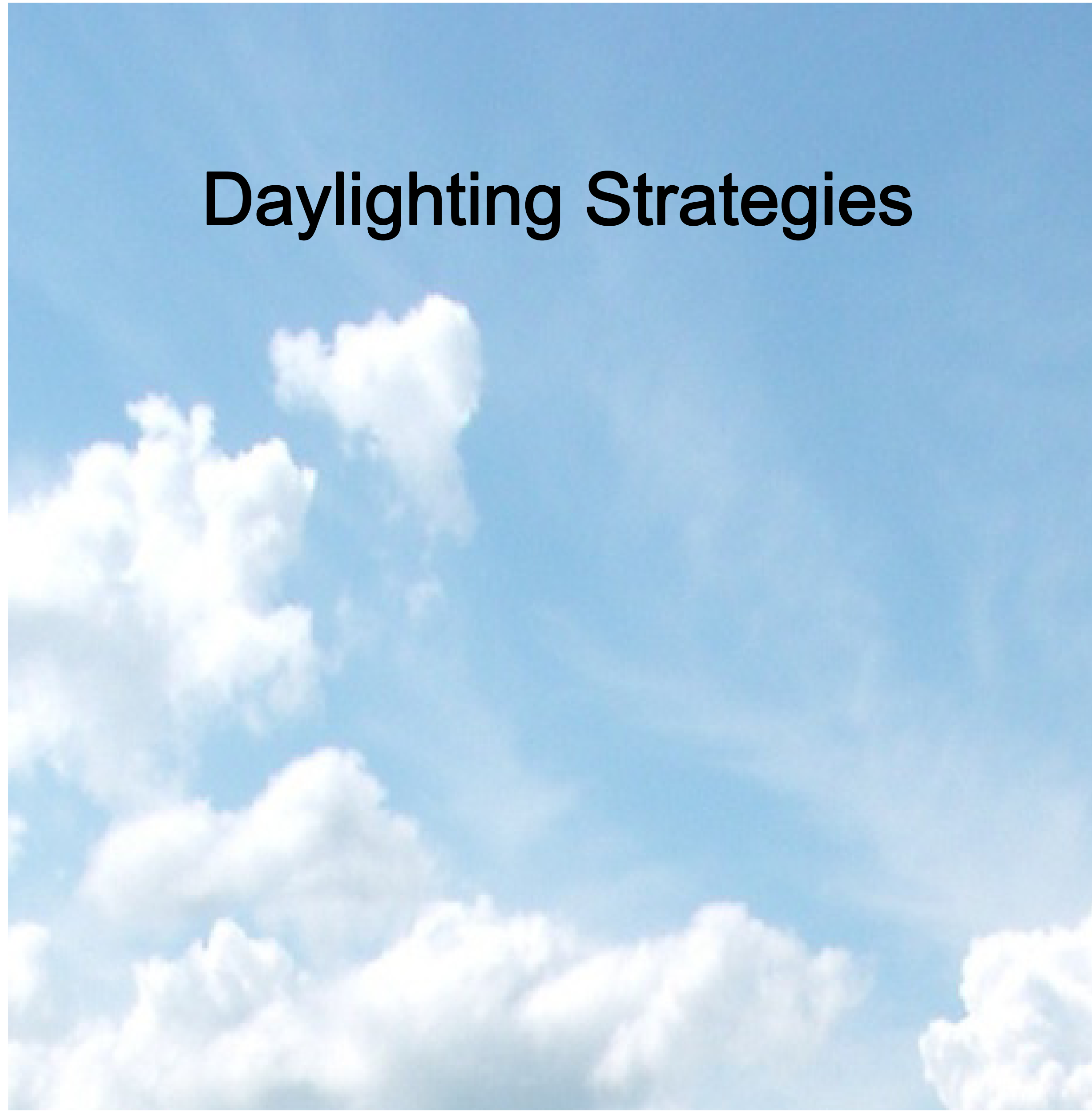
# Daylighting Strategies



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# Daylighting Strategies

Presented by: 3M Corporate Headquarters
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St. Paul, MN 55144-1000

Description: Provides an overview of how to best harness the benefits of natural light with proper daylighting strategies, as well as discussions on how to calculate daylighting accurately and case studies on the performance of daylight redirecting films.

