BRITISH BLIND & SHUTTER ASSOCIATION

Guide to Low Energy Shading

Using blinds, awnings and shutters to save energy and enhance thermal and visual comfort in buildings

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Issue 2

FOREWORD

Solar shading is an accepted energy saving measure. Correctly specified, installed and operated, solar shading will reduce the energy consumption of buildings. In addition it is a passive technology which helps to improve the internal environment of the buildings we live and work in.

Solar shading has an important role to play whether the requirement is to: reject unwanted heat, harvest natural light, reduce building costs, cut carbon emissions, reduce embodied carbon, provide a more productive and comfortable environment, meet compliance, save beneficial heat, or a combination of these benefits.

This guide clearly highlights what must be considered in the specification and use of a solar shading system and the requirements that you should seek from your chosen solar shading specialist.

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Energy efficient shading is the balance between optimising the level of light and heat and reducing energy demands.

Weather conditions are dynamic while glazing properties are static. Dynamic shading devices are an integral part of a modern, adaptive building façade.

"The effects of solar gain in summer can be limited by an appropriate combination of window size and orientation, solar protection through shading and other solar control measures, ventilation (day and night) and high thermal capacity"

Building Regulations Part L1A

1.0 INTRODUCTION

Shading devices have been used for centuries to help make the internal environments of buildings more comfortable. Buildings in hot climates traditionally have small windows, overhangs or are orientated to minimise heat gain in the summer. The basic science is common sense, but in the UK its application is not yet common practice.

Solar shading is a proven energy saving technology and the purpose of this guide is to understand how to maximise benefits. It is estimated that if the equipment already installed in our buildings was used efficiently, building energy costs could be reduced by as much as 10% and this is discussed further in Appendix B.

For commercial and public buildings, solar shading can have a positive impact on: cooling, daylight utilisation, glare control, glazing systems and heating. To meet the economic and environmental imperatives of a building design and refurbishment, a holistic approach is a prerequisite. Solar shading should be ideally considered at the beginning of a project, which then provides further opportunities for HVAC cost reductions and easier integration with the façade and building services.

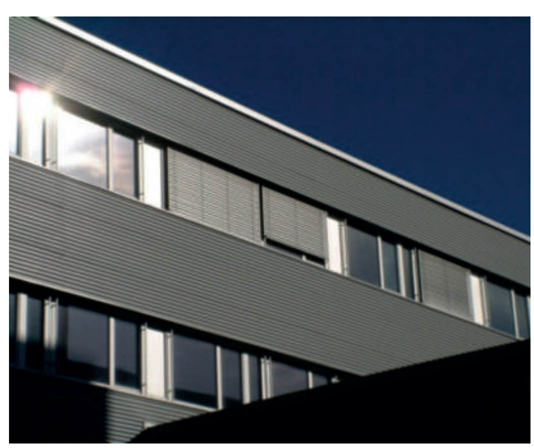
For dwellings, blinds, awnings and shutters can help save precious heat in the winter and keep homes cooler in the summer.

To assess the type of shading that is required for any building, it is necessary to have a basic understanding of the different effects of the sun's radiation. The purpose of this guide is to explain how buildings can benefit from solar shading by controlling the sun's effects that change constantly throughout the day and the seasons and ultimately save energy.

As it is not possible to forecast the exact impact of the weather on a building, optimal shading should ideally be dynamic to react to constant changes. Consequently there is not a simple 'one-size-fits-all' solution and so this guide does not provide specific product guidance. That advice should be sought from your chosen supplier based on the checklist of requirements outlined in Appendix C.

1.1 Energy saving in buildings

As buildings account for almost 40% of the total primary energy use in Europe, pressure has grown to make them more energy efficient. The savings potential is huge. It is not uncommon today to have buildings that consume a total energy of more than 250 kWh/m² per annum, whereas some state-of-the-art technology buildings show figures well below 100 kWh/m² per annum. To assess the energy performance of buildings, the UK government uses two software tools, the Standard Assessment Procedure (SAP) for dwellings and the Simplified Building Energy Model (SBEM) for non-dwellings. Both tools are used to demonstrate compliance with the Building Regulations that are derived from the European Energy Performance of Buildings Directive (EPBD), but unfortunately do not currently allow adequate credit for solar shading measures.



Several European countries are also working on legislation limiting maximum building energy use to 50 kWh/m² per annum. At the same time, Passive and Active House technology is gaining market share and the European Parliament has stated that all new buildings should be near zero energy buildings from 2019 onwards. In autumn 2015 the UK Government scrapped mandatory targets for zero carbon homes although the UK is still bound by the Climate Change Act to achieve a carbon reduction in homes of at least 80% by 2050.

1.2 Why do we need shading?

Controlling the entry of light and solar heat has a considerable beneficial effect on the energy needs of a building. It is a key element for improving the daylight and energy efficiency management of existing buildings and for optimising the low-energy designs of new buildings. Solar shading, although a proven technology, is still under-utilised although it has a major impact on the reduction of energy consumption of buildings whilst simultaneously improving the thermal and visual comfort of the occupants.

However, solar shading is only one element of the building envelope, along with glazing, window frames, walls, doors, roofs and floors. When we think of energy saving we tend to think of insulation. Solar shading in these terms can also be considered as the insulation of the transparent parts of a building - the glazing.

Indeed, solar protection devices enable us to adjust the properties of windows and façades to weather conditions and, most importantly, the needs of the occupants. Effective management of these systems can maximise the solar heat gains in the winter, so reduce the heating loads, and minimise heat gains in the summer to reduce cooling loads.

> *"Solar shading is the insulation of the transparent parts of a building."*
>
> Dick Dolmans, ES-SO

1.3 Health, well-being and productivity

The Zero Carbon Hub's report *Overheating in Homes - The Big Picture* (2015) highlights that overheating is occurring in up to 20% of the housing stock in England and is expected to become more prevalent in the future. There is a complex set of reasons for homes overheating but the report highlights five causes detailed in a report by the NHBC *Understanding Overheating - Where to start* (2012). Amongst the five causes are double-glazed windows with low-e coating that prevents the heat from escaping. The report states that houses with unshaded west-facing glass will suffer from higher levels of solar gain during the warmer parts of the day due to the glass coatings.

Prof Heiselberg from Aalborg University in Denmark highlights in his work on passive cooling project (part of the EU Venticool) that modern air-tight and well-insulated buildings have an increased need for cooling, not only in the summer, but throughout most of the year. He states that indoor temperatures that are too high is the most common reported problem in post-occupancy studies, even during the heating season.

> *"In short, the concern is that more people will become exposed to excess heat in their homes with consequences for their health and well-being. Overheating is therefore an important issue which needs to be dealt with."*
>
> Zero Carbon Hub, Overheating in Homes - The Big Picture

And it is not just homes that are prone to overheating. Lord Krebs of the Climate Change Commission highlights a recent study headed by Prof Alan Short of Cambridge University. It states that types of hospital ward that are vulnerable to overheating currently make up 90% of the total stock by floorspace. The report goes on to state that one solution is external shading devices as retro-fitting air conditioning would be uneconomic.

In both homes and hospitals, solar shading is identified as a key, passive solution to overheating.

Shading can control light, reduce heat gain in summer, reduce heat loss in winter, and provide visual comfort.

The World Green Building Council report *Health, Wellbeing and Productivity in Offices - The next chapter for green building* (2014) identifies four drivers for green buildings that are conducive to healthy, productive occupiers:

1. Good design (such as passive solutions, shading, and natural ventilation where possible)
2. Good construction (new technologies, innovation, smart controls)
3. Good behaviour (appropriate clothing, adaptability and engagement with systems)
4. Good location (enabling low carbon commuting and easy access to services and amenities)

It is very telling that in this global report on improving the internal environment in offices, the first driver identified is good design utilising passive solutions like shading. Productivity and the internal environment is explored more in Appendix L.

It should be noted here that it is almost impossible to cool down a person subjected to overheating by direct sunlight by just mechanical ventilation alone as the thermal comfort depends on the ambient temperature and the temperature of surrounding surfaces.

Energy performance will not only depend on the type of shading but also on the location, the surface area, the type of glazing, the building's orientation, the ventilation rate as well as the internal heat gains from occupants, lighting and equipment, and many other factors.

1.4 What is energy efficient shading?

Solar shading is a broad term used to cover techniques that limit the entry of excessive solar energy. These techniques include shading using trees, fixed awnings or brise soleil all the way through to fully automated blinds and shutters. In the heating season, solar shading can also be used effectively to retain the desired heat as it reduces the thermal conductance of the glazing and therefore acts as an insulator.

Weather conditions such as light and heat change constantly in the course of one day. That is why, in the context of this guide, there is an emphasis on automated systems which help us to benefit from optimal indoor conditions.

When designing a new building or preparing works to an existing one, it is necessary to take into consideration all of the characteristics of solar protection devices in order to select the correct product and façade management strategy. Shading products have an impact on the solar heat transmittance, daylight transmittance and also on the insulation of the façade. Consequently it is necessary to identify the product that will best balance these effects depending on the building properties, its location and orientation.

The science of dynamic shading is simple - to keep the heat out in the summer and keep the heat in during the winter. However, calculating the effects is not so simple. Make sure that the data you are using is correct.

This guide is intended to provide the basic knowledge of how solar shading characteristics are evaluated and what properties are involved in the transmission of the solar radiation in relation to the whole energy balance of the building. It is based on calculation methods taken from European Standards.

Examples of simulations highlighting the impact of solar shading on the total energy loads of buildings are shown in Appendix D.

1.5 What is the most energy efficient form of shading?

There is no straightforward answer to this question.

The sun gives us both daylight, essential for health and well-being, and free passive solar heat energy. The optimal shading solution should:

- Stop or minimise overheating in the summer
- Allow passive solar heating in the winter
- Optimise daylight utilisation in the building
- Provide visual contact with the outside

"In practice an optimal solar control strategy designed to maximise heat gain in winter and heat rejection in summer through use of adaptable shading systems would reduce the UK's housing stock energy use on space heating and cooling."

NEF Glazing Supply Chain Group

Glazing in buildings – reducing energy use.

In addition solar shading should prevent glare problems which are common typically in office buildings and where seating and view positions are fixed.

The main energy cost associated with dwellings is heating, whereas in commercial buildings it is cooling and lighting.

As the position of the sun moves, conditions inside the building change throughout the day and also throughout the year. The choice of shading should be determined not only by the building's orientation and location, but also by the building type and the activities that take place inside. A building with high internal heat gain, like a highly glazed office, will typically require more shading than a domestic building.

Different types of glass and frames will exhibit a different performance when shading is added. The size of a window and the amount of the glazed area will affect the choice of the shading. It should be noted at this point that the selection of the right colour of any shading device is an energy affecting decision as well as a design decision.

To help you select the most appropriate shading for your requirements use Appendix C to prioritise your needs and then discuss these with a BBSA member.

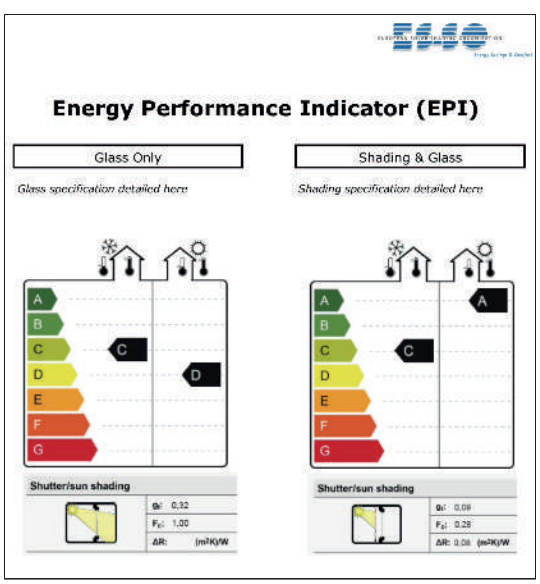
Selecting the right colour of a shading system is an energy as well as a design decision.

1.6 An A-G rating for solar shading

Providing clear energy ratings has proven to be very effective in improving the energy consumption of many products such as white goods.

Producing a simple rating system for shading to cover all of the variables would be difficult to achieve. Ideally we need to know how the shading will perform in conjunction with the different types of glazing also taking into consideration the orientation of the building and its specific location.

