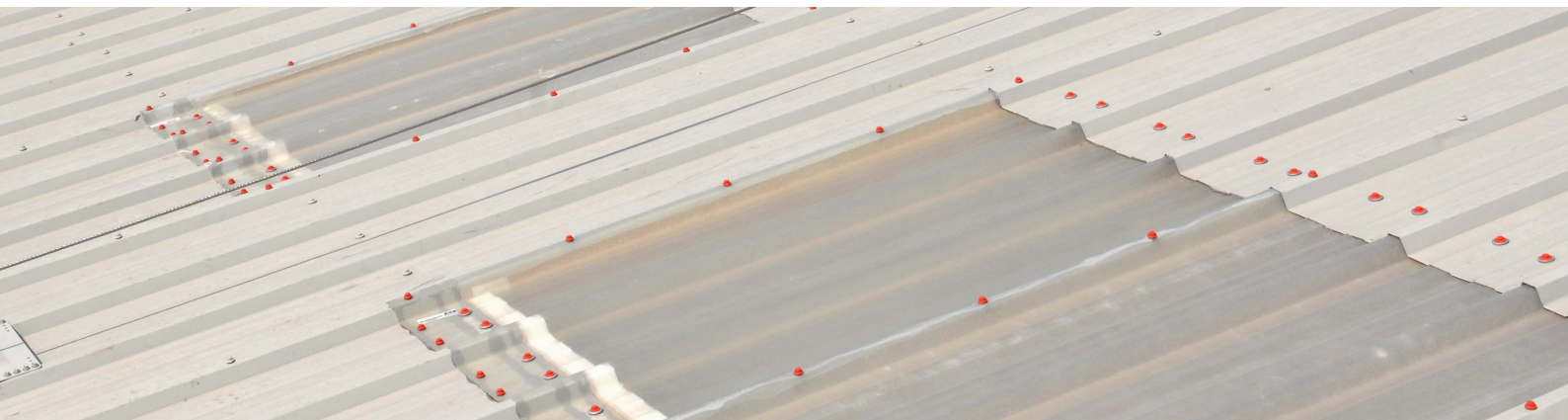


Rooflights: glass, polycarbonate or GRP?

The choice is critical - and you have only one chance to get it right.
Find out here how to select the right rooflight glazing for every application.



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Introduction

Why use rooflights? The benefits offered by rooflights have been well understood for many years, supported by an increasing weight of scientific evidence.

There is already a wealth of research to prove that when illumination is provided predominantly by natural daylight, workplace productivity is higher and absenteeism is reduced. Retail sales are increased as shoppers stay longer. In educational environments, academic achievement and exam results improve. Patient recovery rates improve in hospitals. And natural light is equally important in creating an attractive domestic environment.

In short, it is an undisputed fact that people are happier and more productive in buildings that are naturally lit.

Moreover, with the recent focus on sustainability and reduction of energy consumption and CO₂ emissions, the benefits of rooflighting are equally compelling and well documented.

The increased use of rooflights is currently one of the major factors in the drive to reduce energy use, CO₂ emissions and overall running costs. Transmission of natural light through rooflights can dramatically reduce the use of electric lights (especially when used in conjunction with automatic lighting control systems) which are often the biggest single use of energy and cause of CO₂ emissions when operating a building.

Finally, the simple omission of rooflights can make compliance with essential Part L regulations extremely difficult.

Different types of rooflight system

The selection of rooflight is sometimes an architectural choice, but is usually more influenced by the roof system itself. Rooflights therefore come in two basic types:

- **In-plane rooflights** are used with profiled metal or fibre cement roofing systems where the rooflight fits directly into the plane of the roof.
- **Out-of-plane rooflights** are typically mounted onto kerbs above the plane of the roof, either self-supporting or in glazing bar systems. They include domes, pyramids, barrel vaults, patent glazing and panel glazing systems, hip and gable-ended skylights. They can often incorporate opening sections to provide natural ventilation.

Rooflights can be glazed with a choice of materials, principally glass, GRP or polycarbonate. Again, the glazing material used is sometimes an architectural choice, but it is more commonly influenced by the rooflight type. All three make outstanding glazing materials but there are very significant differences

between them, each offering specific benefits in different applications.

NARM members include Europe's largest manufacturers of both out-of-plane and in-plane rooflights employing all three materials. This document aims to provide wholly unbiased information on the relative merits of these materials, and their suitability for every application.

