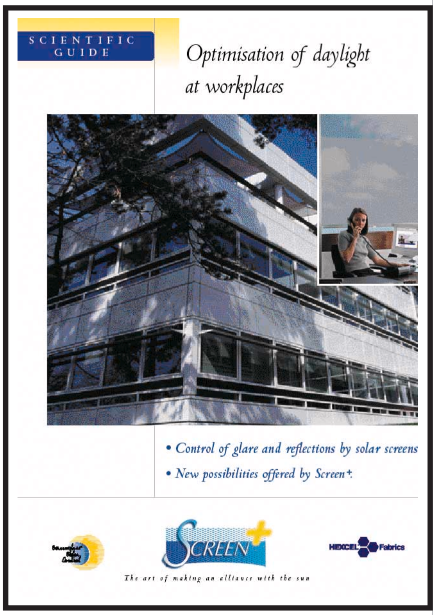
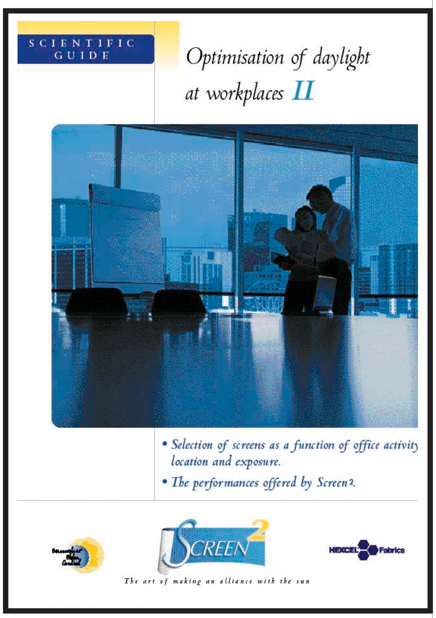
SCIENTIFIC GUIDE

Optimisation of daylight at workplaces



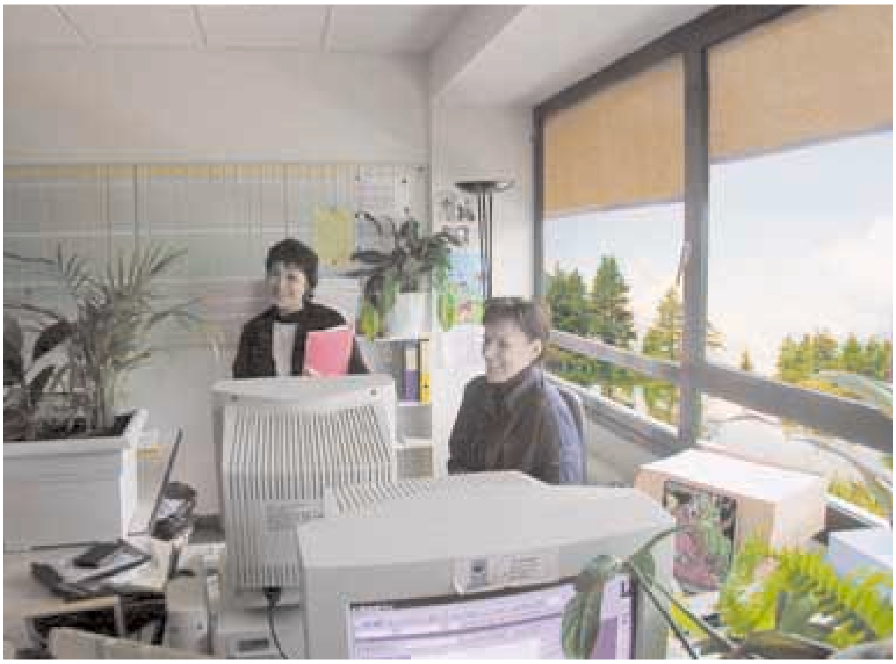


All our scientific guides are made by the Lighting Research Activities at the National Engineering school of State Publics Works (ENTPE), Vaulx-en-velin, Lyon, France.

HEXCEL

Natural light

The best light for human well-being



◁ *Workstations near windows allow, if desired by the occupants, lighting levels far higher than those obtained by artificial lighting. It has been proven that lighting is an important factor in health and psychological balance.*

Nothing seems more natural than to associate light with what we see. In fact, the light that passes through the eye to reach the retina does not only contribute to our vision of what surrounds us, there is evidence that it also affects our moods, our behaviour and our health.

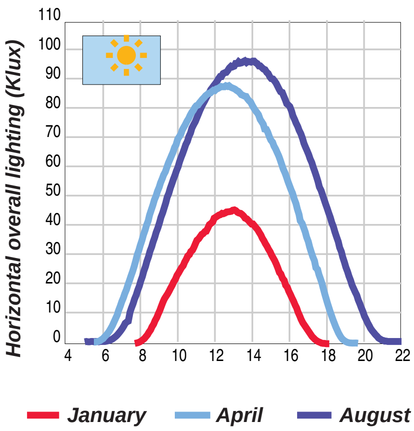
More accurately, this evidence shows that high levels of lighting (more than 1,500 lux) are needed to trigger a certain number of biological functions. In particular, it affects the rate of melatonine, a hormone in the blood that influences sleep and waking. Without light, we are exposed to increased risks of loss of sleep at night and somnolence during the day.

How can such lighting levels be obtained? Outside, of course, since levels vary from a few thousand lux in overcast weather to 100,000 lux in clear weather. This is also true inside, close to windows, for a considerable number of hours (we have 4,000 hours of natural light per year of which half at very high rates).

Health can be affected in other ways by the quantities of light we receive. This can be seen during autumn, when the days quickly become shorter. With many individuals, especially in Nordic countries, a large number of cases of depression are recorded known as "seasonal emotional disorders".

One method of treating this consists of exposing those affected by these depressions to high lighting levels (several thousand lux). Even without going to these extreme lengths, many people are affected by decreases in the intensity and duration of natural light.

Therefore there are good medical reasons for placing workstations near windows. However, the negative effects of this, such as glare and overheating due to the sun, need to be managed.



◁ *The length of daytime and external lighting levels vary considerably according to season. This results in the need to attenuate lighting to differing degrees as a function of the orientation of building façades.*

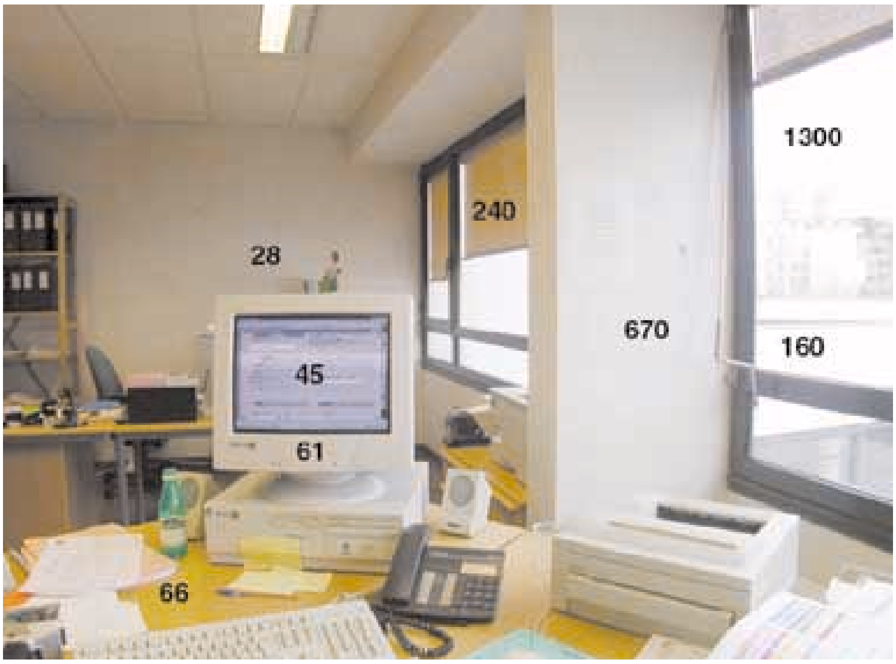
Taming natural light
How to provide the best working conditions

