows). Among other factors is the choice of spacer bar, with a number of alternatives to the conventional aluminium spacer now available. Technology options are considered in more detail in a later section.

Assessing the true energy performance of a window, with so many different component options, is a highly complex process. For the specifier, the BFRC Rating system offers a simple route to ensuring high performance from windows.

Best Practice specifications

The Energy Efficiency Best Practice in Housing programme sets out standards for windows in new and existing housing.

General specifications
The following should be specified in addition to the U-value or BFRC Rating for the window:

- the frames should be high quality, designed for the chosen glazing units
- glazing units should preferably be installed in a properly drained and ventilated frame. Solid bedding should only be used if windows are factory glazed or where a drained and vented system is impractical or unavailable
- units should comply with BS 6262, as described in the Glass and Glazing Federation manual (www.ggf.org.uk)
- glazing units should be dual-sealed and certified in accordance with BS 5713:1979 (due to be replaced by EN 1279)
- correct site installation needs to include sealing round window and door frames

In some situations, the CI may be achieved by using the U-values given in Table 1, but in other cases, better U-values may be needed to compensate for less energy-efficient aspects of a particular building design. Examples of how insulation and window U-values can vary for a particular house type and fuel can be found in Effective use of insulation in dwellings[6].

Table 1: Main requirements of Best Practice Specification for new housing

Heating fuel	**Carbon Index (CI)**
Natural gas	8.6
LPG	8.6
Oil	7.4
Electricity	6.8
Additional constraints	
Element	**Maximum permissible U-value (W/m²K)**
Roofs	0.13
Walls	0.25
Floors	0.20
Windows/doors/rooflights (area-weighted average)†	1.80 or BFRC Rating of –20(C) or better*
Fuel	**Minimum boiler efficiency (%)**
Natural gas, LPG	86
Oil	88

† the area weighted average is only applicable to a U-value approach. Where ratings are used for windows, U-values of 1.8 W/m2K will be required for doors and rooflights.
* the BFRC rating will be sufficient to comply with the Best Practice specification, but the U-value remains necessary to confirm building regulations compliance and to calculate the Carbon Index

New housing
The Best Practice specification for new housing is based on a whole-house approach using the Carbon Index, together with maximum permissible U-values for each structural element. The Carbon Index (CI) is based on the carbon dioxide emissions associated with space and water heating and 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.

The basic requirements of the Best Practice Specification are set out in Table 1. Further details of this and two other specifications (Good Practice and Advanced Design) can be found in Energy Efficiency in New Housing: Summary of Specifications (there are separate documents for Great Britain and for Northern Ireland[4,5]).

Existing housing
The Best Practice specification sets down a U-value of 2.0 W/m²K or BFRC Rating of –30(D), or better, for windows, patio doors and French doors. In Scotland, some situations may require a U-value of 1.8 W/m²K: if in doubt check with the local authority building control.

External doors should be replaced with insulated solid doors (U-value less than 1.0 W/m²K) or half-glazed insulated doors (U-value less than 1.5 W/m²K).

In some cases, it may not be possible to meet the specification in all aspects of a refurbishment project (for example, with respect to wall insulation). In such cases, the highest practicable performance level should be achieved and additional energy efficiency measures taken elsewhere.

Windows and doors can often be specified to a level in excess of Best Practice and can compensate for shortcomings among other elements of the refurbishment package.

The replacement of windows in historically sensitive buildings should only be undertaken after consultation with the local authority's building conservation officer. If high specification windows cannot be used, other compensating measures should be implemented.

Glazing performance

A window's thermal performance depends on a number of factors, including design, the materials used and the combination of components. Table 2 shows the performance of a number of window types: the BFRC Rating has been calculated while the default U-value has been taken from Appendix A of Approved Document L1 of the Building Regulations for England & Wales (the Appendix does not include all possible window combinations). It is important to note that changing the specification of a window may not necessarily result in an improvement to the BFRC Rating, although it may give a better U-value. This is because some specification changes which will improve the U-value may actually detract from the overall thermal performance of the windows by affecting the amount of solar gain. This fact underlines the advantages of the BFRC Rating approach.