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# Purpose and Learning Objectives

**Purpose:** Provides an overview of how to best harness the benefits of natural light with proper daylighting strategies, as well as discussions on how to calculate daylighting accurately and case studies on the performance of daylight redirecting films.

**Learning Objectives:**

At the end of this program, participants will be able to:

- discuss the benefits of using natural light
- list important design considerations for using natural light
- describe different sidelight daylighting strategies, and
- evaluate daylighting performance.

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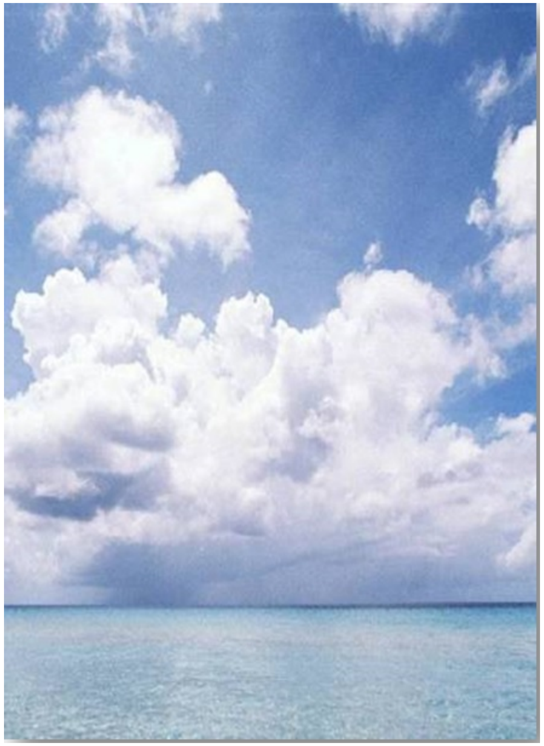


# Introduction to Daylighting

# Daylight

What is the attraction of daylight?

It is beautiful. It makes colors saturated and true, and adds meaning to highlights and shadows.

It varies in time and space, making sights more memorable.

It is mentally and emotionally stimulating, most likely via profound physiological biochemistry.

# Benefits of Daylighting

It is estimated that 90–95% of our time is now spent indoors. The human body has adapted to sunlight, so when we are indoors and do not receive as much daylight, how does that affect us?

There have been many studies showing the benefits of daylighting.

Daylighting improves sleep patterns by providing our body cues as to when to go to sleep. Studies on daylighting have shown that it can increase worker productivity and decrease patient recovery times in hospitals. Student test scores, retail purchase behavior, alertness, mood, atmosphere, memory, and health all improve or increase with exposure to daylight.

# Benefits of Daylighting

Not only does daylight provide many benefits, but it is also available when we need it.

It's available during the typical workday of 8 a.m. to 5 p.m. and will work for the life of the building. The sun never needs a bulb replaced or a backup generator to continue running. Daylight works even when the power goes out—especially important for hospitals, schools, nursing homes, and business continuity during emergencies.