Material availability and formability

Glass is generally only suitable for rooflighting applications when used in flat panes or insulated units, fitted or bonded into a glazing bar system. Curved glass is an extremely specialised product and very expensive, and glass is generally not available in more complex 3D shapes. Care is required to accommodate the weight of glass rooflights which can be in excess of 40 kg/sq.m. This can make glass unsuitable for larger rooflights unless the structure is specifically designed to support such a heavy load without excessive movement.

Polycarbonate is a thermoplastic material, usually extruded into flat sheets for use in glazing bar systems. It can be reformed (for example by vacuum forming) into 3-dimensional products (such as domes), or extruded into a profiled sheet. The accuracy of extruded polycarbonate is usually very good, providing an excellent fit with surrounding products. Polycarbonate can also be extruded into a multiwall-structured sheet for use in similar applications to flat sheets, offering greater rigidity and thermal performance and reduced cost but with a different aesthetic effect.

GRP is a thermosetting material which must be converted from a liquid into the finished product in a single operation. It cannot be reformed. For rooflight applications, a continuous lamination process shapes it into either profiled sheets or flat sheets suitable for glazing bar systems, including barrel vaults. It is sometimes not possible to achieve the same degree of profile definition as surrounding profiled sheets, particularly with thicker grades of rooflight, but it can still be fitted reliably, with the additional rigidity providing better compression of sealants. It is also possible to use GRP for other rooflight types, but it is more difficult to use for 3D shapes which tend to require hand-lamination rather than an automated process.

Light transmission and diffusion

Light transmission, and diffusion are both important considerations for rooflights. Clear materials provide direct light, and are usually required in windows to allow vision without distortion, and are also preferable in some rooflighting applications. However, clear materials can also transmit glare, and create areas of harsh shadow and bright light, and some diffusion is often required in rooflighting applications to provide more even distribution of lighting levels inside a building. Diffusing materials can also mask the effect of dirt and debris which can be more unsightly when viewed through clear glazing.

Glass and polycarbonate are naturally clear materials that offer extremely high levels of clarity and light transmission, providing very high levels of direct light with no diffusion.

Laminated glass is sometimes available with a diffusing interlayer which offers diffusion but with reduced levels of light transmission, and is less common than clear glass. Polycarbonate can also be manufactured with an opal tint to give a diffusing effect (and privacy where that is required) but this is usually accompanied by reduced levels of light transmission. In some applications polycarbonate is also available with a textured inner surface, which can offer diffusion with high levels of light transmission.

GRP is a naturally diffusing material and so is not suitable where clear glazing or direct vision is required. It has slightly lower levels of light transmission than clear glass or polycarbonate, but higher levels of diffused light transmission than opal materials, in conjunction with excellent light dispersal.

Long-term aesthetics

Glass inherently has optimum resistance to UV degradation, suffering no deterioration in its aesthetic properties over many years' exposure to sunlight and the elements.

On the other hand, all plastic materials require protection from the effects of UV light to give their best performance in the long term, ensuring they retain good light transmission and resist discoloration.

Good-quality polycarbonate and GRP are both supplied with an integrated UV-absorbing surface layer. GRP is usually protected with a UV-absorbing film bonded to the surface, whilst polycarbonate normally incorporates a co-extruded UV-absorbing layer.

Polycarbonate and GRP with integral UV absorbing protective surfaces will both retain light transmission and resist discoloration well when handled and installed correctly. In the very long term, there is likely to be less loss of light transmission with polycarbonate than with GRP.

Strength and impact resistance

GRP and polycarbonate are both extremely strong and inherently stable materials that will retain their original strength in most circumstances.

Polycarbonate boasts exceptional impact strength (which is why it is used in applications such as riot shields and visors for safety helmets) and both materials are used to manufacture crash helmets.

Most importantly, both have outstanding resistance to evenly-distributed loads in roofing applications. If failures occur, it is likely to be around point loads (such as fixings) or as a result of deflection (such as pulling out of glazing bars).

Toughened and laminated grades of glass can also be extremely durable; certain grades can even be used as walk-on flooring. Very occasionally inclusions or other defects can lead to unexpected failure of toughened panes, but for critical applications glass can be heat-soak tested to significantly reduce this risk.