The purpose of a typical A - G rating is to allow a simple comparison of products in an example situation and to provide an easily understandable label. The A - G rating for tyres for example does not determine the exact performance level. It is a tested measure indicating the rating that could be achieved based on typical test conditions.



ITRS, the German Solar Shading Trade Association working with the German laboratory ift Rosenheim has developed a simple rating system for shading products when combined with glazing.

A labelling system is also being developed for construction materials to meet The Ecodesign of Energy Related Products Directive 2009/125/EC, a framework directive primarily focusing on energy in use.

KEY PERFORMANCE MEASURES OF SOLAR SHADING DEVICES

g-value is the measure of the total energy transmitted through glazing when exposed to solar radiation.

g_{tot} - is the measure of the total energy transmittance of the glazing in combination with the shading when exposed to solar radiation.

U-value is a measure of thermal conductance which is the ability of a material to transfer heat.

Tv is the measure of the proportion of visible light transmitted through the shading material.

These values must be always measured in conjunction with the glazing.

The lower the g-value or g_{tot}, the lower the heat gain.

This Directive sets minimum requirements for certain energy consuming products and one of the first to be developed will be for windows combined with shading products. This is currently at the consultation stage and is intended to be introduced by 2018.

Until then an Energy Performance Indicator (EPI) has been developed by ES-SO to validate the information provided by manufacturers. It confirms that performance data has been calculated correctly using the ift Rosenheim rating system with peer reviewed validated data. (See Appendix D and the ESSDA database)

The performance figures for solar shading must be calculated to European Standards (see Appendix D and Section 4.0 of this guide).

For a detailed assessment of a building's performance specific computer modelling should be used.

1.7 What is solar gain?

To understand solar gain we need to understand how the sun's rays work. Solar radiation contains a wide range of wavelengths – short wavelengths mainly correspond to visible radiation whilst long wavelengths are perceived as heat.

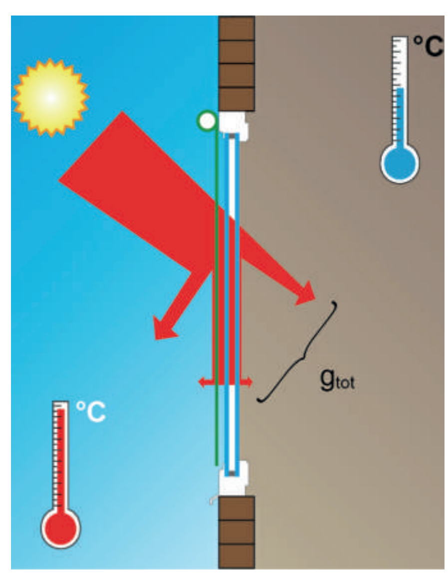
Glass allows most of the shortwave radiation (light) to pass through it but will not transmit most of the longwave (heat). So the sun's rays pass through the glazing as shortwave, hit objects in the room such as walls and furniture which absorb the radiation and re-radiate it back as longwave heat. That heat cannot pass back through the glass as this is opaque to longwave radiation. However, this is absorbed by the glass causing a warming effect internally. This same phenomenon happens in the atmosphere and is known as the Greenhouse effect. See Appendix A.

Blinds, awnings and shutters can help prevent excessive solar gain by blocking some of the incoming solar radiation.

External blinds and shutters are very effective as they prevent the radiation from even reaching the window as the heat is convected to the outside air.

Although less effective, internal blinds also reduce solar gain. This is especially true of fabrics that have a reflective finish facing the window which will effectively reject some of the incoming shortwave radiation, therefore not allowing it to be absorbed and turned into heat. For a more detailed assessment of the effects of solar gain see Appendix A.

When considering the performance of solar shading devices there are three important measures to understand: U-value, g-value and T_v.



1.8 What is g-value?

In effect this is a measure of solar heat gain.

Also called Solar Factor, g-value is the measure of the total energy passing through glazing when exposed to solar radiation. It is the sum of two values; the solar transmittance, Ts, which is the heat absorbed by the glass and re-radiated as longwave inwards and the secondary internal heat transfer factor Qi.

When the g-value of the glazing is combined with the value of the shading, this is known as the g_{tot} value.

The lower the g-value or g_{tot}, the lower the heat gain. The value of g_{tot} is between 0 and 1, where 0 equates to no radiation being transmitted into the room and 1 means all radiation (100%) is transmitted. So a g_{tot} of 0.25 (25% heat gain, 75% heat rejection) reduces heat gain three times more effectively than a g_{tot} of 0.75 (25% heat rejection). External shading helps to significantly reduce g_{tot} values and has a much more significant impact on g_{tot} than internal shading.

For energy calculations it is necessary to use the combined figure of the glass and shading and not just the shading alone. A detailed assessment is shown in Appendix E.

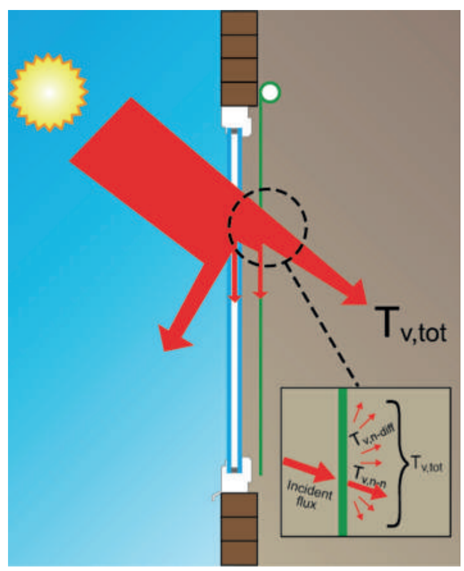
1.9 What is U-value?

U-value is a measure of thermal conductance which is the ability of a material to transfer heat by conduction, convection and radiation. All components of a building have U-values - e.g. masonry, insulation materials, plasterboard and windows. The lower the value, the slower the heat loss through the material. Therefore a material with a low U-value is a good insulator. The U-value of glazing is **always** improved by installing blinds or shutters. For a more detailed explanation see Appendix F.

As with g-value for energy calculations, it is necessary to take the combined figure of the glass and shading and not just the shading alone.

1.10 What is Daylight Transmittance (T_v)?

This measure refers to the fraction of visible light transmitted into a room. As with g-value we have to consider the measure of the glass in combination with the shading device. The value is between 0 and 1, where 0 means no light is transmitted and 1 means all (100%) visible light is transmitted. A T_v value of 0.25 means 25% of light is transmitted. See Appendices A and N for more information.



1.11 Data and calculation tools

When using data it is essential to ensure that the calculation methods are correct. The British Blind & Shutter Association (BBSA), in conjunction with partners in the European Solar Shading Organisation (ES-SO), have developed a database of solar shading materials, ESSDA.

This database includes energy performance data of blind and shutter fabrics and materials independently validated to European Standards. The database calculates the energy performance of blind and shutter products when used in combination with reference (typical) glazing as defined in the European Standards EN 13363-1 and EN 14501. All calculations are also performed in accordance with the relevant European Standards.

The process of independent peer review and use of European Standards employed by ESSDA is identical to the glazing industry database and is a robust and effective way of ensuring the integrity of the database. Outputs include:

- Total solar energy transmittance, g_{tot} (amount of heat gain)
- Thermal transmittance, U-value (amount of heat loss)
- Visible light transmittance, T_v (amount of daylight)

A detailed assessment of calculation methods and data required is shown in Appendix D.

Blinds and shutters can prevent excessive solar gain by blocking some of the incoming shortwave solar radiation and retaining heat when necessary. This is why it is important to know the g_{tot} and the U-values.

The U-value of glazing is **always** improved by the installation of blinds or shutters.

"Shading devices generally improve the U-value of the window, especially if they keep an extra layer of still air on one side of the glazing, just like an extra glass layer."

NEF Glazing Supply Chain Group

Glazing in buildings – reducing energy use.

1.12 What types of shading should you choose?

Installation of blinds, shutters and awnings needs to satisfy a wide range of requirements and there has to be a balance in fulfilling those requirements. Designing for the best energy saving is unlikely to produce the most satisfactory solution.

For example, one of the most effective energy saving solutions is an external blackout roller blind. On the ESSDA database this will probably show one of the best g_{tot} performances, better than 0.05 (95% heat rejection) and good U-values as well - but would it work in practice? Almost certainly not, with no view through and no daylight transmission, resulting in extra energy cost for artificial lighting. This is an extreme example but it shows the need to choose the most suitable, practical solution that best reflects the requirements of the occupants and the building.

So when selecting the right shading solution we need to consider what best meets the needs of the building's occupants. The creation of a checklist of the requirements is necessary in order to recognise and prioritise the most important criteria. See Appendix C for an example.

Effective shading can allow highly glazed buildings to be built in compliance with the latest building regulations.

The completion of this checklist may lead to the same conclusion as several scientific studies conducted by the Fraunhofer Institute of Building Physics amongst others. These show that ideally a window requires both internal and external shading as the solar heat gain may be desirable in winter while the sunlight could cause glare. In this instance, the interior shading would be used to manage glare but still admit some free passive solar heat into the building. The exterior shading would be used to reduce solar radiation in the summer resulting in a reduction in overheating and the need for artificial cooling.

1.13 Commercial building cooling savings

Solar shading typically installed in commercial buildings can have a significant impact on the size or even the requirement for air-conditioning systems. The savings in terms of installation, running and maintenance costs of air conditioning will far outweigh the cost of a typical solar shading installation, especially if full lifecycle costs are considered.

"Selection of solar shading should always be one of the first steps in the design of HVAC systems."

Olli Seppannen, REHVA

Selection of solar shading should always be one of the first steps in the design of HVAC systems. It will prevent unwanted solar heat from entering the building and so avoid the need for additional cooling to remove this heat, saving energy and money. This is particularly important in highly insulated and airtight buildings such as near zero energy nZEB) buildings.

In winter when the shading is raised the free heat from the sun is desirable as it reduces the building's heating costs.

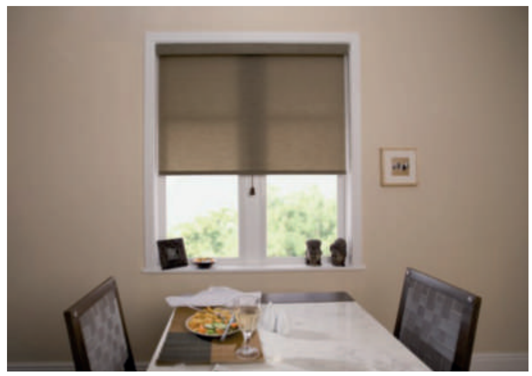
Appendix G shows a cost-benefit analysis based on computer simulations of a typical office building, using solar glass without shading compared to double low-e glass with shading.

Not only is the capital cost lower but there is a continuing payback from reduced running costs. In fact effective shading allows highly glazed buildings to be built in compliance with the latest building regulations.

Moreover, significant productivity performance improvements can also be achieved with a controlled internal environment and an analysis can be seen in Appendix L.

1.14 Domestic building energy saving

Typically domestic buildings do not have mechanical cooling so the greatest energy savings will come from heat retention. However, as the housing stock becomes better insulated and air-tight, overheating is increasingly becoming an unintended consequence even during the heating season. Shading helps to provide a more comfortable environment without the cost of artificial cooling.



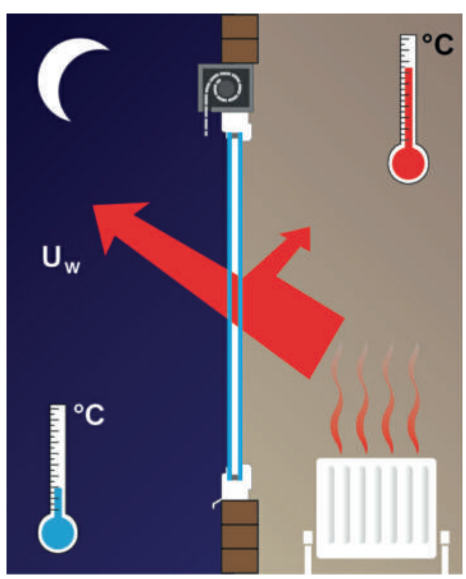
As approximately 27% of the UK's carbon dioxide emissions come from domestic buildings, improving the energy efficiency of the UK's housing stock by improving heat retention will significantly reduce national CO_2 emissions.