Windows and condensation

Double glazing reduces the risk of internal condensation as the inner pane remains at a high enough temperature to prevent this. In conventional units, enough heat still escapes to keep the external pane condensation free as well.

With improved U-values, less heat escapes and so the external pane temperature can fall. Under particular weather conditions (generally damp weather followed by a sharp drop in temperature on clear, calm nights) dew can form on the external surface of the glazing unit.

This is a natural and expected occurrence which shows the window is functioning correctly. The microclimate has a particular influence here which means that some windows may experience condensation while others nearby will not.

Table 2: U-values and BFRC ratings for a range of window types

Frame	Air Gap	Coating	Gas fill	Spacer	BFRC Rating	Default U-value
Timber - Softwood	16	Low-e, hard (en=0.15)	Air	Aluminium	-38.4 (E)	2.0
Timber - Hardwood	16	Low-e, hard (en=0.15)	Air	Aluminium	-45.2 (E)	2.0
Timber - Softwood	16	Low-e, soft (en=0.09)	Air	Aluminium	-37.4 (E)	1.9
Timber - Softwood	16	Low-e, soft (en=0.09)	Argon	Aluminium	-28.5 (D)	1.8
Timber - Softwood	16	Low-e, soft (en=0.04)	Argon	Aluminium	-30.4 (E)	1.7
Timber - Softwood ('High performance' frame)	18	Low-e, soft (en=0.04)	Argon	Aluminium	-17.7 (C)	1.7
Timber - Softwood ('High performance' frame)	18	Low-e, soft (en=0.04)	Argon	Warm edge	-4.6 (B)	1.7
PVC-U	16	Low-e, hard (en=0.15)	Air	Aluminium	-34.3 (E)	2.0
PVC-U	16	Low-e, hard (en=0.15)	Argon	Aluminium	-27.4 (D)	2.0
PVC-U	16	Low-e, soft (en=0.04)	Air	Aluminium	-29.3 (D)	1.8
PVC-U	16	Low-e, soft (en=0.04)	Argon	Aluminium	-15.6 (C)	1.7
PVC-U	16	Low-e, soft (en=0.04)	Argon	Warm Edge	-8.8 (B)	1.7

* data on metal windows unavailable at time of print

Glazing technologies

Low emissivity coatings

A low emissivity (low-e) coating allows short-wave radiation to pass through but inhibits the passage of long wave. When applied to a pane of glass in the form of a microscopically thin coating of metal or metal oxide, it allows short wave solar radiation to pass through into the building. However, it effectively reflects long wave thermal radiation from the interior back into the room. The lower the emissivity, the less radiation is emitted from the window to the outside environment – and the better the U-value.

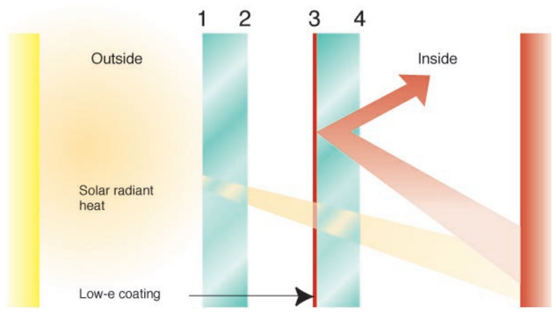

Figure 1: The low-e coating on Surface 3 reflects longer wavelength radiation back into the room, reducing heat loss

Low-e coatings can be either hard or soft. Hard coatings are applied during the glass manufacturing process whereas soft coatings are applied at a later stage of production. The emissivity (εn) of the coating ranges from 0.15 to 0.20 for hard and 0.05 to 0.10 for soft coatings. The coatings are normally applied to Surface 3 of a sealed unit (see Figure 1).