For the occupant, glare is influenced by the luminance of what can be seen from the window: whether this be the sun itself, the sky, or the façades of buildings opposite lighted by the sun. Visual comfort is improved by attempting to reduce the difference between the average luminance of everything seen through the window and the luminance of what is seen by the occupants: computer screen, sheet of paper, desk surface, walls, etc.

Although certain occupants prefer brighter environments than others, there is a tendency to adjust screens in order to reduce luminance from the window by a factor of ten for visual tasks, and by a factor of 5 if the work requires high concentration.

The fact that the luminance of a sheet of paper or computer screen is in the region of 100 cd/m² means that the occupants expect windows to provide a luminance less than 1,000 cd/m² for normal office work.

Thus, the ideal shading system should permit sufficient natural light (for health) without ever risking situations of glare. The table opposite shows the maximum transmission factors required to attenuate the glare generated by external elements such as the sky, lighted facades and the sun. Screens with transmission factors lower than 10% are sufficient to avoid glare due to the sky, and values in the region of 1 to 2% are needed for efficient protection against the sun. These values are obtained easily when the rays strike the window at a certain angle.



∆ *Typical luminances of objects seen by office personnel from their workstations. (units: cd/m²)*

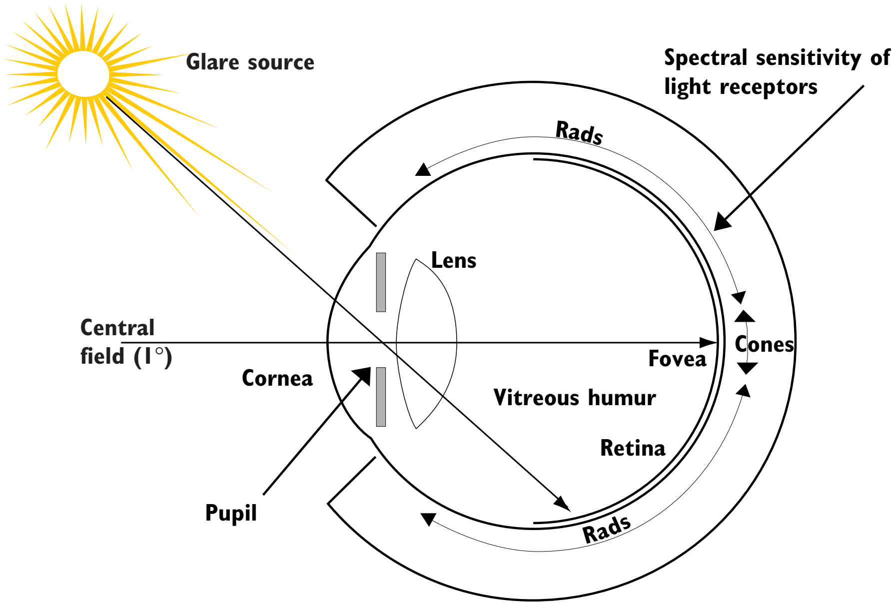
Object seen from the window	Luminance of object	Necessary light transmission factor
White cumulus reflecting the sun	10 000 cd/m²	T = 10 %
Hazy summer sky	10 000 cd/m²	T = 10 %
Intermediate hazy sky	5 000 cd/m²	T = 20 %
Concrete façade lighted by the sun	8 000 cd/m²	T = 12 %
Sun at the end of the day	50 000 cd/m²	T = 2 %
Reflection of the sun on a glass facade	100 000 cd/m²	T = 1 %
Full sun	1 million cd/m²	T = 0.1 %

∆ *Screens with transmission factors lower than 10% are sufficient to avoid glare from the sky and values in the region of 1 or 2% are needed for efficient protection against the sun. The screens have no trouble in dealing with rays striking the window at certain angles.*

∆ *In the case where the sun enters the field of vision directly, protection is easily obtained by moving one's working position. In addition, the solar rays inside the office are attenuated efficiently by a screen with transmission lower than 10%.*

Glare phenomena

an ocular fatigue



△ Optical behaviour of the human eye.
Increasing or decreasing the size of the pupil allows the eye to adjust the illuminance (lux) on the centre of the retina to provide the local receptors with an appropriate amount of light to detect the details of the scene and the colour information. The glare sources located in the field of view bring additional light to the retina which disturbs the reflex mechanism of the eye.

To understand glare phenomena, it is useful to thoroughly understand how the human eye behaves. The scene we observe is projected upside-down on our retinas. The light receptors, of which the retina consists, then transmit a signal to the optic nerve and onwards to the brain for analysis. To operate effectively, these photoreceptors need an optimal range of illuminance (lux), a quantity which can be adjusted by the pupil. The diameter of the pupil's aperture is continuously adjusted in response to the perceived brightness, or more precisely, the brightness of the area located in the centre of the direction of vision.

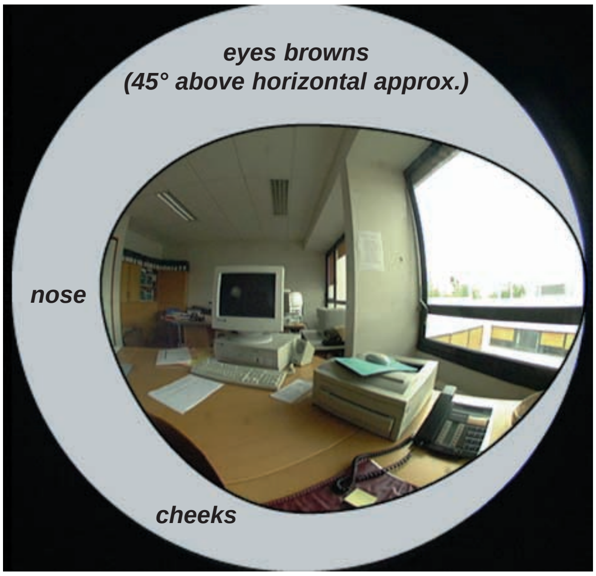
When a parasitic source of light is present in the field of vision, its light is received by some of the retina's photoreceptors, leading to a reflex reduction of the diameter of the pupil thus reducing the amount of light coming from the centre of the direction of vision.

To reduce discomfort, we squint our eyes or try to look in directions away from the source of glare. If the source of glare is maintained for long periods, ocular fatigue can result due to the continuous increasing and decreasing of the diameter of the pupil.