1.15 Refurbishment

It is estimated that 75% of the UK's existing building stock was constructed before 1980. Whilst by 2020 all new buildings are expected to be nearly zero energy only 1-1.5% are replaced every year.

In both new build and renovation, better insulation of the opaque (solid) parts of the building envelope is what is normally thought of first alongside reducing air leaks through windows and doors. What is often overlooked is the serious risk of overheating in the summer.

Windows are typically one of the weakest elements of all the building components. Their properties are static whereas the position of the sun and weather conditions vary continuously.



Shading reduces or eliminates the need for active cooling in summer conditions by controlling the amount of solar energy entering through the windows. Correctly managed solar shading also allows harvesting of free solar energy in the winter season and offers additional insulation to the transparent parts of the building structure which helps to reduce heat loss in cooler weather and particularly at night time.

Solar shading will also control daylight admittance, reduce glare and improve visual comfort. According to Part L of the English Building Regulations when seeking to limit solar gain, the provision of adequate level of daylight needs special attention. An effective way to control the quantity of light transmitted through windows is by using blinds. For more details see Appendix N.

"The current development in building energy efficiency towards nearly-zero energy buildings represents a number of new challenges to design and construction of buildings. One of the major challenges is the increased need for cooling in these highly insulated and airtight buildings".

Per Heiselberg, Aalborg University, Denmark

Around 75% of the existing building stock was constructed before 1980 and so is poorly insulated compared to modern standards.

The PassivHaus principle encourages high levels of insulation and large areas of glazing to maximise winter heat gains.

However, heat gains have the opposite effect in the spring and summer when they become excessive, causing overheating. External blinds or shutters can be an effective solution.

1.16 PassivHaus and near zero energy buildings

The development of the PassivHaus concept has created requirements for shading that have not previously been considered in UK design.

The PassivHaus principle encourages high levels of insulation and large areas of glazing to maximise winter heat gains. However, these positive heat gains have a detrimental effect especially in the spring and the summer when they become excessive, causing overheating. This could be reduced by a passive fixed systems to reduce high angle peak solar gain. However, this only solves part of the problem as in the winter months, when the sun's path is lower, heat gain will still be an issue particularly on east façades. Also the high level of insulation of this new building technology is likely to cause overheating unless a more effective external solar shading system is integrated into the design.

In order to achieve the best results shading needs to be moveable, allowing it to be lowered for cooling and raised for heating depending on the season. Several post-occupancy studies of high performance buildings report high temperatures as one of the most frequent problems of PassivHaus buildings.

"Consideration should also be given to the optimal integration of shading systems within the building envelope, e.g., a double skin façade. A high potential lies in this solution that combine the benefits of external shading, protected by the adverse effects of weather, with natural ventilation flow created within the façade and high heat rejection. Advancements in controls are likely to push in the direction of automated shading systems able to provide flexible solutions to the occupants."

NEF Glazing Supply Chain Group

Glazing in buildings – reducing energy use.

1.17 Double Skin Façades

For extensive commercial renovation that includes the replacement of the glazing or in high traffic zones, consideration should be given to a double skin façade that incorporates shading within the building envelope. This is an effective option that has the benefits of the external shading system utilising the natural ventilation created within the façade. The design of The Shard in London was only possible with highly effective automated shading within the façade that enabled the g-value of the glazing alone to be reduced from 0.68 (32% heat rejection) to a g_{tot} figure of 0.12 (88% heat rejection). More detailed analysis of Double skin façades can be found in Appendix M or in REHVA Guidebook *Solar Shading - How to integrate solar shading in sustainable buildings.*

1.18 Automation

The optimum energy saving benefits of solar shading will only be achieved if the system is controlled to react to changing outdoor conditions. The most effective way, especially for commercial buildings, is an automatically controlled system. It will operate effectively and react to the environmental conditions regardless of the occupants' presence, ensuring the energy balance of the building is maintained. Control of the internal environment can be achieved with simple stand-alone systems or large scale systems integrated into the building or home management system. Indeed dynamic shading could even be operated with active solar energy since shading will typically be needed when the sun is shining.

Automated solar shading systems will maximise energy savings, improve internal comfort and accommodate the varying needs of the occupants. Automation will also protect external shading from damage from high winds or extreme weather conditions.

Careful consideration must be given to the selection of an automated system. For more detailed information please see Appendix K.

1.19 Understanding shading is essential for changing our energy use

Behavioural change is a key part of the UK strategy to reach environmental and energy saving targets.

With energy prices set to increase even further in the future, the only way for home owners and businesses to save money on energy is to change the way it is used - that is behavioural change. When energy was cheap and plentiful there was no incentive to consider how energy was used and how it could have been saved.

By adopting best practice when using shading, occupants will quickly realise how they are saving energy and money. Occupants' understanding how the system works is essential for reaping its full benefits.

The World Green Building Council report *Health, Wellbeing and Productivity in Offices - The next chapter for green building* (2014) states that; "True sustainability is found at the 'sweet spot' of good design (passive solutions such as shading, orientation and natural ventilation), good technology (including air-conditioning, automation, and temperature control) and good behaviour (clothing, acceptance of wider temperature ranges and familiarity with systems). Often, good behaviour can be the most elusive to achieve and the hardest to maintain."

Advice on understanding the benefits of, and applying, behavioural changes is shown in Appendix B.

1.20 Designing buildings using a holistic approach

Designers, architects and engineers, now more than ever, should consider the performance characteristics of solar shading, rather than their decorative value, at the early design stage of the building in order to satisfy low energy building requirements.

Solar shading is increasingly seen as an essential building service and one that positively affects the energy balance of the building when controlled and used correctly.

Unfortunately the relegation of solar shading to the fixtures and fittings section (N10) in the National Building Specification (NBS) typically masks the positive impact that correctly specified solar shading systems can have on façades and building services such as reducing the capital cost, running and maintenance costs and the effective control of the internal environment.

"The change towards an ecological design in the fields of urban planning, agriculture, manufacturing, and energy systems as well as architecture will require a major change in how we think and so changes in education at all levels."

Prof. David W. Orr
Oberlin College

The conclusion of several scientific studies is that ideally a window should have both internal and external shading. Internal shading is better for glare control while external shading is better for solar gain control.

2.0 CONCLUSION

In order for blinds, awnings and shutters to improve the energy performance of buildings and their internal comfort they need to be correctly specified, installed and used. Automation will ensure the chosen solar shading devices provide the optimum benefit but manual systems can also be highly effective.

The power consumption of automated systems is minimal in comparison to the energy they save and with latest developments in solar power technology they could even be operated by free solar energy.

When considering the performance of a solar shading system, it is important to remember:

- Blinds and shutters should be considered at the design stage of the building as they will affect other building services. This early design stage thinking also ensures a better architectural integration of the shading device with the façade design
- Blinds and shutters must always be considered in combination with glazing to determine energy saving calculations

Solar shading will have a beneficial impact on the specification and will result in reducing the costs of:

- Glazing
- Artificial lighting
- Heating systems
- Cooling systems
- Mechanical ventilation

Solar shading systems can be installed externally or internally or within the glazing itself. In each position the performance characteristics will be different. Similarly, the type of glazing, colour, material, fitting, operation and position of the blind, awning or shutter will all affect performance.

With the ever increasing costs of energy and stricter control on building design and use, solar shading has an important part to play in managing the energy costs as well as improving the thermal and visual comfort of the occupants of a building.

The available solutions are many and varied so expert advice should be sought from a BBSA Member.

3.0 APPENDICES

APPENDIX A WHAT IS SOLAR GAIN?

This appendix explains some key information concerning the different types of radiation that have to be considered with regard to the performance of solar protection devices and the position of the sun. It also explains how a material behaves when it is affected by such radiation.

The solar irradiance depends on the position of the sun in the sky which can vary throughout the year and during the day. *Figure 1* shows that the sun's peak position in winter is lower than in summer. This gives an opportunity of harvesting large amounts of irradiance during the day through glazing in colder months.

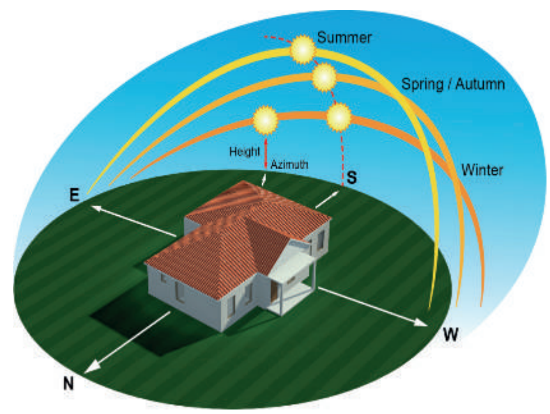


Figure 1. *Position of the sun in different seasons*

Types of radiation

We are exposed to a large variety of radiation, either natural or artificial. Radiation has differing wavelengths and the "power" of radiation is represented by its irradiance in W/m². For a given wavelength, we talk about spectral irradiance and it is expressed as W/m²nm. *Figure 2* shows the distribution of electromagnetic radiation depending on its wavelength.

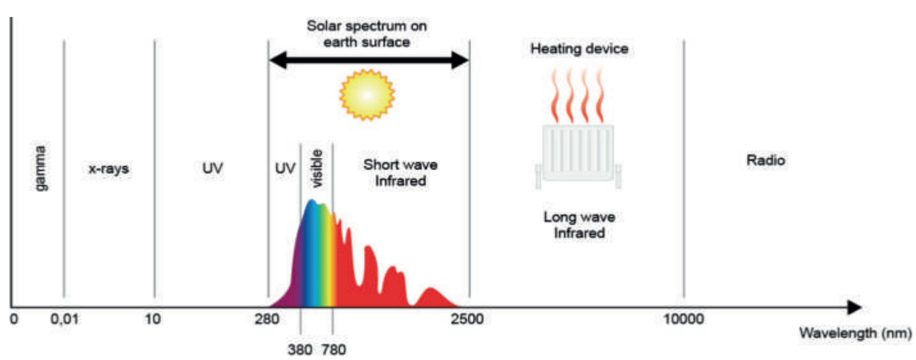


Figure 2. *Classification of various electromagnetic radiation depending on their wavelength*

Based on its wavelength, radiation can be divided in two types:

- The solar radiation (solar gain) with a wavelength range between 280 nm to 2,500 nm that can be subdivided into three parts: UV, visible and near infrared. This radiation is emitted by the sun.
- The longwave infrared with wavelength range between 2,500 nm to 10,000 nm that is emitted by objects on Earth and caused by the raised temperature of their material (e.g. a heater or any warm surface). This radiation is in the far infrared spectrum which is in the invisible range.

The heating effect of the sun is called solar irradiance and consist of three different wavelengths: UV, visible and infra-red.

Solar radiation

The sun's surface produces an enormous amount of energy (66,000,000 W/m²) which is transmitted to the Earth through radiation. Only a fraction of this energy reaches the atmosphere (around 1,300 W/m²). Around 6% is reflected directly back into space, approximately 15% absorbed by the atmosphere and emitted in all directions in the form of diffuse radiation and the remaining part (79%) on a clear day is directly transmitted to the ground through the atmosphere - see *Figure 3*.

As a consequence, the solar energy at ground level is much lower than at the top of the atmosphere. It is generally considered that in the UK the energy reaching the ground when there is a clear blue sky is around 1,000 W/m².

When considering a solar protection device, it is necessary to distinguish the three parts involved in the solar radiation - see *Figure 4*.

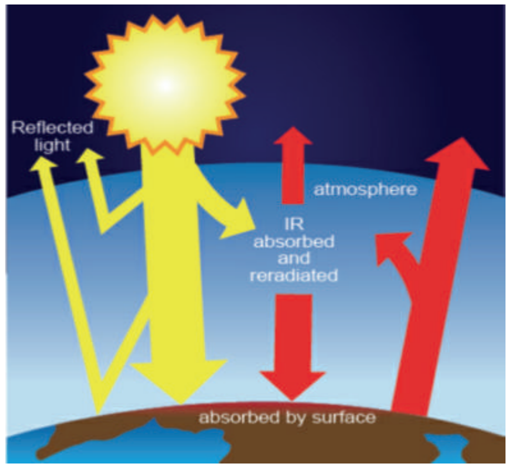


Figure 3. *Solar Radiation*

- Ultraviolet (UV): from 250 nm to 380 nm. These are invisible to the human eye and are responsible for ageing, changing and damaging our skin and objects around us.
- Visible (Tv): from 380 nm (violet) to 780 nm (red). These provide us with light and allow us to see colours and shapes.
- Shortwave infrared (IR): from 780 nm to 2,500 nm. These rays are invisible to humans but are felt as heat.