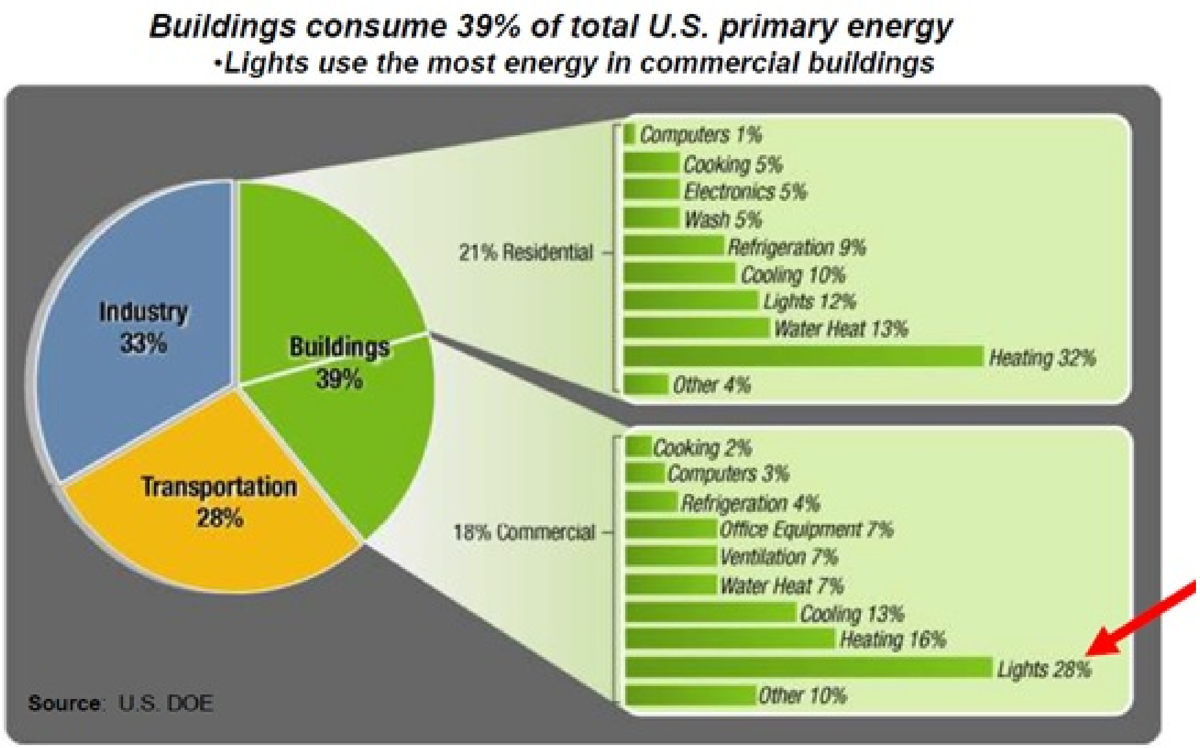
Using daylight is free, and there is no electricity used in taking advantage of its energy. Daylighting decreases building energy use when properly harnessed with integrated lighting controls.

Additionally, many codes and standards—such as LEED®, ASHRAE/IES 90.1 and 189, IECC/IgCC, Title 24, etc.—are either requiring daylighting to be used, or at least considered and evaluated.

# Building Energy Use

Buildings use a lot of energy in the built environment: 30% of all energy consumed in the U.S. is used by buildings, and globally the amount is 40% (Eckard, Navigant Research, 2013). Buildings also account for 67% of all electricity used in the U.S.

This chart shows that in commercial buildings, lighting demands the most energy at 28%.




Daylighting can significantly reduce artificial lighting demand, resulting in a 30–80% lighting energy savings, a 5–10% whole-building energy savings, and a 10–20% reduction in peak electricity use.

# Daylighting Definitions and Measurement

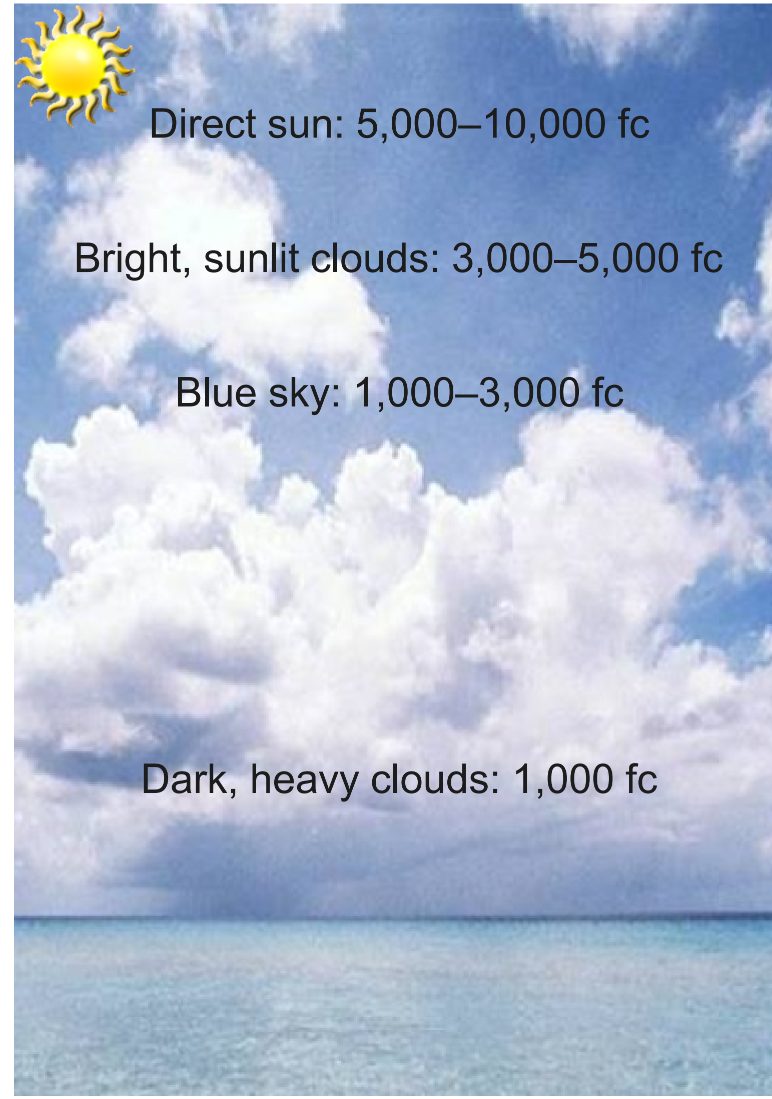
- Illuminance is defined as the measure of incident light.
- The term “footcandle” dates back to the days before electricity. One footcandle was defined as the light output of one candle, one foot away.
- 1 footcandle (fc) = 1 lumen per square foot and is the imperial unit.
- 1 lux = 1 lumen per square meter and is the metric unit.
- 1 fc = 10.76 lux
- Most interior tasks require 20–100 fc. A typical office environment lighting level is 30–40 fc.