◁ The brightness of a window is the major source of glare at the workplace

Glare phenomena

Presence of glare sources in the field of vision



∆ The scene on the previous page projected on the retina of the right eye. It can be observed that the field of vision is reduced by the eyebrows, the cheeks and the nose (angular height approx. 45°).

∆ The same projection, but with binocular vision. Superimposition of the vision of each eye allows the obstruction due to the nose to be suppressed. Note that areas of the field of vision located higher than 60° above the horizontal are not visible, and that glare sources located above the angle of 60° are at the borders of the field of vision.

∇ Glare due to a source of light decreases as it moves further away from the centre of view. More specifically, light coming from above the occupants and from the upper part of the windows tends to have a small contribution to the sensation of glare.

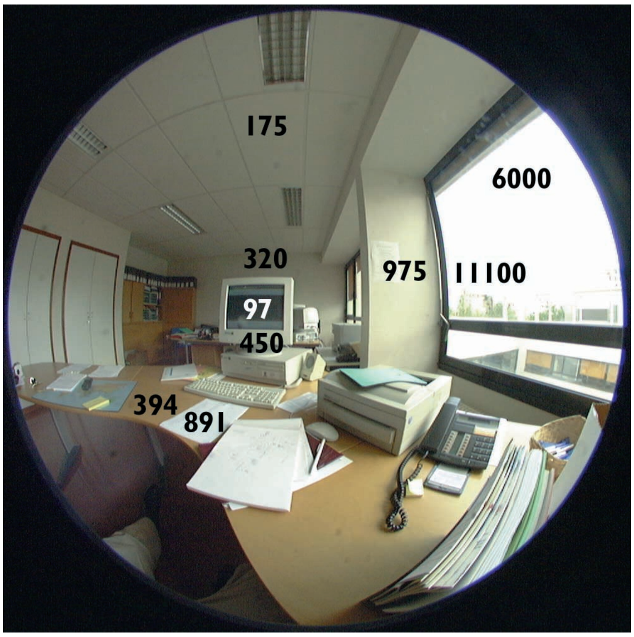
A: High glare zone

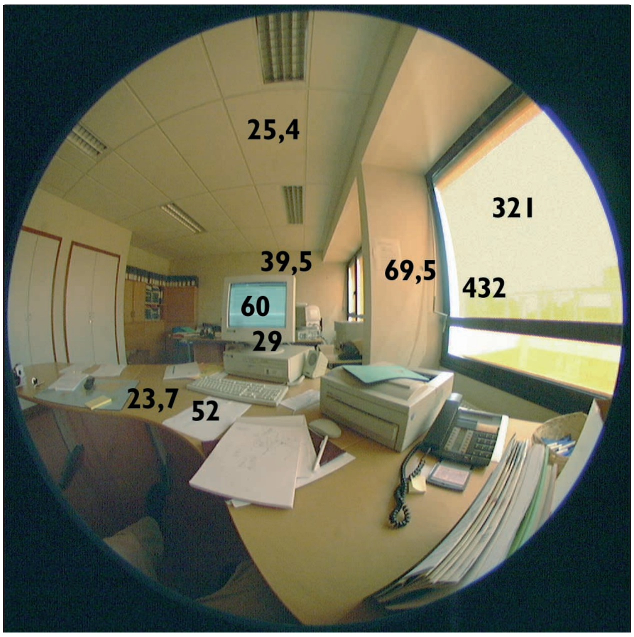
B: Moderate glare zone

C: Glare-free zone (glare source is beyond the visual field).

Light reflections on VDU screen

Glare reduction with solar screens





△ ◁ Typical luminance values measured at a work place. A solar screen allows the luminance of the window to be reduced. Values below 500 cd/m² can be reached. Such a value does not generate any visual disturbance for the human eye.

▽ The brightness of a surface can be measured in terms of its luminance, (expressed in Candelas per square metre), using a luminance meter.

The pupil's size varies according to the luminance of the zone located in the centre of the field of vision, a very limited zone situated in a cone of only 1°. When, for example, we work at a Video Display Unit (VDU) screen, our eyes cover an area of about 15°. Most ergonomic standards recommend that the luminance levels of areas located in the central field of vision (30° cone) be no more than three times the luminance of the visual task, and no less than one third of this value. Thus, in the case of a screen with an average luminance of 50 cd/m², luminance levels in the 30° cone should range between 16 and 150 cd/m².

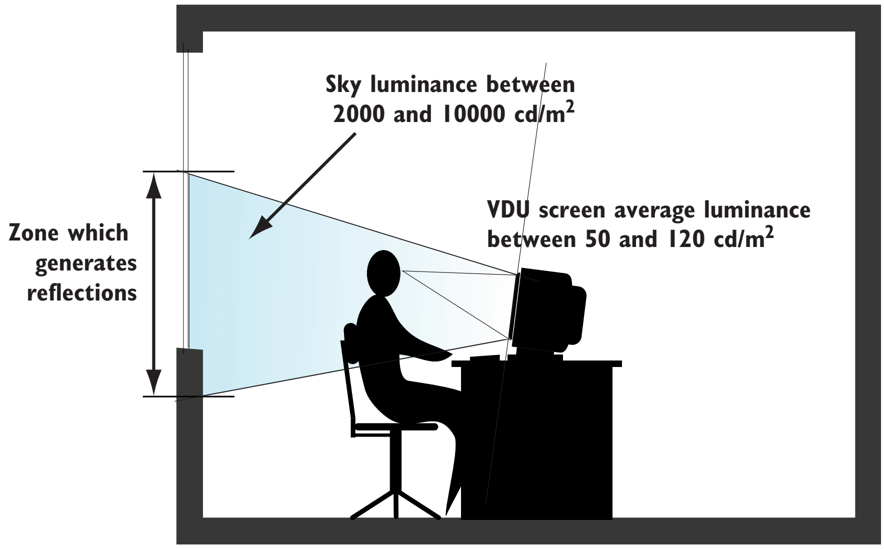
These same standards suggest that the luminance levels within a cone of 90° should be within 0.1 and 10 times the luminances of the visual task. In the case above, this would mean between 5 and 500 cd/m².

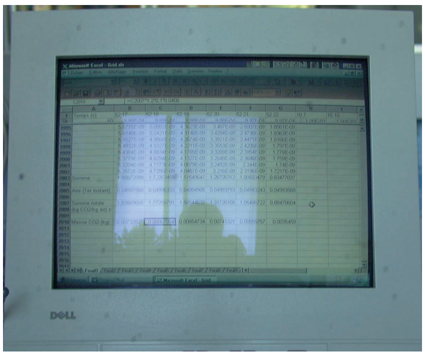
Light reflections on VDU screen
External luminance reduction

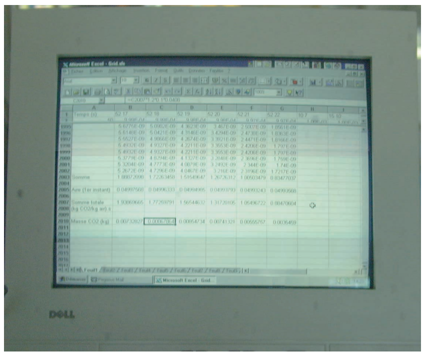
In practice, for effective protection against glare when working at a VDU, the solar protection should be able to reduce external luminance to values below 500 cd/m².