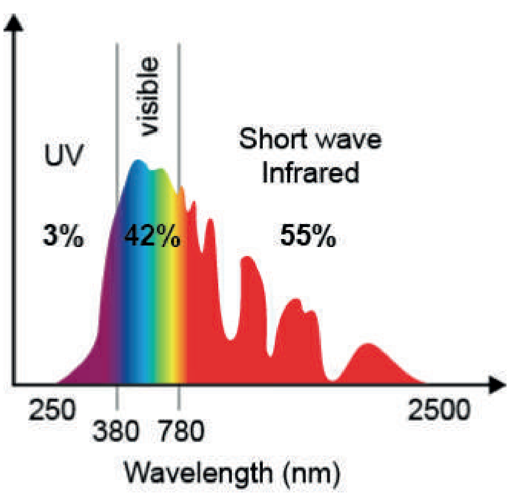


Figure 4. *Spectral irradiance at the sea level for the solar spectrum*

When the sun irradiates a surface for example glazing, fabric or a venetian blind slat, incident radiation splits into three parts (*Figure 5*):

- Transmittance τ – which is transmitted through the material.
- Reflectance ρ – which is reflected by the material.
- Absorptance α – which is absorbed by the material

So that $\tau + \rho + \alpha = 100\%$

The actual values of the above are specific to a material and are affected by its type (fabric, metal, glass), the density or openness, the colour and also the wavelength. This is measured in a laboratory in nanometers (nm). The amount of reflection and transmission will vary through the solar spectrum.

Solar radiation (250 - 2,500 nanometers) when in contact with an object (material) splits into:

- T_s - Solar Transmission
- R_s - Solar Reflection
- A_s - Solar Absorption

Visible light (380 - 780 nanometers) also splits into three:

- T_v - Visible Transmission
- R_v - Visible Reflection
- A_v - Visible Absorption

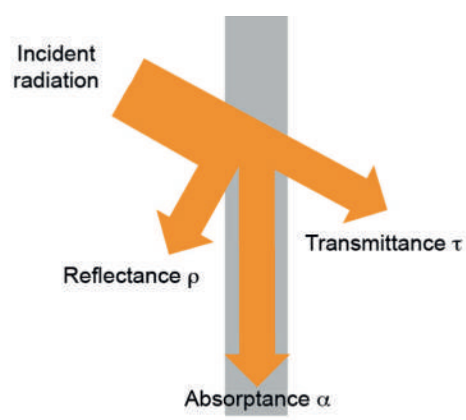


Figure 5. *Behaviour of radiation in contact with a material*

The solar radiance also depends on the position of the sun in the sky, which can vary throughout the year as well as during the course of the day.

When the sun irradiates a surface (glazing, fabric or a slat for example), incident radiation splits into three parts: transmittance, reflectance and absortance.

These values are assessed for solar gain and visible light to determine the thermal and visual properties of the glazing combined with a shading device.

The specific material properties are then used in calculations which combine the material data of the blinds, awnings or shutters with glazing data - see Appendix D.

A more detailed assessment of the methods and calculations can be found in *Solar Shading for Low Energy Buildings.* These characteristics are measured in accordance with the European Standard *EN 14500 Blinds and shutters - thermal and visual comfort - Test and calculation methods*.

APPENDIX B   BEHAVIOURAL CHANGE

Summer cooling with blinds and shutters

In hotter climates such as in southern Europe it is normal for the blinds or shutters to be closed from early morning so that the room becomes a cool refuge from the sun throughout the day. It is a natural, efficient method of preventing a room from overheating without using any energy.

In order to save energy, blinds and shutters just need to be operated effectively. To achieve this, follow the best practice guide recommended by the BBSA.

In the UK also hot in the summer, we have traditionally preferred large areas of glass requiring the need for air conditioning in offices and fans in our home to help regulate temperature. Utilising passive cooling methods such as shading and ventilation have been typically over-looked.

One of the traditional ways of minimising heat from the sun entering the interior is planting trees outside windows. In the summer the leaves provide shade and in the autumn the loss of leaves will allow the sun to penetrate to provide some natural winter heating even when temperatures outside are low. Trees can be a positive and an effective environmental solution except for the fact that they need time and space to grow. and so blinds and shutters are more practical solutions.

An office worker exposed to direct sunlight can never feel comfortable even with mechanical cooling since their perceived thermal comfort is affected by the surrounding air temperature and the radiation from surrounding surfaces. The only way to become more comfortable is to change place or to sit in the shade, away from direct sunlight.

Winter heat saving with blinds and shutters

A significant amount of heat can be lost from a building through its windows, especially during the cold winter months. Also in the winter it is important to maximise heat gain from the low angle sun. Blinds and shutters can help reduce the amount of heat loss as they can also be raised to maximise passive solar gains entering the building when needed. In contrast, solar protective glass will reduce solar gains year-round, even in the winter.

In commercial buildings this can mean that less heating is required in the morning to get the building to a comfortable temperature and in homes we will appreciate the lower heating bills. To achieve this, follow the best practice guide recommended by the BBSA.

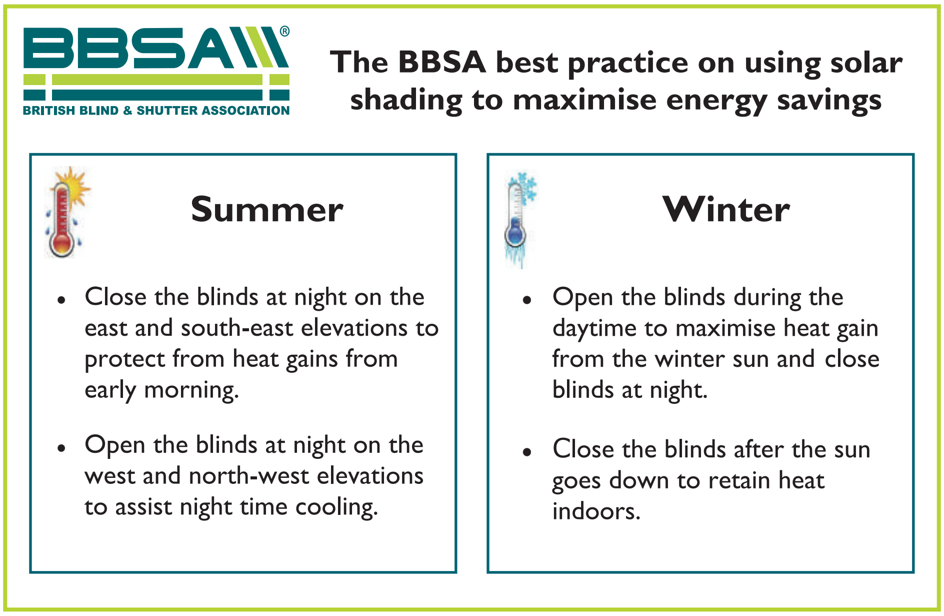


Figure 6. *The BBSA best practice guide on using solar shading to maximise energy savings*

APPENDIX C CHECKLIST OF REQUIREMENTS FOR SOLAR CONTROL MANAGEMENT

What do you expect the blinds or shutters on your project to achieve? Do you know all of the benefits that blinds and shutters could provide for you? Which are the most important?

Blinds and shutters can perform many functions and this list is intended to help you identify the issues rather than direct you to a specific type of product. It is unlikely that a single product will achieve every requirement and in many cases two shading systems may be required. Therefore it is necessary to prioritise needs and check them against the products you have selected. See *Table 1*.

Solar shading fulfils many functions and requirements such as building control, user control, compliance with regulations and standards and aesthetics. Therefore, it is important that the user prioritises their needs so that the most appropriate product can be selected.

Function	Degree of Importance		
	High	Medium	Low
BUILDING CONTROL			
Control of solar gain in summer			
Daylight level control			
Heat retention			
Interface with building or home management system			
Master override of automated system and wind override			
Shading when area is unoccupied			
Automatic control of primary heat gain			
Minimal reduction of light levels on dull days			
Light shelf to diffuse and spread light			
Control of energy costs			
USER CONTROL			
Glare control for visual comfort			
VDU screen glare control			
Ease of operation			
Visual perception, allowing external vision			
Privacy during daytime			
Privacy during nighttime			
Manual override of automatic control			
REGULATIONS AND STANDARDS			
Compliance with Building Regulations			
Compliance with energy performance software (SAP and SBEM)			
Local authority planning			
Energy performance and energy audits			
Help to reduce carbon emissions in buildings			
AESTHETICS			
Co-ordination with decor			
Same solution for every elevation			
Symmetry of appearance of external shading (elevational consistency)			
Internal symmetry			
BUILDING LIFECYCLE COSTS			
Manageable maintenance costs			
Designed for long life			
OTHER FUNCTIONS AND NEEDS			
Blackout			
Dim-out for projection and AV equipment			
External shade area for sitting under			
Rooflight shading			
Advertising sign			
Flame retardant materials			
Prevent UV fading of furniture and decoration			

Table 1. *Checklist of requirements for solar control management*

APPENDIX D DATA AND CALCULATION TOOLS

The European Solar Shading Association (ES-SO) in conjunction with the British Blind and Shutter Association (BBSA) and other partners have developed a database of shading material performance. The European Solar Shading Database (ESSDA) includes independently validated energy performance data of blind and shutter fabrics and materials measured to European Standards.

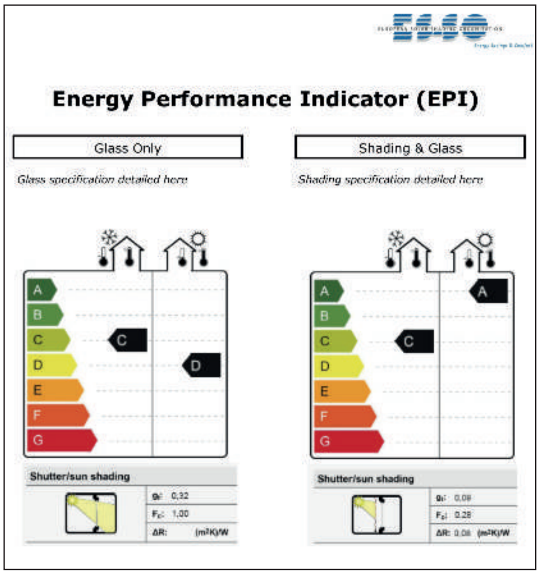


Figure 7. *Example Energy Performance Indicator (EPI)*

A user-friendly Energy Performance Indicator has been developed to be similar to the one used by the Glass and Glazing Federation except that it combines shading with glazing. See *Figure 7*.

The database enables the calculation of the performance of shading products in combination with the glazing (this combination is known as 'complex glazing'). It takes the performance data for the glass and the shading product to enable the calculation for the actual combinations of g_{tot} and U-values of glass and blinds or shutters.

A holistic approach to low energy shading means solar shading should be considered with regards to other aspects of the build and therefore at the planning stage.

To correctly calculate the energy performance of a blind, it is essential to do this in combination with the type of glazing (single, double, triple or low-e) and the blind's position (external, internal or mid-pane). This is important because for each combination of glazing and shading system the results will be different. Consequently it is not a simple calculation and this is why ESSDA is such a useful tool.

The output from ESSDA shows the thermal and visual performance characteristics of a blind in combination with a particular glazing. However, to ascertain how these characteristics perform in a specific building it will be necessary to use a building modelling system. This is usually a computer simulation tool which creates a virtual building and calculates the energy requirements of the building. A building modelling system which accurately considers shading will be able to show the reductions of heating, cooling and electric lighting loads resulting from the installation of solar shading. One such example is Early Stage Building Optimisation (ESBO) developed by EQUA Simulation in Sweden (www.equa.se/en)

To predict the energy performance of a building both with and without solar shading, "reference" (typical) buildings are used and many aspects need to be considered such as:

- Dimensions of the building
- Orientation of the windows
- Occupancy schedules
- Weather data
- U-values of building components (roof, external and internal walls, ground and internal floors and windows)
- Transmission of heat loss
- Ventilation heat loss
- Solar gain
- Internal gains
- Utilisation factor
- Gain utilisation factor for heating

- Loss utilisation factor for cooling
- Space heating requirement
- Space cooling requirement
- Day and night profiles during a complete year

Computer models tend to use solar shading performance data and apply them to the reference glazing combinations from EN 13363-1 and EN 14501, see *Table 2*.