Low-e coatings often have a slight tint and this varies between suppliers, so it can be noticeable if glazed units from different sources are used alongside one another. Careful record keeping is necessary if broken units are to be replaced with identical products.

The coatings also reduce the amount of light that passes through the glass (its transmittance), which in turn reduces the solar gain entering the building. While this does not affect the U-value of the window, it does alter the BFRC Rating. So whilst soft coatings may reduce heat loss more than hard ones, they also reduce heat gain.

Several devices are available which can detect the presence of a low-e coating in a sealed unit, although they cannot determine the type of coating. For more information, see Post-construction testing – a professional's guide to testing housing for energy efficiency (GIR 64).

Gas filled units

Heat is lost between the panes of a sealed unit by radiation from one to the other and also by convection. Replacing the air in the cavity with a more viscous, slow-moving gas minimises the convection currents and reduces the overall transfer of heat.

Argon is the most commonly used gas for this purpose, although krypton and even xenon can be used, especially where the cavity width is limited. These gases are inert and non-toxic and so do not pose any risk to health in the event of a breakage.

The gases are normally inserted via an inlet port and vent in the spacer bar, or through the use of special corner pieces. Correct specification of the sealed units to reduce the risk of breakdown and subsequent gas loss is important for continuing energy efficient performance.

Insulating spacer bars

The panes of glass in a sealed unit are separated by a spacer bar – normally made from aluminium. The metal's high conductivity creates a thermal bridge around the edge of the unit. This results in greater heat loss and, in addition, the area is prone to condensation which can promote mould growth.

Stainless steel spacer bars have a lower conductivity than aluminium (17 W/mK as opposed to 230 W/mK). While this is an improvement, the term 'insulating spacer bar' should only be used to refer to spacers that have reduced (or even zero) metal in them.

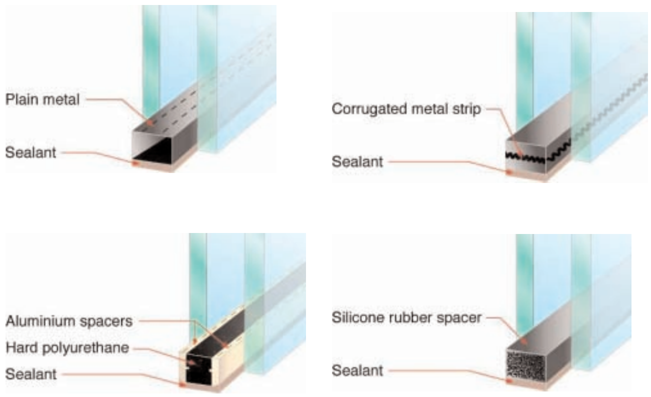

Figure 2: Conventional plain metal and 'warm edge' insulating spacer bars

Frame design

The energy performance of the frames themselves can be improved. Significant advances have been made over recent years and more are possible.

PVC-U: Thinner frame sections or 'profiles' are increasing the proportion of glass in the overall window space allowing greater solar gain. Many manufacturers are now producing profiles with four or five internal chambers, which provide slightly better thermal performance compared with conventional three chamber designs. A few are filling some of the chambers with insulating foam, but this option is not generally available yet.

Timber: Improvements in technology have led to greater sectional stability and less movement in use. This reduces the likelihood of draughts. New preservation treatments and paints are extending the life of timber windows and reducing maintenance costs. Composite windows, consisting of a timber frame with an aluminium or plastic protective layer on all external surfaces, are more widely available: the coverings reduce the need for maintenance still further (Figure 3).

Figure 3: Section through a composite window (image courtesy of Rationel Windows)

Metal: In aluminium and steel windows, manufacturers have increased the size and performance of the 'thermal breaks' which reduce the heat flow across the metal window sections (Figure 4).