The visual disturbance associated with reflections on VDU screens is another aspect of the problem. The behaviour of the eye is not a concern here. The problem arises from the difficulty we have in reading information of a screen due to reflections on it. In essence, the zone of light reflection provides luminance in the same range as, or higher than those of the VDU screen which makes reading of information on the VDU difficult, or even impossible.

Even if the reflectance of the VDU screen is low (around 10%), any source of light with a luminance higher than 500 cd/m² will generate a disturbance, since it will create reflections with luminance levels above 50 cd/m². Therefore, any source of light with a luminance higher than 500 cd/m² should either be attenuated (with a shading device in case of a window) or, as in the location of luminaires, placed in an area from which it will not generate any reflections on VDUs.







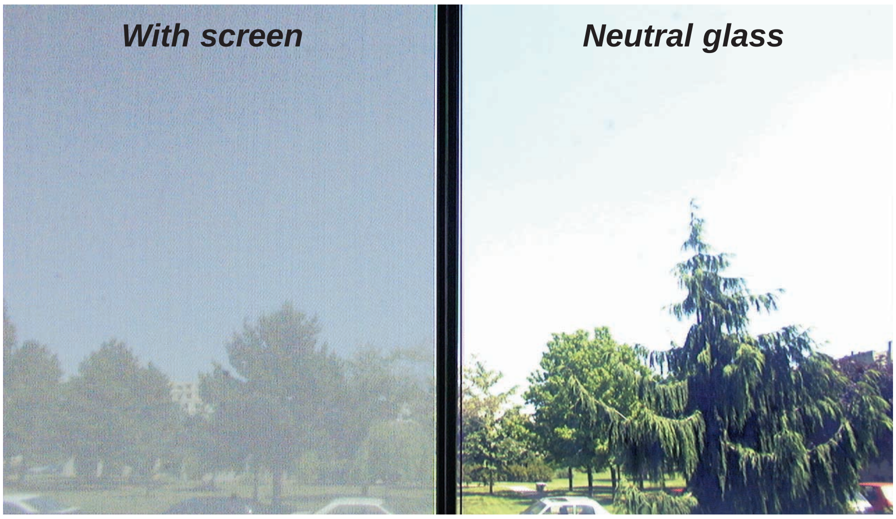
∆ *An exterior screen with a transmission of 5 to 10% allows reflections from the sky vault, and the associated disturbance, to be totally suppressed.*

A few words on lighting quantities which may be measured.
Illuminance (lux) characterises the amount of light incident on a surface: 400 lux on a desk, 1000 lux in a supermarket, 10,000 lux outdoors under overcast sky conditions, 80,000 lux for sunny conditions, for example.

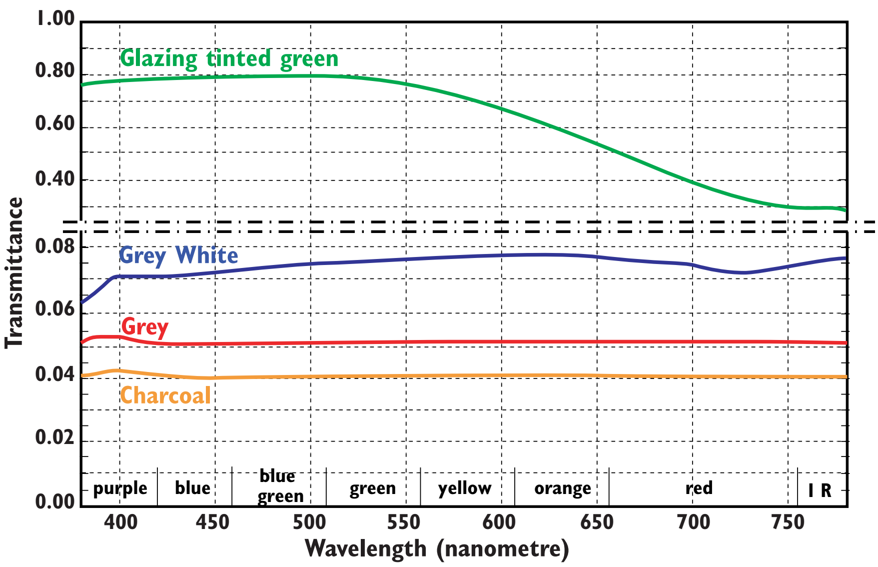
Luminance (candela per m²: cd/m²) characterises the brightness of a surface when we look at it. It is a measure of light coming from the surface. Example are: indoor surfaces 5 to 100 cd/m²; a computer screen 50 to 120 cd/m², a fluorescent tube 10,000 cd/m².

Search for neutral colour

∆ *Colouring of the outdoor environment with tinted glass (blue and bronze). A blue tint tends to filter the haze of the sky; a bronze colour increases the brightness of the surroundings.*



∆ *Attenuation, without colouring, using an external screen.*



Colouring of the outdoor environment with tinted glass (blue and bronze). A blue tint tends to filter the haze of the sky; a bronze colour increases the brightness of the surroundings.

Sometimes, tinted glazing is used to offer a constant reduction of sky brightness. Such solutions are often chosen in the case of large window areas, large meaning larger than the minimum reasonable window size which would be used in the case of clear glass.
This reduction in the transmission of light is often coloured: glass may be treated throughout its volume, and on its surfaces, to change the patterns of the transmission of radiation in the Ultra Violet, the visible and the Infra-Red domain. The result may be a distortion of the colours of the outdoor view that some observers may find objectionable. As most tinted glazing offer transmittances between 25% and 60%, this type of glazing cannot provide the necessary reduction of incoming light, which requires a transmittance below 10% as has been shown earlier.
The use of a solar screen does not modify the colours of the outdoor environment, since light enters the room through the natural apertures of the textile material. In screens, the threads are opaque and when colours such as grey or black are employed, the spectrum of the transmitted light is not modified.

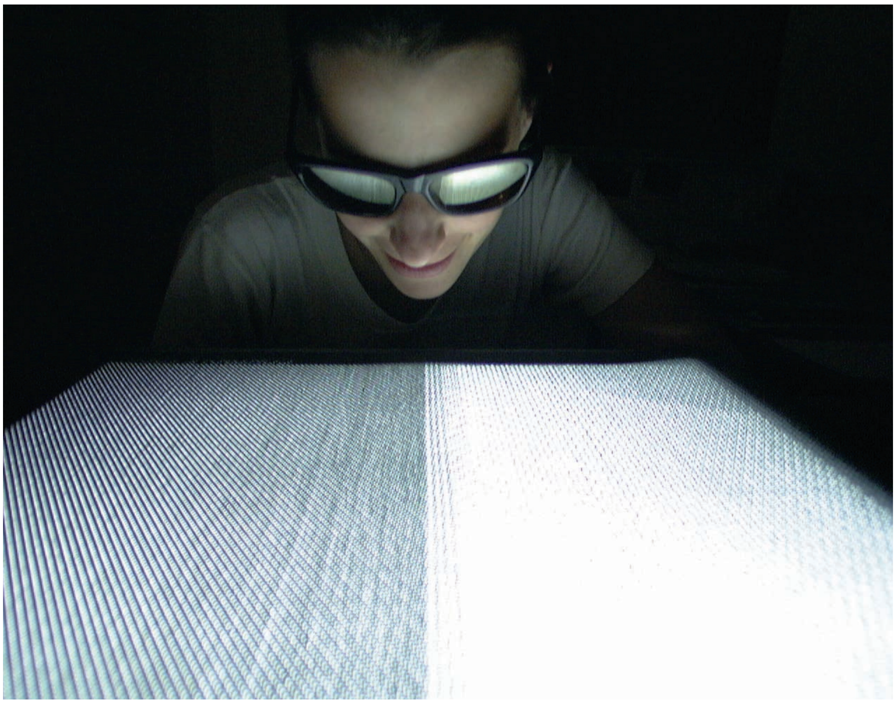
◁ *Colour neutrality of three HEXCEL 525 solar screens Grey White, Grey, and Charcoal, by comparison with tinted glazing.*