Glass in rooflight applications should always be a safety glass which means it will need to be either wired, toughened or laminated, or a combination thereof. Toughened glass is much more resistant to damage and cracking so is more suitable for use as an outer pane – but, when broken, can fail completely and fall into a building in many small rounded pieces. Laminated glass is far more prone to cracking, but the lamination ensures it stays in place even when severely damaged, so may be more appropriate as an inner pane. Further guidance on the selection of appropriate glass types for different locations can be found in Section 8 of BS 5516-2:2004. Particular care is required when fixing glass to ensure there is no significant potential movement in the structure or glazing bars or any misalignment that places the glass under stress, as these can easily cause glass to crack.

Correct precautions should always be taken when handling any material. This is particularly true with polycarbonate, as significant loss of strength can be induced by a number of factors if handled incorrectly, leading to premature failure.

Durability and long term structural performance

Glass is an extremely stable material, almost unaffected by UV attack or weathering. Whilst prone to mechanical damage under impact, normal weathering will have virtually no effect on the material itself even in the very long term.

Where glass is supplied in a sealed double glazed unit, standard seals are not suitable for use where they may be exposed to UV but silicone seals are available which have an expected lifespan of at least 25 years.

GRP is inherently exceptionally stable and inert and can be trusted to provide excellent long-term performance under almost all circumstances. Polycarbonate is also an extremely strong, high-performance material which will give good long-term performance when handled correctly and in ideal conditions.

However, whilst both these plastic materials – polycarbonate and GRP - require protection from the effects of UV light to give their best aesthetic performance in the long term, there is a very significant difference between them when considering the need for UV protection for long term structural performance which must always be taken into consideration.

If unprotected, GRP will slowly yellow and the surface may slowly erode, but the inherent strength of unprotected GRP is maintained in the long term. There are many GRP rooflights over 40 years old which have had no UV protection at all yet remain structurally sound, although now exhibiting significant discoloration and reduction in light transmission.

On the other hand, polycarbonate requires UV protection not only to resist discoloration and maintain light transmission but also to maintain its basic structural properties. This makes it vulnerable to premature failure if there is any rough or incorrect handling which damages its UV-protective layer.

In fact, a range of other factors can also induce premature failure of polycarbonate rooflights. For example, a number of common chemicals such as plasticisers attack polycarbonate. Direct contact with either plastisol-coated profiled metal or PVC tape can result in rapid degradation and must be avoided.

Subjecting polycarbonate to permanent stresses (for example around overtightened fixings, or failure to accommodate thermal movement properly) or prolonged contact with trapped water can also accelerate its deterioration.

It must be stressed that both GRP and polycarbonate offer excellent performance for well over 20 years when handled correctly. Good-quality polycarbonate potentially offers less loss of light transmission and less yellowing in the long term than GRP. However, much greater care is needed to overcome the much higher susceptibility to physical degradation which can result from incorrect installation or handling of polycarbonate. This should always be factored into your choice of materials.

Resistance to condensation

Care is required with any rooflight to minimise the risk of condensation. Every rooflight should have sufficient skins to provide good thermal insulation but should not incorporate any thermal bridges which would create cold spots. Special care should also be taken to prevent relatively warm moist air from inside the building entering the cavity between rooflight skins where it will cool, increasing risk of condensation.

Glass is also available in sealed double glazed units (DGUs); the seals on these must be correctly designed, manufactured and installed to minimise the risk of failure which can lead to unsightly condensation.

The cavities between the skins of plastic rooflights should never be completely sealed. Particular care is required with polycarbonate as it is a hygroscopic material, meaning it naturally absorbs moisture. This increases the internal humidity and risk of condensation in any rooflight cavity, so it is essential to ventilate any cavity in a polycarbonate rooflight to avoid moisture build-up and condensation. Whilst external ventilation of cavities is generally beneficial in all large plastic rooflights (and can often be easily achieved in many designs) it is essential with polycarbonate rooflights.

Thermal performance

Rooflights are generally multi-layer to provide satisfactory thermal performance and resistance to condensation.

Glass is available in sealed units comprising either double or triple layers; it is also available with hard or soft coat low emissivity (low-E) coatings (on one surface facing into each cavity) or with high performance solar control coatings (on the outer pane) which improve thermal performance. Thermal performance of sealed glass units which incorporate low E or solar control coatings can be further enhanced by filling with argon (or krypton, if cavity size is very restricted) although the insulation value of gas-filled DGUs can diminish slightly over time as the gas content gradually reduces.