Standard	Glazing	U-value W/m2K	g-value
EN 14501	A. Clear single glazing	5.8	0.85
EN 14501	B. Clear double glazing	2.9	0.76
EN 14501	C. Double glazing with low emissivity	1.2	0.59
EN 14501	D. Solar control double glazing	1.1	0.32
EN 13363-1	Triple glazing	2	0.65
EN 13363-1	Double clear glazing with low-emissivity	1.6	0.7

Table 2. *Reference glazing from European Standards*

A calculation tool for office buildings Textinergie® has been developed by the French Association of Blind and Shutter Manufacturers, SNFPSA. For more information visit: www.textinergie.org

The g-value, also called solar factor, is the total solar energy transmittance through a building element. The symbol g is the solar factor of the glazing alone while g_{tot} is the solar factor of the combination of a glazing and a solar protection device.

APPENDIX E G-VALUE CALCULATIONS

The g-value, also called Solar Factor, is the total solar energy transmittance through a building element. It is the sum of the solar transmittance, Ts, and the secondary internal heat transfer factor Qi. The latter term is the portion of heat absorbed by the window which is transferred to the inside of the building.

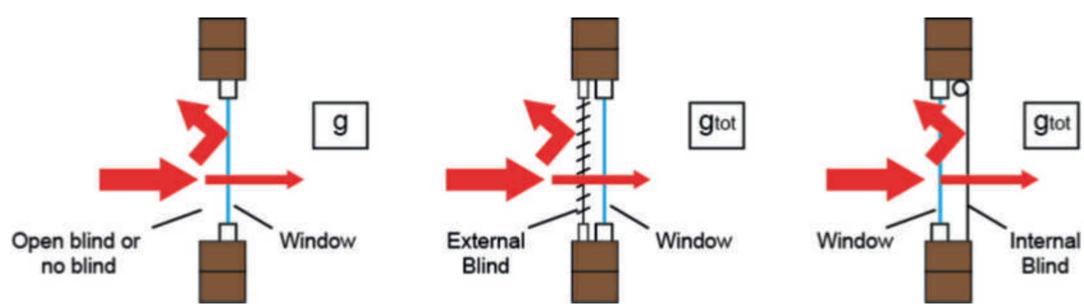


Figure 8. *g-value (glass only) and g_{tot} (shading and glass)*

The symbol g is the solar factor of the glazing alone while g_{tot} is the solar factor of the combination of a glazing and a solar protection device - see *Figure 8*.
The g-value of glazing alone is determined by the calculation method given in EN 410.
There are two methods for the calculation of the g_{tot} of a blind and glass combination (also known as complex glazing). A simplified method is given by EN 13363-1 and a detailed method given in EN 13363-2.

The simplified method is considered adequate for basic energy calculations and this is the one used in the database described in Appendix D.

If we know the performance characteristics of the glazing and that of the blind or shutter being used, it might seem simpler to just add the two values together but that will not provide an accurate result.

The reason for this is that solar radiation travels through the window and the blind (*Figure 9*) and the sun's rays are absorbed by objects in the interior and converted to heat. This heat cannot entirely pass back through the solid glass because most of the heat becomes trapped between the two panes and some is absorbed by the panes of glass. That heat is also transferred by convection and some is re-radiated back through the second pane into the room, some remains trapped and some is radiated through the first pane to the outside (see *Figure 10*).

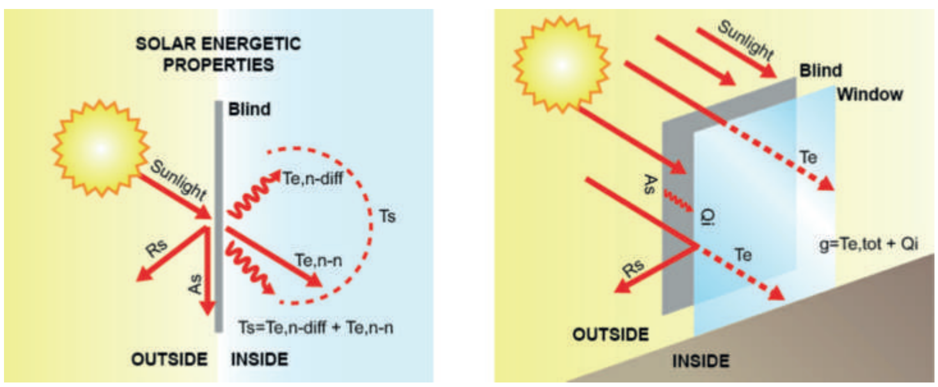


Figure 9. *Solar energy properties*

That is why we need the ESSDA database to calculate the way this energy is reflected and transmitted. The simplified formulae for the calculations for external, internal and mid-pane blinds are specified in EN 13363-1 and analysed in *Solar Shading for Low Energy Buildings.*

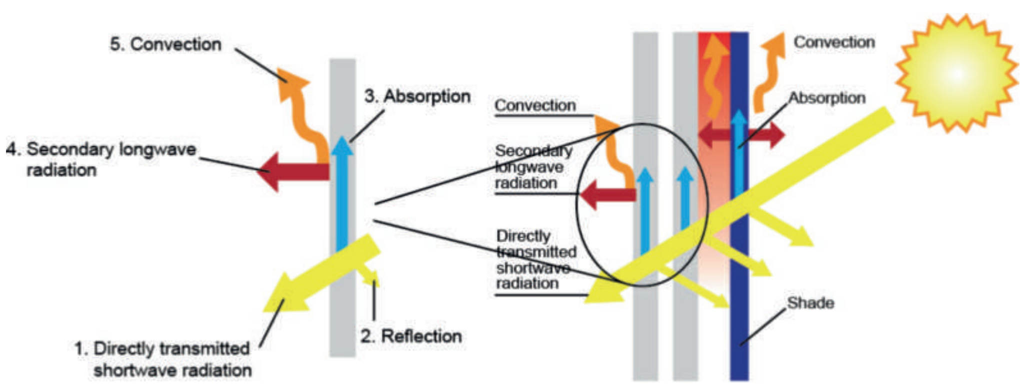


Figure 10. *Solar radiation transmission and interaction with different objects*

There are two European Standards that are used to compare the performance data for standard glazing types: EN 13163-1 and EN 14501.

The industry standard for g_{tot} comparisons is reference glazing C from EN 14501 which is for double glazing with low-e glass. This is the minimum level of glazing for a new build design.

APPENDIX F U-VALUE CALCULATIONS

A U-value is a measure of thermal conductance which is the ability of a material to transfer heat. Closing a blind or shutter will help improve the U-value of a window and help to retain more heat during the heating season.

The performance of the solar shading products is measured in combination with glazing. That will give a different figure depending on where the blind is fitted - internal, mid-pane or external and the type of the glass - single, double, triple - and which pane and on which side a low-e or other coating is applied. It is not a simple calculation which is why we need the ESSDA database.

U-value is a measure of thermal conductance which is the ability of a material to transfer heat. The lower the U-value, the lower the thermal conductance.

Many components of a building such as masonry, insulation materials, plasterboard, metals and windows have U-values. This measure is expressed as Watts per metre square Celsius $W/m^2\,^{\circ}C$ or Watts per metre square Kelvin W/m^2K; for example the typical U-value of a clear glass double glazed window is 2.9 W/m^2K.

Heat transfer (loss) through windows

Heat is conducted (lost) through a window in the heating season by (*Figure 11*):

- Conduction – direct loss of heat through the window to the outside
- Convection - where the warm air in the room hits the cold surface of the glass and cools the air inside the room
- Radiation and Re-radiation - this is where the cold surface of the glass absorbs the heat from inside the room
- Air leakage – heat lost through cracks in the frame or from around poorly fitted glazing

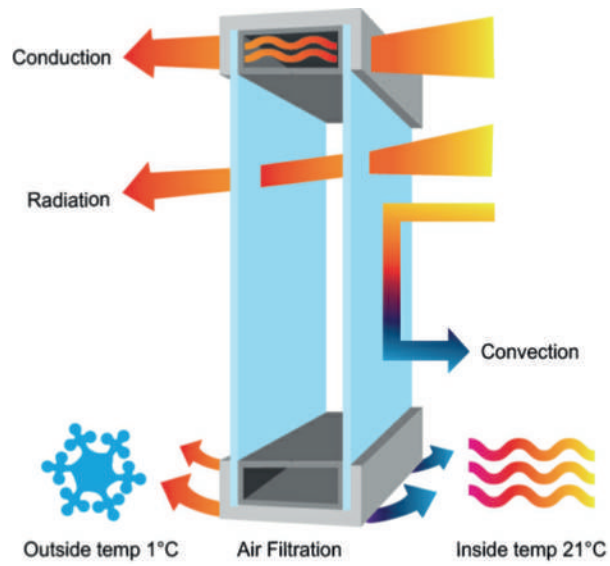


***Figure 11**. Heat transfer through windows*

When assessing the U-value, we need to combine both the glass and blind or shutter as the results will vary depending on the type of glazing and the type of blind or shutter. Shading will reduce the heat loss which is particularly important during the winter months.

An internal blind with average air permeability can reduce the heat loss through single glazing by almost 40%. The reason why we need to know the performance of blinds in combination with glazing is simply illustrated in the graph opposite.

A blind installed with low-e glazing provides an improvement in U-value of 12%, still a significant improvement when you consider that low-e glazing already has a low U-value. (An example of an average air permeability blind would be an internal blind that has no openness factor and peripheral gaps of 20 - 80mm between the blind and the window frame.) See *Table 3*.

The U-value of glazing is **always** improved with shading.

		Clear single glazing Ref: A	**Double clear glazing Ref: B**	**Double glazing with low emissivity Ref: C**
	Glass Alone	***U=5.8 W/m^2K***	***U=2.9 W/m^2K***	***U=1.1 W/m^2K***
Internal Blind and Glass	High air permeability	4.0	2.4	1.0
	Average air permeability	3.5	2.2	1.0
	Low air permeability	3.2	2.1	1.0

***Table 3.** Reference glazing U-values*

Figure 12 shows the U-value of glazing is improved by the fitting of blinds. The example also shows that the effect of the blind or shutter is more pronounced when it is combined with a window with low energy performance for example single glazing or first generation double glazing.

The effect of the blind or shutter is more pronounced when the window has low energy performance such as single glazing or first generation double glazing.

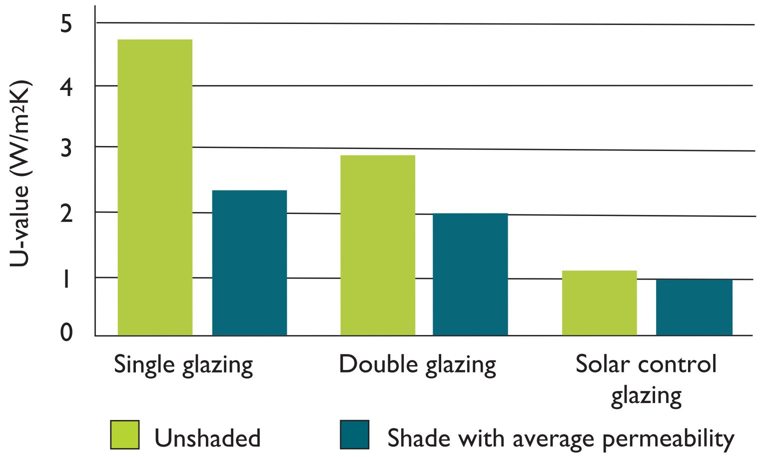


Figure 12. *U-Value of blinds combined with different types of shading*

CIBSE Guide A quotes that a conventional roller blind (unsealed) would have a U-value of 2.53 W/m²K when installed on double glazing. If the same blind was installed with a cassette, casing or channels on the same double glazing then the U-value would be improved by 25% to 1.9W/m²K.

A product such as an external insulated shutter which is fully sealed is likely to give a lower U-value and be more effective in reducing winter heat loss than an internal solution.