Screen⁺:

a new answer to visual requirements

△ *The upper part of Screen⁺ has a higher transmission, but it reduces the luminance of the sky vault by a factor of five.*

▽ *The transition between the two types of material is straight, thanks to a continuous weaving process. This also improves the appearance of the product.*



The search for a means of reducing veiling reflections on computer screens leads to a significant reduction in the quantities of daylight penetrating the room, typically in a ratio of 20:1 (for a shading device with a transmission of 5%, for instance). As a consequence, indoor illuminance values can easily fall below 100 lux, a value which tends to require additional artificial lighting. Hence the idea of a solution which would offer the same quality of glare attenuation but supply more daylight to the room. This is the principle of Screen⁺, which offers a complement of daylight in its upper part (above 2.00 m from the floor), through an increase in its transmittance from about 6% to 22%. The transition between the two types of material is straight, thanks to a continuous weaving process.

Screen⁺ material functions to suppress all reflections on VDU screens while still maintaining satisfactory light levels in the rooms. If the room surface finishes have light colours, light levels can be higher

Screen⁺:

a brighter luminous environment

For bright overcast skies, found in summer (luminances exceeding 10,000 cd/m^2), a standard solar screen must be fully rolled down. By comparison with a standard screen having the same luminous transmittance, Screen$^+$ supplies 60 % more daylight to the interior. Thus illuminance levels on indoor surfaces are increased by about 60%.

In sunny conditions, when the elevation of the sun is low over the horizon, sunlight penetration is also increased by about 60%. However, the general brightness of the room will depend on the lightness of the surface finish of where the sun-patch is located.

The images opposite show results of measurements using scale models under real sky conditions with the sun low over the horizon. This situation represents the conditions found in front of East or West-facing facades very well. This situation can last for several hours and the additional amount of daylight can be highly beneficial.

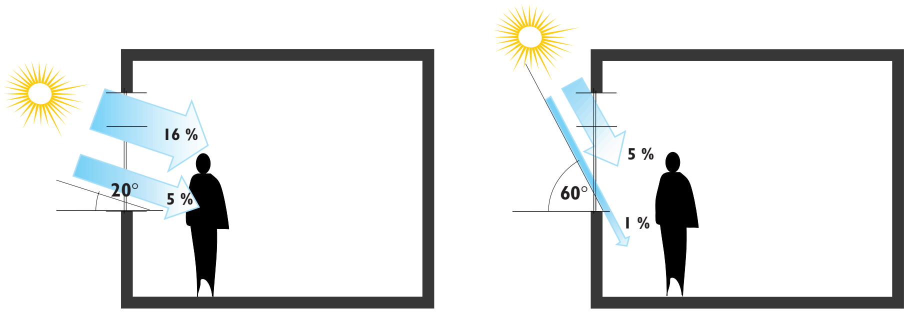
White fabric is not used in Screen$^+$ since it does not provide sufficient luminance reduction. However, white solar screens may be attractive solutions in cases without VDUs, or for regions with very cloudy climates.

Lux	Screen 525	Screen$^+$ 525$^+$	%
grey	122	190	56
grey white	163	320	96
white	879	-	-

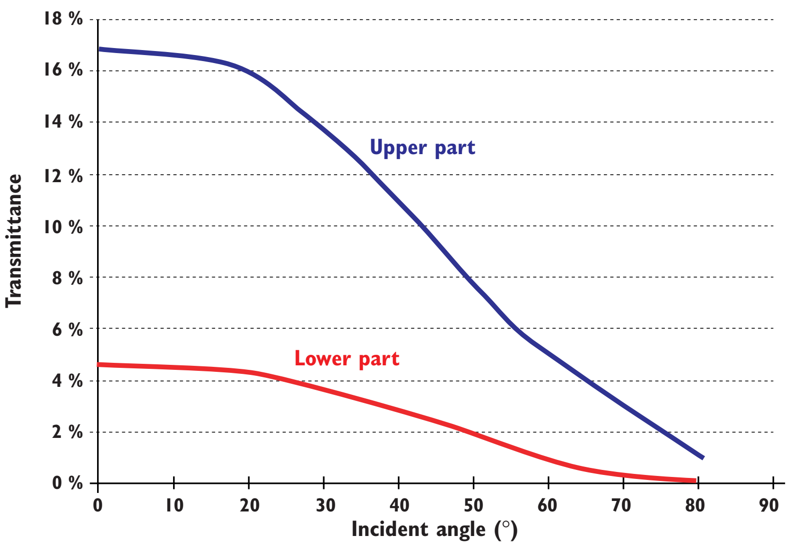
△ *Measurements taken on 28 May 1999 on the floor of the room*

△▽ *Principles of Screen$^+$: by comparison with a standard solar screen with only one mode of light transmission, Screen$^+$ offers the same protection against reflections on VDUs. However, the indoor illuminance values are increased. In areas away from sun-patches, indoor illuminance levels can sometimes be more than doubled.*

Screen$^+$:
performance which adapts to changing climatic conditions



△ *When the sun is high above the horizon, Screen$^+$ offers a higher level of attenuation, leading to a higher protection of the occupant.*

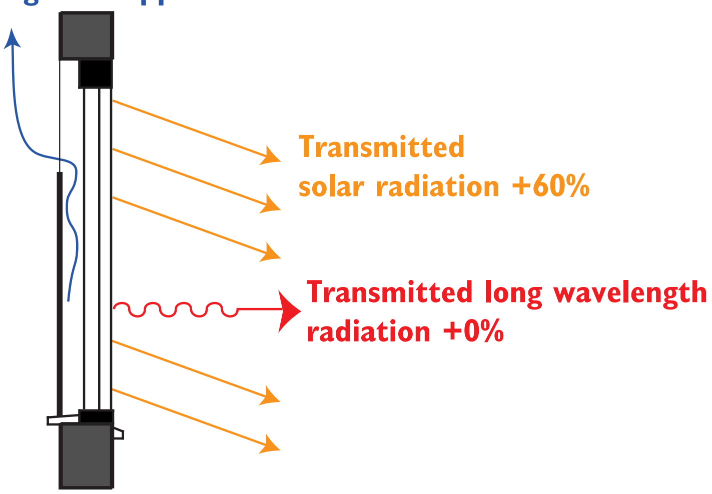


△ *The graph above shows the variation of the directional luminous transmittance as a function of the angle of incidence, for the two parts of Screen$^+$.*

The weaving structures used in Screen$^+$ offer a solar protection which increases as a function of the angle of the sun above the horizon. For instance, the directional transmittance decreases in a ratio of 3 to 1 (even 5 to 1) when the angle of the sun above the horizon increases from 20° to 60°. This behaviour is particularly useful to provide good protection for the occupants situated within 2 metres of the windows.