Low-E coatings are not available on either polycarbonate or GRP, and cavities cannot be gas filled (cavities in polycarbonate rooflights must always be ventilated to minimise risk of condensation). However, the number of rooflight skins can be increased to provide similar levels of thermal performance to glass.

Building Regulations currently require a worst case U-value of $2.2\text{W/m}^2\text{K}$ in the vertical plane.

Plastic rooflights should always be at least triple skin to achieve a U-value of $2.2\text{W/m}^2\text{K}$. Increasing the number of skins further or incorporating an insulating core can reduce U-values significantly. For example, polycarbonate is available as a single 10-wall sheet which can offer U-values of approximately $1.0\text{W/m}^2\text{K}$; rooflights with multiple sheets can achieve even better U-values. However, it should be noted that low U-values are usually associated with lower light transmission, which can increase use of electric lighting which will reduce or eliminate any potential overall energy saving.

Glass double glazed sealed units, air filled with hard coat low-E coating will achieve centre pane U-values of approximately $1.7\text{W/m}^2\text{K}$; use of soft coat low-E coatings and argon filling can reduce centre pane U-value to approximately $1.1\text{W/m}^2\text{K}$. Triple skin sealed units offer centre pane U-values typically between 1.0 and $0.6\text{W/m}^2\text{K}$ depending on specification. For Building Regulation compliance the whole rooflight U-value rather than centre pane value is required: for sealed glass units the effect of the edge spacer should also be taken into account. Use of warm edge spacers can reduce the difference between centre pane and whole rooflight values.

U-values quoted above are in the vertical orientation (as required for comparison to limiting values by Building Regulations). When rooflight orientation varies towards the horizontal, actual U-value increases. The difference between horizontal and vertical U-values depends on the number of skins and cavity geometry: for double skin glass sealed units it can be as great as $0.7\text{W/m}^2\text{K}$ for some glass specifications, for triple skin plastic rooflights (polycarbonate or GRP) it is likely to be less than $0.2\text{W/m}^2\text{K}$ and for 10 layer multiwall polycarbonate (where cavities are very small in both directions) it is likely to be negligible.

Thermal movement

The coefficient of thermal expansion of GRP is $22 \times 10^{-6}\text{m/m}^\circ\text{C}$ - slightly higher than that of steel but marginally lower than that of aluminium.

Thermal movement may need special consideration in a few GRP applications (for example, where the whole of a large roof is clad with GRP or where extremely long rooflight sheets are used) but is generally not a problem in most applications as thermal movement is very low and the material can generally accommodate any internal stresses created if no thermal movement is allowed, without any problem.

Polycarbonate expands about 3x more, with a coefficient of thermal expansion of $66 \times 10^{-6}\text{m/m}^\circ\text{C}$. Failure to accommodate thermal movement effectively will generate internal stresses (especially around fixings), which polycarbonate is particularly susceptible to and can lead to stress cracking and premature failure.

It is therefore essential to ensure that thermal movement is accommodated without generating significant stresses in the polycarbonate. This is easily accommodated in certain rooflight applications (for example when polycarbonate is permitted to move in glazing bars) and less of an issue where glazing panels are small, but more difficult in other applications.

The coefficient of thermal expansion of glass (around 9×10^{-6} m/m°C) is significantly lower than most metals and no special precautions are required to accommodate movement. However, care must be taken to avoid creating any thermal stresses - for example if a single pane crosses insulation from a warm to cold environment - as a steep temperature gradient in annealed glass can cause it to crack quite easily in certain conditions (if in doubt a thermal safety check should be carried out). Toughened or heat strengthened glass are resistant to thermal stress but it should be noted that heat strengthened glass is not a safety glass and therefore should only be used in overhead glazing as part of a laminated pane.

Fire performance

Rooflights should generally meet the Building Regulations requirements for fire performance of both the roof and inner lining, and rooflight suppliers should be able to provide the correct certification.

The requirement for the inner lining (typically Class 1 to BS476 part 7) is usually the more onerous, and can usually be achieved by glass, polycarbonate, and correctly specified GRP without difficulty.

The requirement for the outer covering (typically AA, AB or AC to BS476 part 3) can be achieved by glass and GRP. Thermoplastic materials cannot be tested to BS476 part 3, but Building Regulations deem that polycarbonate which achieves Class 1 can also be regarded as having an AA rating.