EN standard 13125 provides the methods and formulae for calculating different values. For more information see *Solar Shading for Low Energy Buildings*.. U-Values for blinds combined with glass can be found on the ESSDA database, see www.es-so-database.com

APPENDIX G COMMERCIAL BUILDING SHADING COST-BENEFIT ANALYSIS

Correctly specified blinds and shutters can significantly reduce the capital cost and energy running costs of HVAC systems. Comparisons of HVAC, lighting, glazing and shading systems are not straightforward as the systems all interact with one another and are inter-connected. We must bear in mind that a positive design benefiting one aspect of the system could negatively affect another.

In office buildings the direct transmission of sunlight that can cause thermal discomfort and glare issues will in particular not be solved with a passive solar protective glass nor with a mechanical ventilation system alone. In the majority of cases solar shading will be an appropriate solution to provide comfort to the building occupants and the real savings in buildings will be reflected by the improvements in the productivity of the employees by due to a comfortable working environment.

Therefore a holistic approach combining all different aspects is essential. It is precisely this holistic requirement which means that solar shading should be considered at the planning phase of a building or building refurbishment. Solar control management using blinds and shutters must be a building services consideration.

Based on the cost-benefit analysis presented in this section, blinds have a payback period of less than a year because the total investment required for the solar control glazing with no solar shading is higher than the investment for the low-e glazing with solar shading.

This demonstrates that shading represents an investment rather than a cost.

Computer simulations carried out by REHVA and ES-SO considered a model office under two different scenarios:

1. Solar control glazing installed

2. Low-e glazing and automated external venetian blinds installed (controlled by a seasonal programme)

Amsterdam	**Solar control glazing**		**Low-e glazing with solar shading**		**Investment difference**
Investment cost	Quantity	Cost (€)	Quantity	Cost (€)	(€)
HVAC	1490W	1729	1053W	1423	306
Solar shading	6.48m^2		6.48m^2	626	-626
Glazing	6.48m^2	791	6.48m^2	441	350
Total investment		**2519**		**2490**	**30**
Recurring cost					
Lighting	99W	10	91W	9	1
Cooling	404m^2	20	292m^2	14	6
Heating	447m^2	22	372m^2	19	3
Total recurring/ year		**52**		**42**	**10**
In this example the payback is less than one year					

Table 4. *Example investment and payback for solar shading versus low-e glazing*

Table 4 shows a comparison of the two model scenarios under Amsterdam's climate conditions. It highlights that overall the payback period for the solar shading is less than one year. This is because the investment required for the shading is lower than the investment for the advanced solar control glazing and HVAC costs. This demonstrates that shading represents an investment rather than a cost by realising significant reductions in running costs (lighting, cooling and heating).

The same model comparisons were carried out for Stockholm and Madrid climate conditions. See *Figure 13*.

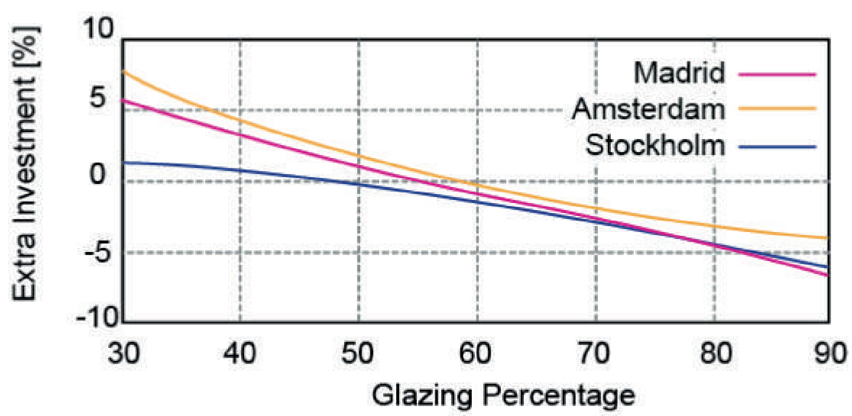


Figure 13. *Solar control glazing with HVAC and extra investment required depending on the amount of glass used*

Both of these cities also showed a payback for the capital cost of the solar shading in less than a year. Here the results for Amsterdam were chosen for demonstration as this city has similar weather conditions to some parts of the UK. Results for other cities cam be seen in *Solar Shading for Low Energy Buildings*.

In the Amsterdam model, a reduction of 20% is seen between the office without shading and the office with window blinds installed.

The graph shows the amount of investment required to install shading compared with the base case of investment for HVAC and solar control of glazing. When a building has a glazing percentage of greater than 50-60% (depending on the location) it requires no extra investment to install solar shading. This is because significant savings will be achieved through reduced running costs for lighting, cooling and heating and a smaller HVAC system can be specified saving additional capital investment.

APPENDIX H THE GREENHOUSE EFFECT - HOW SHADING ENABLES LARGE AREAS OF GLASS TO BE USED IN BUILDINGS

As mentioned in Appendix A when solar gain passes through glass, it hits objects in the room and transfers from short wave radiation, which is mostly light, to long wave radiation which is mostly heat. As glass is opaque to long wave radiation, it does not allow it to pass through and so it becomes trapped in the room. This is known as the greenhouse effect.

Solar glass has been developed to reduce this effect but there are limitations on the ability of glass alone to reduce solar gain. Even the most effective glazing combination currently available cannot improve on a g-value of 0.22 (that is 78% heat rejection) and to achieve that figure there has to be a compromise with a higher U-value. For large areas of glazing a g-value of 0.22 will not be sufficient for thermal comfort without additional measures such as mechanical cooling to reduce the heat gain.

External shading stops the solar gain before it reaches the glass and can improve the g-value of 0.22 by 10 fold to a g_{tot} of just 0.02. Admittedly this is with the shading in a closed position and so would be suitable for a low energy domestic property. For an occupied or working area shading that allows outward vision is more beneficial so shading with a g_{tot} nearer to 0.10 should be considered. This is still an improvement of more than double in most situations will reduce the gain to adequate comfort levels.

It will also avoid the need for high specification glazing, enabling the façade to be configured more cost effectively for the lowest U-value.

Dynamic shading is very effective and its use will allow buildings with large glazed areas to be built and still meet building regulations.

The Shard in central London is an excellent example of where glazing and shading combined allow a fully glazed building to pass building regulations and be comfortable to live and work in. The double skin façade of this tallest building in Europe had a g-value of glazing of 0.68 (32% heat rejection). The use of fully automated blinds improve this performance to a g_{tot} figure of 0.12 (88% heat rejection).

APPENDIX I COMPARISON OF ENERGY SAVING TECHNOLOGIES FOR DOMESTIC BUILDINGS

There are many different technologies available to improve energy efficiency of domestic buildings resulting in reduction in energy bills. This appendix demonstrates different options that reduce the amount of heating a home requires and compares energy saving rates of different domestic technologies.

Technology	Saving/year (£)	Installed (£)	Payback (years)	CO_2 savings/year (kg)
Roller blind	96	500	5	478
Cavity wall insulation	140	500	4	560
Loft Insulation 0-270mm	180	300	2	730
Loft Insulation 100-270mm	25	300	12	110
Single glazing to double glazing	170	2500	15	680

Table 5. *Energy savings of home improvements - Source: BBSA and Energy Saving Trust*

Technologies in this category include: blinds and shutters, cavity wall insulation, loft insulation and double glazing. All of these will improve the thermal performance of a building by reducing the amount of heat loss through the building elements such as walls, roofs and windows. The Energy Saving Trust estimates that 18% of all heat loss is through windows, 33% through walls and 26% through the roof.

The table above compares the indicative installed cost, annual savings, payback period and CO_2 savings associated with a range of domestic heat loss reducing products. The values are all based on a three bedroom semi-detached house with single glazing.

It is clear that double glazing is the most expensive of the products considered and therefore has the longest payback period. Loft insulation (0 - 270mm) shows the shortest payback period, highest annual saving and has a low initial cost.

Installed on single glazed windows the roller blinds have a payback time of 5 years and can save around £100 per year on heating bills which makes them competitive with other domestic energy saving products in terms of recouping investment.

Blinds installed on single glazed windows are competitive with the other domestic energy saving products available.

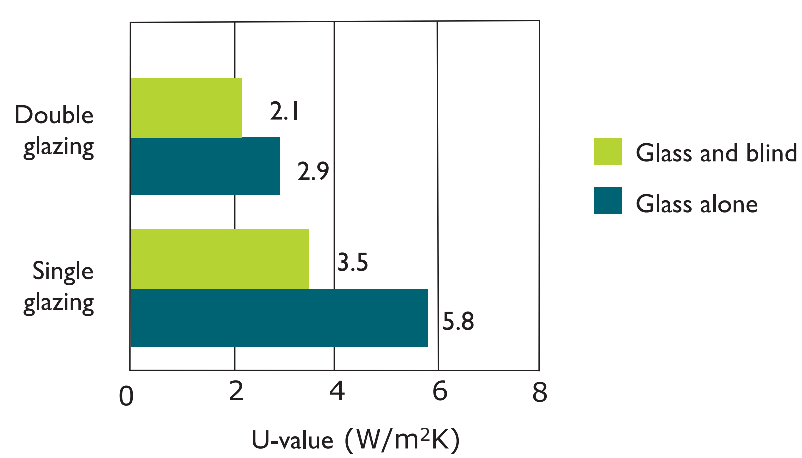


Figure 14. *Glazing and shading - better insulation*

The graph in *Figure 14* shows that glazing with blinds has a lower U-value than the window without blinds for both single and double glazing. As the U-value is the measure that represents the heat losses through materials (for instance windows) the lower the value, the lower the heat loss. Therefore, in all cases blinds and shutters always improve the insulation properties of glazing.

APPENDIX J SUMMER SOLAR GAIN

Traditionally air conditioning has not been used in domestic buildings that tend to have smaller glazed areas than commercial properties and there has been more tolerance of excessive heat. The development of large glazed areas in the conservatory market has created areas where the heat gains are intolerable without shading with blinds. As the use of fans and, in particular, cooling systems is the least energy efficient option - as with commercial buildings, the use of shading with blinds and shutters should be the first consideration.

In addition, the regulatory requirement for energy efficiency and nearly zero carbon emission buildings has resulted in a drive for more highly insulated and airtight dwellings, in both new build and retrofit.

These are often designed with large areas of glazing, mechanical ventilation and/or communal heating systems and have the potential to overheat throughout the year, not just in the summer months.

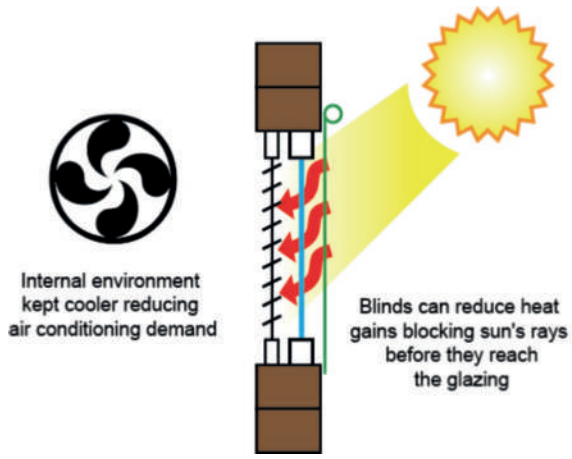


Figure 15. *Using external shading to reduce heat gain*

In rural and suburban locations it may be easier to utilise natural ventilation (e.g. window opening) to help cool dwellings, but in urban and deep-urban locations it is often not possible due to excessive noise, pollution and security concerns. Overheating may become an issue where cross ventilation is not possible in airtight houses with little or no solar shading.

As mentioned before in this guide for effective energy savings, blinds and shutters should be considered at the building design stage. If shading is not considered when the area and type of glazing are decided, it is likely that the building will require larger than necessary heating and cooling systems.

APPENDIX K TYPES OF AUTOMATED CONTROL

The benefits of a solar shading system in terms of energy savings, the best use of daylight, improved indoor conditions and visual comfort can only be fully optimised if the system is automatically controlled. It will respond to the climatic conditions even when the occupants are absent throughout the day and night, not requiring any attention. Automation is needed to maximise the energy saving benefits.

Automated solar shading can operate on timers and with light and heat sensors that ensure the shading is operating in the most energy efficient way.

There are different control systems to suit a single blind, groups of blinds or whole building management systems. Yet even basic "plug and play" single blind systems have energy-smart functions. Sensors such as those measuring wind, light levels indoor or outdoor temperature or the use of timer controls will ensure that the shading is in place to help control heat loss and heat gain.

The development of large glazed areas in the conservatory market has created areas where the heat gains are intolerable without shading with blinds.