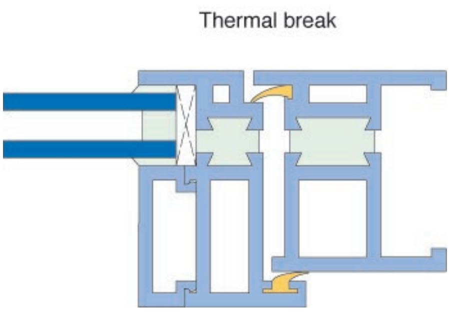

Figure 4: Section of metal window showing thermal breaks

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 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.

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 windows, 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).

Case study – Greenwich Millennium Village

A flagship development, the Greenwich Millennium Village in London has been built to high standards of energy efficiency, with careful attention being paid to the environmental performance of the materials employed. The architects for Phase 2, Proctor and Matthews Associates, used the Green Guide to Housing Specification to assess the suitability of different products. A and B rated materials were permitted for Phase 2A, but only A rated products were used on Phase 2B.

Two types of high performance window were considered: one of timber and the other a composite of timber with an aluminium cladding. A life cycle analysis was undertaken to underpin the environmental assessment. This considered cost, embodied energy, maintenance requirements and the thermal performance of the products.

The study found that differences in life cycle costs between the two options were small but that the non-composite had slightly lower long term costs. As a result a window with an overall U-value of 1.6 W/m^2K was specified.

Had the BFRC Rating system been available, the evaluation process would have been simpler. In the event, project architect James Burch had to take account of the inter-relationship of a number of complex factors in order to reach his decision. He expects to be able to use the rating system in future specifications, feeling they will provide a better and certainly simpler tool for specifiers to use.

The suppliers of the project's chosen window, Rationel, have recognised the growing demand for high thermal performance windows and have used the BFRC Rating to fine-tune their product development programme. They have had several of their designs rated under the system, achieving B and C classifications for several products in their range. The process has given their technical development team an added dimension to their planning, and provided their sales effort with extra data to present to clients when discussing project specifications.

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. Energy efficiency in new housing: Summary of specification for England Wales and Scotland (CE12)
5. Energy efficiency in new housing: Summary of specification for Northern Ireland (CE24)
6. Effective use of insulation in dwellings (CE23)
7. BR390 The Green Guide to Housing Specification, Anderson and Howard, BRE, 2000

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**

Benefits of Best Practice: Glazing (CE14)

Domestic Energy Efficiency Primer (GPG 171)

Energy efficiency in new housing: Summary of specification for England Wales and Scotland (CE12)

Energy efficiency in new housing: Summary of specification for Northern Ireland (CE24)

Effective use of insulation in dwellings (CE23)

Energy efficient refurbishment of existing housing (GPG 155)

Refurbishment site guidance for solid-walled houses - windows and doors (GPG 295)

Summary specification of whole house refurbishment – Solid walled housing (CE58)

Summary specification of whole house refurbishment – Timber frame housing (CE59)

Summary specification of whole house refurbishment – Cavity walled housing (CE57)

Post-construction testing – a professional's guide to testing housing for energy efficiency (GIR 64)

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Further reading

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

Glass and Glazing Federation Technical Manual, GGF

The survey and installation of windows and external doorsets (to be published) - available from trade bodies

Relevant organisations and websites

British Fenestration Rating Council
Website: www.bfrc.org

British Plastics Federation
Tel: 020 7457 5037
Website: www.bpf.co.uk

British Woodworking Federation
Tel: 020 7608 5050
Website: www.bwf.org.uk

Building Research Establishment
Tel: 01923 664000
Website: www.bre.co.uk

Council for Aluminium in Building
Tel: 01453 828851
Website: www.c-a-b.org.uk

FENSA
Website: www.fensa.org.uk

Glass and Glazing Federation
Tel: 020 7403 7177
Website: www.ggf.org.uk

Steel Window Association
Tel: 020 7637 3571
Website: www.steel-window-association.co.uk

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