It can be observed that the directional transmittance values are slightly smaller than global transmittance values. The reason is that the global transmittance includes the light due to the slight dispersion of light on the fibres of the textile materials.

Increased natural ventilation through the upper section of Screen$^+$



◁ *Screen$^+$ increases the natural ventilation between the solar screen and the window. As a result, the increase in solar radiative flux transmitted by Screen$^+$ does not lead to an increase in the temperature of the glass, by comparison with a standard solar screen. Therefore, the Solar Factor is only increased by the increase of solar transmission of the upper section of Screen$^+$.*

Screen+:

a greater choice of luminous environments.

The presence of a strip with higher transmittance at the top of the Screen+ allows new luminous environments to be created The occupant can adjust the supply of additional daylight coming either from the top or the bottom of the window, by raising the Screen+ a few centimetres. Another benefit is the ability to adjust the balance of illuminance levels between the work-plane and other parts of the room. Within 0.40 m of movement, Screen+ makes a wide variety of luminous environments possible.

Solar screens do not impair outward vision. The outside view from the work place is maintained, from left to right and from bottom to top. No vertical or horizontal line is visible as is the case with venetian blinds. The upper part of Screen+ offers an increase in transparency towards the sky, a pleasant feeling when the sky is blue.

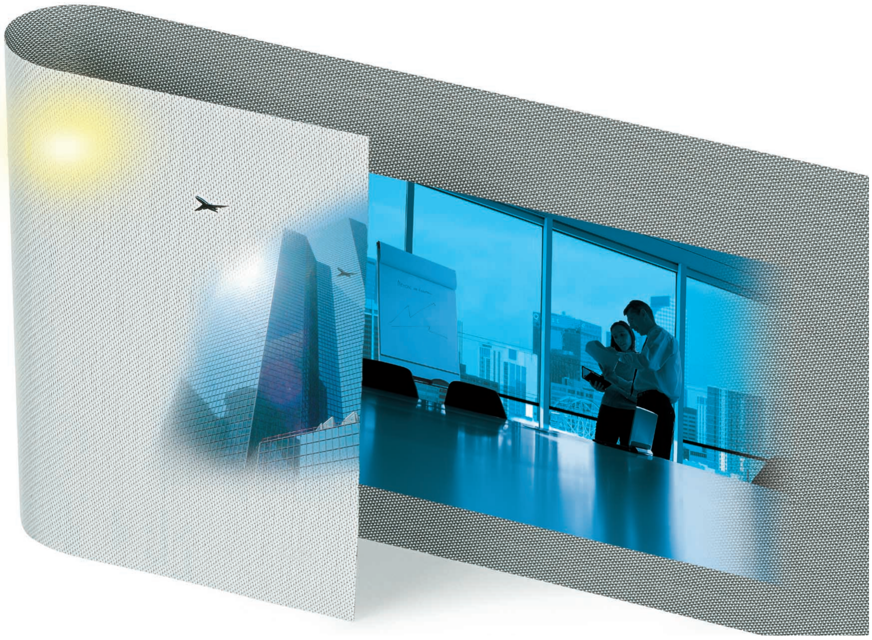
The result is a greater feeling of transparency, with the same reduction of reflections on VDU screens that is obtained when a traditional solar screen material is used.

◁ *1- Fully closed Screen+ leading to optimal glare control on VDU screen*

◁ *2- Screen+ slightly raised to bring additional light to the work plane.*

▷ *3- The upper part of the Screen+ may be hidden to offer total protection when the sun is high above the horizon*

Screen²,
Two sides, two functions.



∆ Screen²*: Two sides, two functions. Thermal performance and visual comfort.*

∆ *The three families of* Screen² *permit adjusting the reduction of external luminance to levels of 3%, 5% and 10% of the luminance from external sources.*

The principle of Screen² is to reflect the maximum amount of solar rays from its white external surface, and to considerably reduce transmission to ensure optimum control of glare phenomena thanks to its grey interior colour. Three opening settings are proposed: 3%, 5% and 10%.

The screens are woven so that the white thread is visible over 88% of the external surface, which is that exposed to the sun. By contrast, the grey thread is visible over 88% of the internal surface.

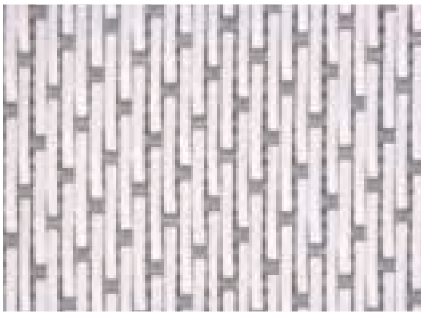
The sun's rays are reflected, transmitted or absorbed by the screen. The reduction of thermal effects requires calculation, by adding the screen and the glazing. Two cases are possible: the screen can be placed either outside, or inside the glazing. The following tables show the characteristics of screens placed either outside, or inside

Solar factor (SF): ratio between the total quantity of energy transmitted and emitted to the interior by the window and the incident energy under normalised conditions.

Shading coefficient (Sc): ratio between the solar factor of the window with shading and the solar factor without shading under normalised conditions.

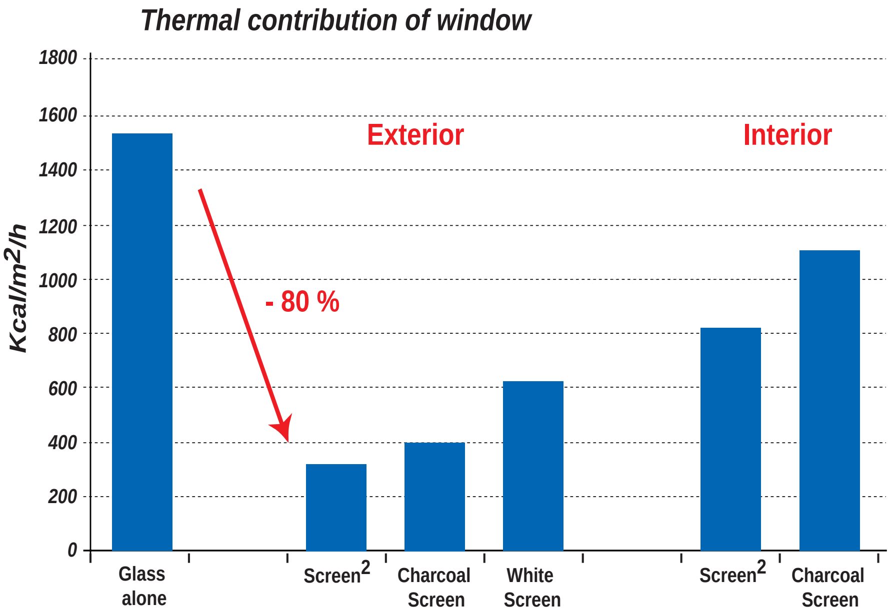
Screen^2,

Thermal performance and visual comfort



∆ *Enlargement of the "white" surface of Screen^2.*

The screen placed inside, the heat absorbed by the fabric is added to the heat transmitted. The Sc can only be attenuated substantially if the highest possible reflection factor is possible on the exterior. Here again Screen^2 is more efficient than traditional screens, while offering good attenuation of luminosity (Tv = 6% for an opening factor of 3%). Under these conditions, Screen^2 has the highest efficiency at thermal level while providing excellent conditions for visual comfort (which is not the case for traditional white screens).