"Overheating may become an issue where cross ventilation is not achievable in lightweight, airtight houses with little or no solar shading"

NHBC Foundation

For multiple windows there are two solutions. Either a stand-alone basic system can be expanded to enable multiple controls or a system that links into the building management controls can be used. All of the systems require sensors that will track the actual climatic conditions around the building. The most frequently used sensors are wind, outdoor temperature, rain, indoor temperature and occupancy detectors.

Stand-alone systems with a variety of control functions are cost effective for domestic and smaller commercial installations but only allow simple controls and interfaces.

All of the systems require sensors that will track the actual climatic conditions. The most frequently used sensors are wind, outdoor temperature, rain, indoor temperature and occupancy detector.

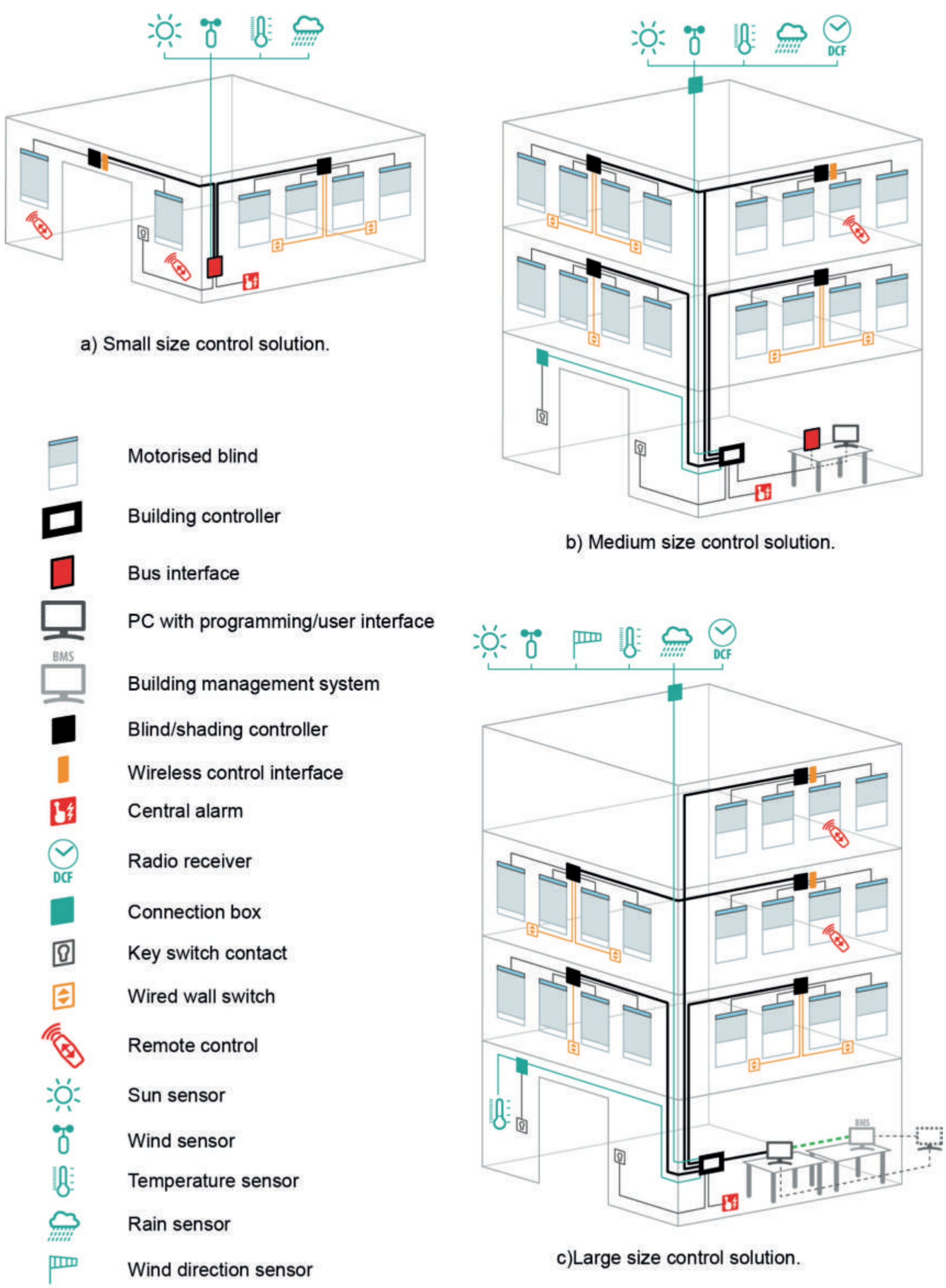


Figure 16. *Schematic showing automated systems controls*

In order to maximise energy efficiency a holistic approach to control is essential by linking all of the building services - lighting, heating, cooling and shading (*Figure 16*). That is why home automation for domestic dwellings and Building Management System (BMS) for commercial properties that function with a "bus" system are becoming increasingly popular.

A carefully designed automatic control will allow the management of glare, personal settings, energy use as well as the interaction between solar shading, lighting, heating, ventilation and cooling.

A bus system is a network where all devices are attached directly to a line and all signals pass through all of the devices. Each device has a unique identity and can recognise the signals that are intended for it. The market offers a range of solutions but probably the most common are KNX and LON. All of these are based on an "open" data transfer language that is non-proprietary and allows different suppliers to connect to the bus.

This allows the user to create a control strategy prioritising their particular requirements. The possibilities are almost limitless but early discussion between the system designer and the supplier of the shading system is essential so that the full benefits can be achieved. Computer technology and advanced software of today offer vast possibilities to interconnect systems in a building, however that does not necessarily mean better energy efficiency or user satisfaction. It is easy to make the daily use of the system more complicated than needed.

Before designing a system it is recommended that some basic questions are considered:

1) What functions do we really need?
2) Why do we need them?
3) How would we use them?
4) Will they meet the needs of the user?
5) Will they assist with building regulation compliance?

Keep it simple when designing automated systems

A building services engineer and solar shading specialist will be necessary to plan and deliver the correct system.

APPENDIX L PRODUCTIVITY AND INTERNAL ENVIRONMENT

A good quality internal environment typically has a positive effect on productivity. It is widely acknowledged that the visual and thermal comfort of an internal environment will affect people's relative comfort and consequently their work. This can be true in schools, offices, factories and any other building where the productivity can be affected by an uncomfortable working environment. Research from the University of California in Los Angeles found that employees of companies voluntarily adopting environmental practices and standards are 16% more productive than the average worker.

Thermal Comfort

Working in a comfortable temperature can have a significant impact on employee productivity. However, building designers often do not consider thermal comfort as a priority and believe that it is more important to reduce construction and operating costs. But when the whole lifetime of a building is assessed, it is clear that employee's salaries and associated costs are significantly higher than building operating costs. See *Figure 17*.

The flow chart below shows that salary and employee costs typically account for around 80% of the total operating cost of a building. Increases in productivity will lead to increased efficiency and also reduced absenteeism.

If productivity is increased by 1% in an organisation, this equates to 0.8% of the total operating expense. In the bigger picture this 0.8% is more than the total cost of energy for the organisation which is typically between 0.3 - 0.6% of the total costs.

Relatively minor reductions in productivity can result in a large increase in costs.

This shows on the other hand that even relatively minor decreases in productivity have a large economic impact and provides a valid case for organisations to invest in improving the quality of their indoor environments.

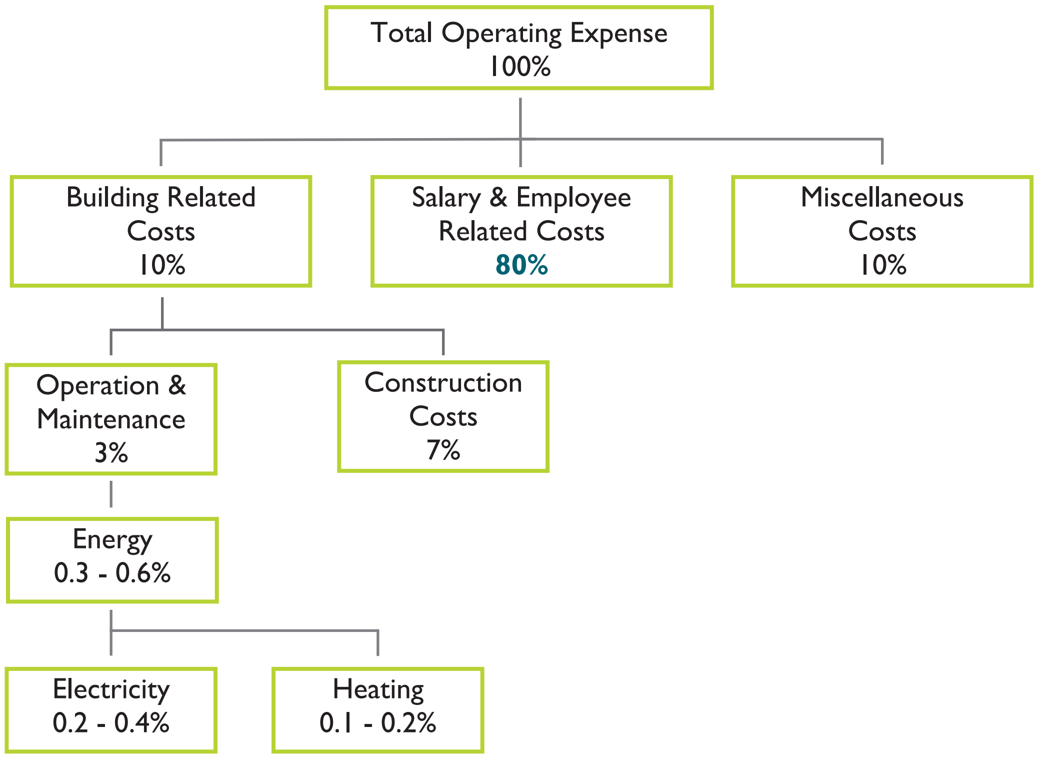


Figure 17. *Typical operating cost of an organisation*

Issues associated with incorrect indoor thermal conditions include:

- High indoor temperatures - increasing the prevalence of sick building syndrome, symptoms of which include sensory irritations of eyes, nose and throat; neurotoxic and general health problems.
- High temperatures in classrooms - harmful to performance of school work. In a controlled Danish study the performance of school tasks was found to be better at 20ºC than 25ºC and declines as the temperature rises.
- Lower temperatures - reduced the dexterity of hands and may affect the performance of manual tasks.

Figure 18 shows the optimum temperature range for productivity for office based work. It shows that the ideal range is between 20-24ºC. Above and below these temperatures there is a sharp drop in productivity as people become uncomfortably too hot or too cold and find it difficult to concentrate.

Productivity drops by more than 1% for every degree that the temperature is outside of the optimum range. The impact of this fall in productivity will be significant to the organisation. The cost of an effective solar shading system preventing such drops through temperature variation is typically a fraction of the lost productivity cost.

This data offers a different perspective on the seemingly high capital cost of external shading for building control coupled with internal shading for user control. However, the capital payback is quick and the ongoing running costs for cooling will typically be significantly reduced. Where internal shading is the only option the payback on the additional investment in the most effective shading solution instead of a basic option is quickly recovered. The added value of a comfortable workforce is a welcome bonus.

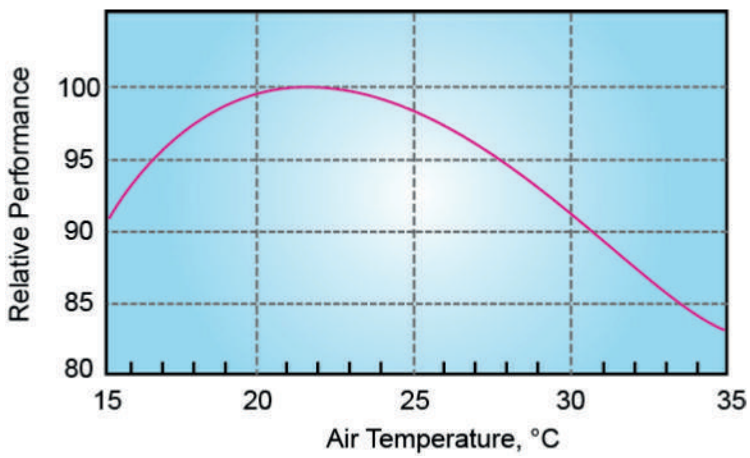


Figure 18. Optimum temperature range for productivity level

Visual Comfort

People prefer daylight to electric lighting in buildings. Visual contact with the outside world positively affects our state of mind and it is proven that it can increase our productivity as we feel happier. Maximising the use of daylight without glare and providing daylight responsive lighting control increased productivity in a workplace by 3.75%.