Where sprinkler systems are fitted, insurers may additionally specify that rooflights can resist a temperature of 300°C for at least 5 minutes, although this is not a Building Regulation requirement. This is not covered within BS476 and would require separate certification, but it is unlikely that thermoplastic materials would meet this performance.

BS476 part 22 specifies requirements for fire resisting materials (including, for example, fire doors). These requirements are not usually relevant to rooflights; it is unlikely that GRP or polycarbonate would be able to meet these requirements, which would probably necessitate special grades of glass.

Acoustics

Acoustic performance may be important in some circumstances, both acoustic insulation (R_w) to keep noise out of a building and minimise noise escaping from within a building, and rain noise penetration (L_{IA}) to prevent rain on rooflights being a source of noise within a building.

Heavier materials provide much better acoustic performance: glass performs well where sound reduction is a requirement. GRP and polycarbonate are much lighter so do not perform so well; in addition thinner sheets of polycarbonate can “drum” and do not perform as well as GRP.

The best sound reductions can be achieved by using secondary glazing, as the air gap between glazing panes is the biggest contributory factor, with the optimum cavity space about 200mm. Increasing the number of skins can also be of benefit, providing they are independently mounted, rather than directly linked together.

The acoustic performance of glass can be further improved by use of thicker (heavier) panes, selecting asymmetric glass combinations and the use of laminated glass in at least one of the panes where special acoustic interlayers can be used which act as a damper to improve the acoustic performance. Double glazing specified specifically for noise reduction can achieve performances of up to $R_w=50\text{dB}$.

Any acoustic specifications will contribute to reducing rain noise as well as improving acoustic insulation.

Rooflight applications and installation issues

The widely differing properties of glass, GRP and polycarbonate have a major bearing on the suitability of each material for different applications – and on the way they are installed by contractors.

OUT-OF-PLANE ROOFLIGHTS

DOME ROOFLIGHTS are three-dimensional shapes which are much easier to manufacture from polycarbonate, the ideal material for these applications. Good design of the rooflight can ensure the material is handled correctly. GRP is difficult to use in these products so is generally not recommended for dome rooflights, whilst glass is not suitable for dome manufacture.

Flat topped modular rooflights can be used in exactly the same application as domes, and glass is the ideal material for this application: plastic materials may deflect preventing drainage, making them unsuitable for this application.

BARREL VAULT ROOFLIGHTS may be formed from flat sheets in a curved glazing bar system, and either polycarbonate or GRP sheets can be used. Good design of the rooflight system allows issues such as external ventilation of the glazing cavity, thermal movement and contact with compatible materials to be easily incorporated into the rooflight design, making polycarbonate a sound choice in these applications. Multiwall structured polycarbonate sheet may be an economic alternative to several flat solid sheets in this usage, depending on the radius of curvature. Solid flat sheets can accommodate a much tighter radius than multiwall sheets.

Barrel vaults may also be formed from curved profiled sheets, and these products may be equally suitable in either polycarbonate or GRP.

Curved glass is very expensive and generally not used in barrel vault rooflights, except for very specialised applications.

GLAZING BAR SYSTEMS (either flat panel glazing systems or, for example, gable- or hip-ended skylights) use flat glazing panels making glass or polycarbonate ideal choices in these applications. Again, careful design of the rooflight system allows issues such as external ventilation of the glazing cavity and thermal movement to be easily incorporated into the rooflight design, ensuring polycarbonate as well as glass can easily be accommodated in these applications. Multiwall structured polycarbonate sheet is an economic alternative to a number of flat solid sheets when aesthetics permit.

IN-PLANE ROOFLIGHTS

These are generally supplied as light-transmitting versions of the surrounding opaque profiled roofing sheets or panels, to be fitted by the roofing contractor. Particular care is required, relying on installation skills rather than product design, so can need more careful consideration.

Glass is not suitable for this application. Profiled polycarbonate is the only choice where clarity is required and is often used in stadia roofs for this reason, although diffusing materials are also sometimes preferred in this application to avoid deep shadows

GRP or polycarbonate can be used when fitted with metal or fibre cement sheets or panels. Polycarbonate can offer advantages in certain applications, however requires correct specification and installation and may need extra precautions. However, GRP is the more commonly used material for in-plane rooflights, offering diffused light and a robust product suitable for a wider range of applications.

SITE-ASSEMBLED IN-PLANE ROOFLIGHTS

Rooflight cavities should be vented (using ridge-to-eaves ventilation through the whole roof). Whilst this is merely recommended with GRP, with polycarbonate it is essential to remove the moisture that would otherwise accumulate due to the hygroscopic nature of the material.