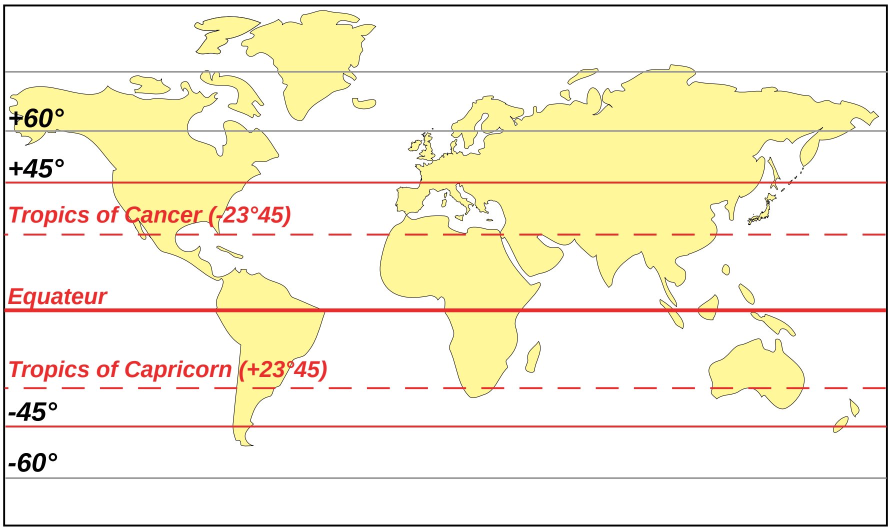
Ts is the transmission factor of solar radiation through the screen,
Rs is the reflection factor, and As its absorption factor,
Sc is the Shading Coefficient when the screen is associated with a window.

Screen^2 :

How to choose the degree of attenuation of Screen^2

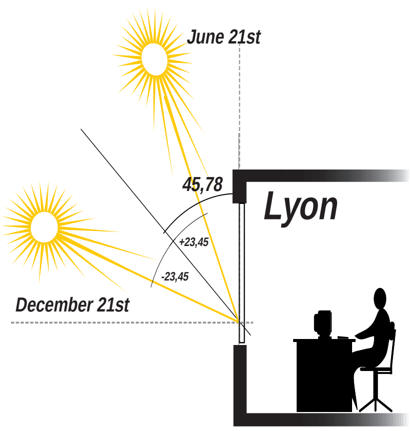
Influence of site latitude

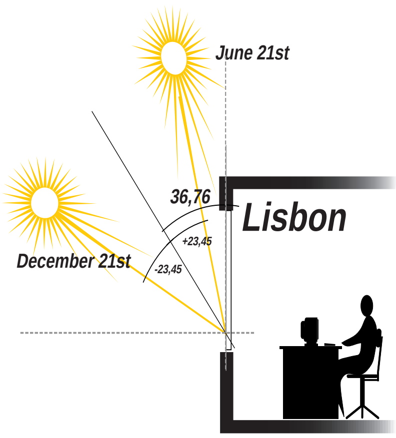
The latitude of a site on the Earth makes it possible to characterise its distance from the equator. It varies from 0° on the equator to 90° at the North Pole and -90° at the South Pole. It is the latitude that conditions the area of sky crossed by the sun, in spite of its movement as a function of the seasons.
In particular, the maximum height of the sun over the horizon at midday can be expressed quite easily as a function of latitude and date.
At the equinoxes (21st March and 21st September), at the sun's midday zenith, the angle between the sun's rays and the vertical is equal to the latitude of the place.

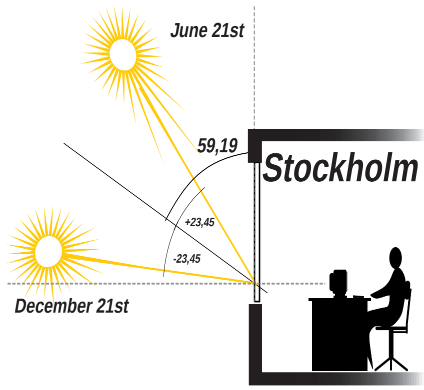


△ *Chart of latitudes*

▷▽◁ *To know the position of the sun in the sky at midday (sun in the south), all that are needed is the latitude and the date. The diagrams here under show the sun's positions for the summer solstice (21st June), the winter solstice (21st December) and the equinoxes (21st March and 21st September).*





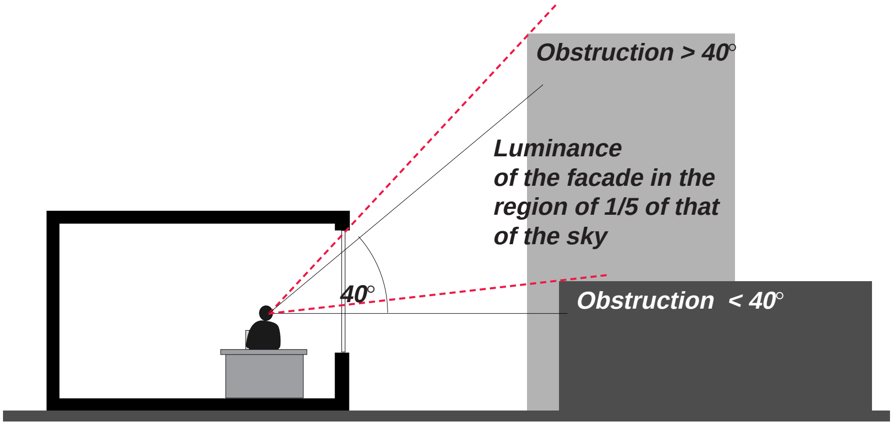


Influence of façade orientation.