Adjustable shading that reflects and directs natural light will improve visual comfort and also have a significant effect on reducing lighting costs. In addition, many studies have demonstrated that solar-protective glass alone could not guarantee glare protection since it cannot reduce the luminance of the sky view or bright objects to sufficiently low levels.

"Windows shall be fitted with a suitable system of adjustable covering to attenuate the daylight that falls on the workstation."

The Health & Safety (Display Screen Equipment Regulations) 1992.

APPENDIX M   DOUBLE SKIN FAÇADES (DSF)

A double skin façade system consists of:

- an external glazing
- a ventilated cavity
- internal glazing

There are two types:

Naturally ventilated façades - composed of an external single layer of glass and an internal double glazing unit. The cavity between the two skins is naturally ventilated with outdoor air, which comes up through the base of the glazing and returns to the outside at the top.

Mechanically ventilated façades - composed of an external insulated glazing unit and an internal single layer of glass. The cavity between the two skins is ventilated with return room air which is extracted from the room at the base of the glazing and returned to the air-handling unit at the top.

A double skin system consists of an external glazing, a ventilated cavity and an internal glazing. Overheating and excessive light transmittance can be overcome by shaded Double Skin Façades.

Blinds in Double Skin Façades do not interrupt the external appearance of the clean glazing lines and also remove any concerns regarding weather protection concerns.

Blinds and shutters are important enablers of daylight as they regulate the flow of both direct solar radiation and diffuse radiation.

What are the issues with a standard glazed façade?

- Excessive heating demand during the winter
- Overheating of the building and/or high cooling requirements during the summer
- A difference in surface temperature of external walls resulting in discomfort for the occupant placed near the façade i.e. draughts and asymmetric radiation

All of these main issues can be overcome with a shaded DSF.

What is the importance of shading in a Double Skin Façade?

Glass is a static element in a building. It is static against the dynamics of the weather and static in the face of dynamic building loading and use, as the number and the needs of the people inside will change constantly.

Shading is an established technology that is not normally associated with energy efficiency and its energy saving benefits are generally not fully appreciated. g_{tot} figures for shading between the façade are improved by the natural ventilation within the façade. This enables fully glazed areas that would not otherwise be achievable within the requirements of the regulations with systems typically rejecting better than 88% of the solar gain.

The proof of the shading in a Double Skin Façade

The REHVA Guidebook *How to integrate solar shading in sustainable buildings* shows that when the correct ventilation strategy is used, a blind placed between the outer and inner glazing of a DSF will have a similar effect in solar energy reduction as an external blind. This resolves the issue of interruption of the external appearance of the clean glazing lines and removes any weather protection concerns enabling the shading systems to be fully functional throughout the year. The graph in *Figure 19* shows that a DSF with integral blinds has almost the same net cooling demand as a standard façade with an external shading system. It also illustrates that a traditional façade with a standard internal blind typically has a much higher cooling demand.

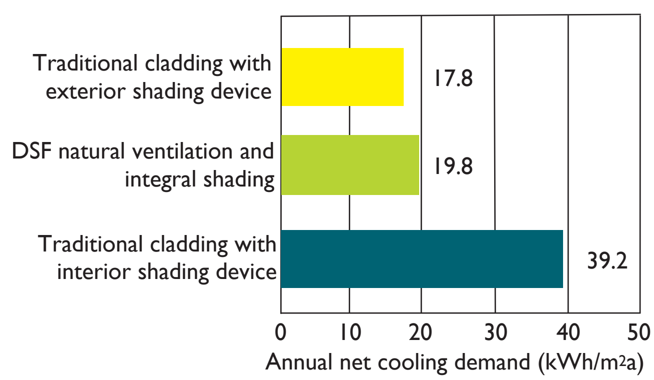


Figure 19. Cooling demands with shading

In summary, some of the benefits of integrating blinds into DSF are:

- Allows large full height glazing to be used
- Reduces energy consumption by helping to control heat gain in the summer and heat loss in the winter
- Turns a static element into a dynamic one
- Improves the internal environment leading to higher productivity
- Allows for natural light to be harvested but glare to be controlled
- Improves acoustic properties
- Assists with building regulation compliance
- Assists with noise control

APPENDIX N LIGHT AND GLARE CONTROL

Solar control management by blinds and shutters can harvest natural light and help reduce the use of electric lighting. In a typical office building 30-40% of electric energy is spent on lighting so this represents one of the biggest uses of electricity in commercial buildings.

Blinds and shutters are important devices enabling us to control the levels of daylight. They regulate the flow of both solar radiation and diffuse radiation. The illuminance, or what is most commonly called brightness, is measured in lux. Illuminance levels by direct sunlight in summer are as high as 100,000 lux. For a general office environment (tasks such as computer work, writing, drawing) a recommended lux level is 500. Direct sunlight can also cause glare. So attenuating and diffusing the incoming light reduces the chances of glare and brings light deeper into the space. This function is performed especially well by internal blinds.

Illuminance can be measured by a Luxometer which quantifies only Visible Light (T_v) only. They are typically deployed within the room/building or more frequently several are deployed within the same room to assess different light levels in the various parts of the space.

Visible Light Transmittance (T_{vis}) and Openness Coefficient (C_O) are among the important factors that impact on the quantity of light. The Visible Light Transmittance determines the total amount of brightness and glare that will pass through the fabric of the blind. The Openness Coefficient is the ratio between the area of opening in the fabric and the total area of the fabric so, put simply, this is related to the number and the size of the holes in the fabric. Therefore the Openness Coefficient is an indicator of the amount of visible light transmittance and of the degree of visibility through a fabric. Both factors are typically expressed as a percentage.

When a blind has a lower openness coefficient there is typically less visible light transmittance and therefore glare is reduced when the blind is closed. As the openness value increases so does the possibility of glare, however daylight levels and through vision are increased. But reducing the openness coefficient of a fabric does not necessarily mean that the light entering through the fabric is the level required for all occupants.

Colour is another factor to consider when selecting for light control. Lighter colours are more reflective with lower heat gains and higher visual light transmittance. They illuminate the interior but surface brightness can be too much for visual comfort. Darker colours provide a better outside view (with screen fabrics) and glare free environments making them more ideal for viewing computer and TV screens but absorb more light and thus heat.

It is often assumed that light can be separated from heat in the context of solar radiation. This creates the illusion that you can have light without heat. This is incorrect, light is latent heat. Visible light (shortwave) that enters the room and is neither reflected out nor transmitted through will be absorbed and then re-radiated as (longwave) heat.

As well as controlling light levels, glare and heat there is another important consideration and that is the quality of the light. Solar shading combined with clear glazing can provide the full spectrum of visible daylight and maintain a high Colour Rendering Index (CRI). CRI measures how faithfully colours appear in natural light and artificial light.

Tinted glass designed to reduce g values affects CRI and using clear glass with dynamic shading will reduce g_{tot} and maintain the quality of light at the same time.

Blinds and shutters will not only improve the quality of an indoor environment and therefore productivity but they will also reduce the energy costs of an organisation through reduced heating and cooling requirement and reduced use of electric lighting.

"When designing for maximum daylight (and views), designers must evaluate and balance a number of environmental factors, including heat gain and loss, glare control, visual quality, and variations in daylight availability in different seasons and climates. Appropriate interior or exterior shading devices to control glare and reduce solar gain will help provide better visual comfort and reduce the need for additional cooling."

World Green Building Council

4.0 STANDARDS

- EN 410 - Glass in buildings. Determination of luminous and solar characteristics of glazing.
- EN 13120 - Internal blinds. Performance requirements including safety.
- EN 13125 - Shutters and blinds. Additional thermal resistance - Allocation of a class of air permeability to a product.
- EN 13363-1 - Solar protection devices combined with glazing. Calculation of solar and light transmittance. Simplified method.
- EN 13363-2 - Solar protection devices combined with glazing. Calculation of total solar energy transmittance and light transmittance. Detailed calculation method.
- EN 13561 - External blinds and awnings. Performance requirements including safety.
- EN 13659 - Shutters and external venetian blinds. Performance requirements including safety.
- EN 14500 - Blinds and shutters. Thermal and visual comfort - Test and calculation methods
- EN 14501 - Blinds and shutters. Thermal and visual comfort - Performance characteristics and classification

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6.0 GLOSSARY

Air permeability
The unintended leakage of air through gaps and crack in the external envelope of a building.

Conduction
The transfer of heat between substances that are in direct contact with each other.

Convection
The transfer of the heat in fluid or air, caused by the movement of the heated air or fluid itself. In a building warm air rises and cold air settles to create a convection loop and is termed free convection.

g-value
The measure of the total energy passing through the glazing when exposed to solar radiation.

g_{tot}
The measure of the total energy transmittance of the glazing in combination with the blind or other shading when exposed to solar radiation. Also known as the Solar Factor.

Glare
The condition of vision in which there is discomfort or a reduction in the ability to see significant objects, due to an unsuitable distribution of or range of luminance.

Light Transmittance (Tv)
The proportion of visible light transmitted through the shading material.

Lux
The measure of illuminance on a surface (1 lux = 1 lumen/m^2).

Nanometers (nm)
A unit of one billionth of a metre, which is used to measure the wavelength of the light emitted by the sun.

Natural Ventilation
The supply of adequate fresh air to space within a home through windows, trickle vents etc. Removal of air may take place by natural or mechanical means.

Openness Coefficient
The ratio between the area of openings in the fabric/material and its total area.

Q_i
It results from heat transfer by convection and longwave infra-red radiation of that part of the incident solar radiation which has been absorbed by the glazing. It is the absorbed heat that will not go back through the glass.

Radiation
The emission or transfer of energy in the form of electromagnetic waves or particles transferring energy from a warm body to a cold body without heating the air in between.

Standard Assessment Procedure (SAP)
A software that calculates the energy performance of dwellings. It has been developed by the Building Research Establishment (BRE) for the Department of Energy and Climate Chance (DECC). SAP assess the cost per year to provide a home with heating, lighting and hot water and presents the cost per square metre of floor area.

Simplified Building Energy Model (SBEM)
A software that calculates the energy performance of buildings that are not dwellings. It was developed by the Building Research Establishment (BRE) for the Department of Communities and Local Government (DCLG). SBEM estimates the amount of CO_2 emissions produced by the building per square metre of floor rather than the cost.

Solar Gain
The solar radiation that enters the building through glazing hits objects and is converted to heat. This reduces the need to artificially heat the space.

Solar Reflectance (Rs)
The measure of the fraction of solar energy reflected by the fabric. A high value means that the fabric performs well at reflecting solar energy.

Solar Transmittance (Ts)
The measure of the fraction of the solar energy transmitted through the fabric. A low value means that the fabric performs well at reducing solar energy transmission.

U-value
A measure of thermal conductance which is the ability of a material to transfer heat.

7.0 ACRONYMS

BBSA
British Blind and Shutter Association

BRE
Building Research Establishment

CIBSE
Chartered Institution of Building Services Engineers

CRI
Colour Rendering Index

DCLG
Department for Communities and Local Government

DECC
Department of Energy & Climate Change

DSF
Double Skin Façade

EPBD
Energy Performance of Buildings Directive

EPI
Energy Performance Indicator

ESBO
Early Stage Building Optimisation

ESSDA
European Solar Shading Database

ES-SO
European Solar Shading Organisation

HVAC
Heating Ventilation and Air Conditioning

ITRS
Industrieverband Technische Textilien-Rollladen-Sonnenschutz

LON
Local Operating Network

NBS
National Building Specification

NEF
National Energy Foundation

NHBC
National House Building Council

nZEB
Nearly Zero Energy Buildings

REHVA
Federation of European Heating, Ventilation and Air-conditioning Associations

SAP
Standard Assessment Procedure

SBEM
Simplified Building Energy Model

8.0 CREDITS

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- Hallmark Blinds
- Louvolite
- Luxaflex
- Pentel Contracts Ltd
- James Robertshaw & Son (1954)
- Torbay Blinds

Notes

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