In addition, if using polycarbonate in-plane site-assembled rooflights, thermal movement must be accommodated without restriction (which would generate stresses in the material leading to premature failure). Sheet lengths should be restricted, and oversize fixing holes must be used at main and sidelap fixings with care taken to ensure this does not lead to leaks or reduced load capacity. Overtightening of fixings which could restrict movement or create deflections and stresses must be avoided.

Special precautions must also be taken to prevent any risk of polycarbonate coming into direct contact with plastisol-coated metal – or with flexible PVC (including PVC tape, sometimes used as a barrier) as the plasticisers would migrate into the polycarbonate, and rapidly attack the rooflight leading to failure.

FACTORY-ASSEMBLED IN-PLANE ROOFLIGHTS

Factory assembled rooflights are specifically intended for use with composite panel roofs, and face similar challenges to in-plane site-assembled rooflights, with the additional consideration that there can be no ventilation through the roof structure, making it impossible to ventilate the rooflight cavity externally.

GRP rooflights do not require ventilation so the use of factory-assembled rooflights which prevent warm moist air from inside the building penetrating the rooflight cavity provides excellent resistance to condensation.

The cavity of a polycarbonate rooflight must never be sealed, and in this application the only option is to ventilate the rooflight cavities to the relatively warm and moist air inside the building, inevitably increasing the risk of condensation.

GRP factory assembled rooflights perform extremely well and are usually the recommended solution in this application although polycarbonate rooflights have been developed for certain composite panel types.

Conclusions

There is no doubting the benefits that rooflights offer, or that polycarbonate, GRP and glass are all outstanding hi-tech glazing materials which offer excellent performance as rooflight materials in their various applications - when correctly treated, of course.

Correctly specified and installed, use of glass, GRP or polycarbonate rooflights can introduce daylight into most types of building, making an outstanding contribution to the internal environment and to reduced energy use.

However, as previously shown, there are very significant differences between them. Each has its own set of benefits and requires its own precautions which make them individually more suitable for quite specific applications.

In order to get the optimum performance from a rooflight, care is always required to choose the correct material for any given application, also ensuring correct precautions are taken appropriate to the specific rooflight system and its glazing material. The table below gives you a necessarily simplified overview of their relative strengths and weaknesses in every area of importance to the architect, roofing contractor and end-user.

Material comparison

Material Properties	CLEAR MATERIALS		DIFFUSING MATERIALS		
	Glass	Polycarbonate	Glass with white interlayer	GRP	Opal Polycarbonate
Light transmission single skin	Excellent (up to 89%)	Excellent (up to 90%)	Up to 70%	Good (up to 85%)	Up to 60%
Light transmission insulated (U-value < 2.2W/m ² K)	Excellent (up to 77%)	Excellent (up to 70%)	Good (up to 61%)	Good (up to 65%)	Up to 58%
Clarity	Excellent	High	n/a	n/a	n/a
UV resistance Retention of light transmission Resistance to discoloration Retention of mechanical strength	Outstanding (100%) Outstanding (100%) Outstanding (100%)	Excellent Excellent Very good	Outstanding (100%) Outstanding (100%) Outstanding (100%)	Very good Very good Excellent	Excellent Excellent Very good
Coefficient of thermal expansion (m/m°C)	9x10 ⁻⁶	66x10 ⁻⁶	9x10 ⁻⁶	22x10 ⁻⁶	66x10 ⁻⁶
Need to accommodate thermal movement	Low	High	Low	Low	High
Chemical resistance	Excellent	Susceptible to specific chemicals	Excellent	Excellent	Susceptible to specific chemicals
Risk of premature failure in adverse circumstances	Low	Medium	Very low	Very low	Medium
Expected service life	Glass: over 30 years DGUs: 20-25 years	Up to 25 years (typically 15-20)	Glass: over 30 years DGUs: 20-25 years	30 years	Up to 25 years (typically 15-20)
Requirement to ventilate rooflight cavities	None	High	Low	Low	High
Impact resistance	Varies - can be high	High	High	High	High
Tensile strength	Varies - can be high	High	High	High	High
Acoustic insulation	Excellent	Poor	Good	Good	Poor
Formability	Poor	High	Poor	High in 2 dimensions Poor in 3 dimensions	High

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