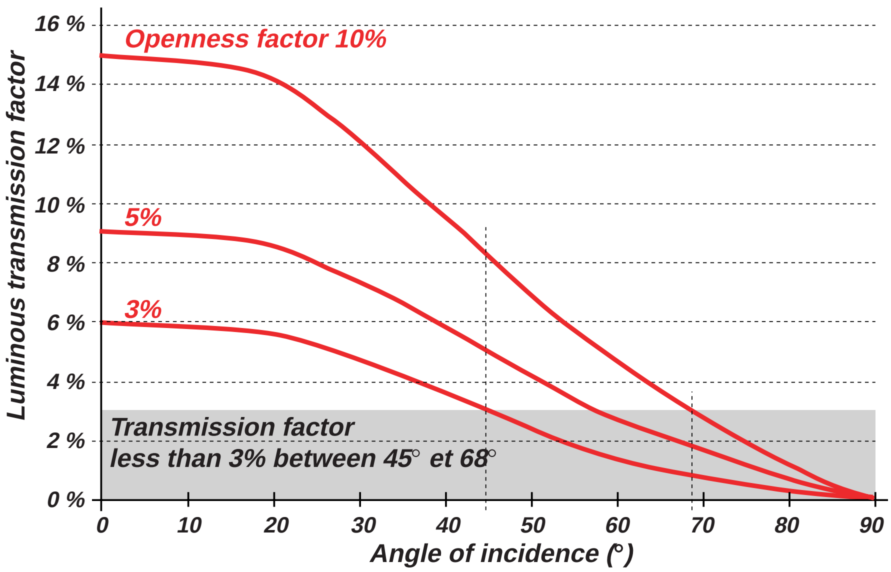
The choice of the screen fabric best adapted for each façade is defined by the trajectory of the sun or its absence on the façade concerned. In fact, in Northern European countries the sun is low over the horizon for most of the day, lighting south oriented façades. Therefore a screen with a very low transmission rate must be installed (Screen^2 3%). On the contrary, north facing facades need to optimise the sky's luminance, as there is no direct exposure to the sun. In this case, there is no point in using a screen with a low transmission rate, as this would considerably reduce the contribution of natural light inside the office. Screen^2 10% will manage this level of external luminance perfectly.

Screen² :

How to choose the degree of attenuation of Screen² (cont)



△ *In the case of substantial obstructions, especially when they form an angle of obstruction in the region of 40° above the horizon, it is preferable to use slightly attenuating screens, whatever the orientation of the facade.*



△ *The curves above show the variation of the directional light transmission factor as a function of the angle of incidence, for three* Screen² *opening factors.*

Openness factor (%)	3	5	10
Transmission factor (incidence 0°)	6	9	15
Transmission factor (incidence 60°)	1,2	1,8	3

△ *Matrix measurements*

Influence of buildings opposite.

When estimating the risks of glare due to the external environment, the buildings opposite are of prime importance. The more the site is obstructed by façades opposite, the more the luminance seen by the occupant decreases. It can be seen that when façades are not lighted by the sun, their luminance is in the region of 1/5 of the luminance of the sky.

If the observer is positioned so that the facade opposite obscures the sky more than 40° above the horizon, the sky is no longer considered to be a source of glare; moreover, the conditions requiring reduced luminosity decrease when the sun is above the obstruction or when the façade is subjected to intense light.

It should be noted that screens provide much lower light transmission factors for large angles of incidence than for horizontal rays. By way of example, when the transmission factor is approximately 6% at normal incidence, it is no more than 1.2% under an angle of incidence of 60°. The above remarks only concern normal façades. If the obstruction is composed of "mirror" type façades, it is not possible to expect reduced luminosity from the sky; this is especially true in the case of north facing façades opposite south facing glass façades.

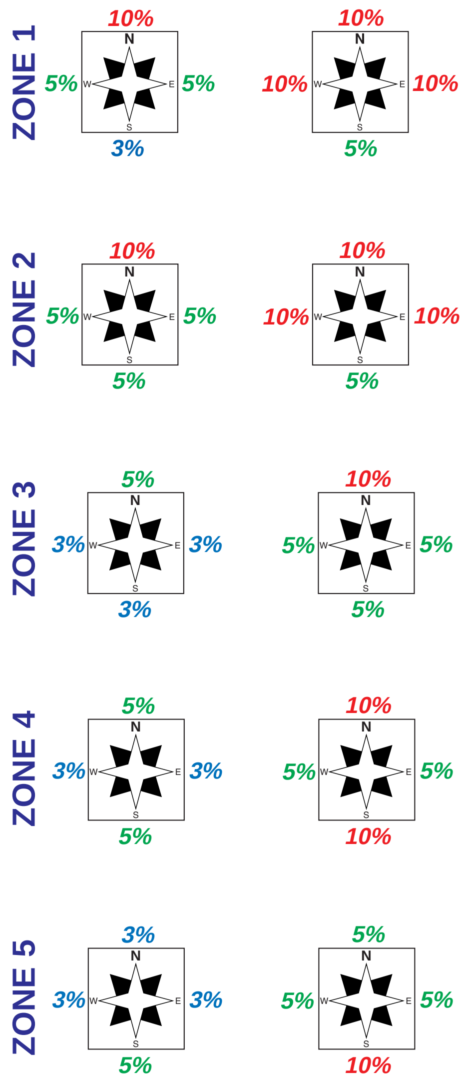
Screen² :

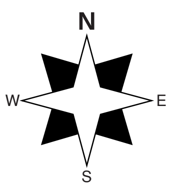
Choice of the most efficient and suitable openness factor

CHOICE OF
THE MOST EFFICIENT
AND SUITABLE OPENNESS FACTOR

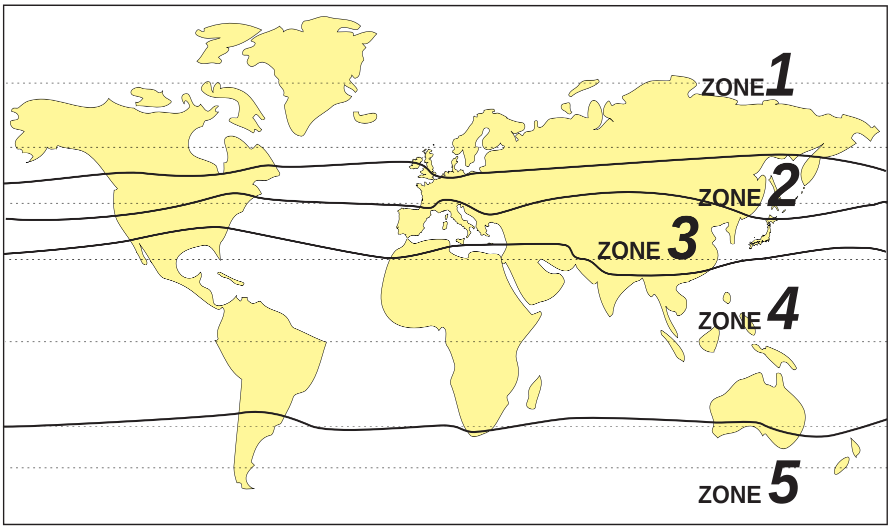
Clear view
Obstruction < 40°

Obstructed view
Obstruction > 40°





∆ *The compass card indicates the right level of light transmission according to the orientation of your façade.*



∆ *Here, we present a map of the world permitting the selection of the type of* Screen² *according to the regions concerned.*

◁ *Openness factor of* Screen² *selected for the 4 main orientations in order not to exceed luminances of 1,000 cd/m² more than 5% of the time between 8 a.m. and 8 p.m. during office hours. Furthermore, the screen must attenuate the direct rays to less than 5%.*

Choose the level of performance that best corresponds to your activity :

Ex 1: a control room requiring a high level of concentration; select the lower openness factor

Ex 2: a cafeteria. For a friendly atmosphere, select the upper openness factor