# Skylight versus Sunlight

There are a number of differences between skylight and sunlight as light sources.

Sunlight is a powerful resource when it is available. It is a direct beam of light with very sharp, crisp shadows. Sunlight is always moving on a predictable path, and the intensity varies with position and will change dramatically with cloud cover. Sunlight provides 1,000–10,000 fc from a single point source, with a sunny day providing 5,000–10,000 fc. Refer to the image at right for more measurements.

Skylight, on the other hand, is a diffuse, even lighting with soft shadows. Skylight varies with cloud cover and solar position, and provides 1,000–5,000 fc from the whole sky hemisphere.

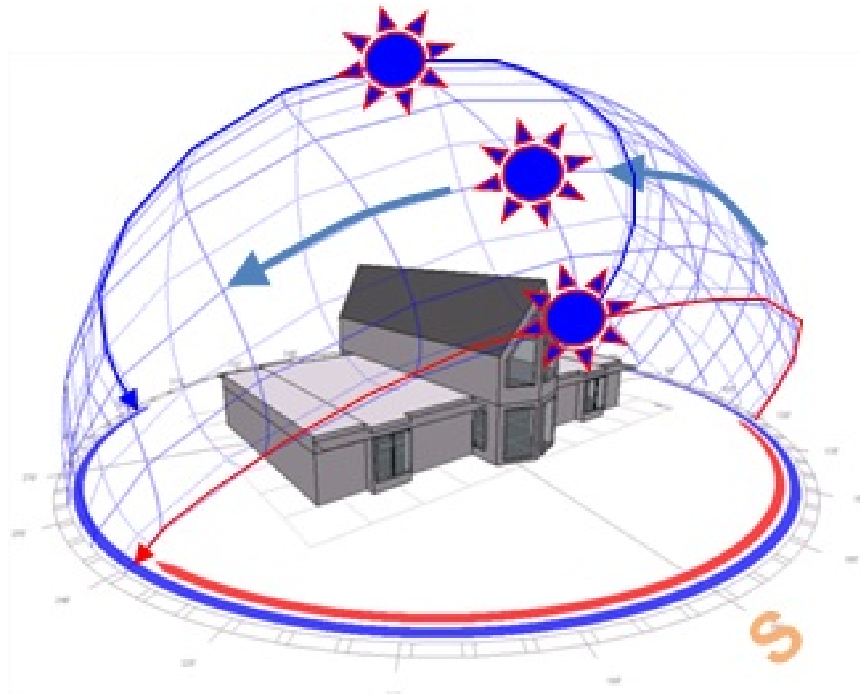


# Daylight versus Direct Sunlight

Proper daylighting provides diffuse light and even illumination. It should be at an evenly spread, consistent lighting level that allows electric lights to be turned off.

In contrast, sunlight comes in direct rays from the sun; it is bright and hot, and creates uncomfortably strong contrast. It can make a space appear darker by comparison. Sunlight needs to be diffused and filtered over a large area to be used comfortably.

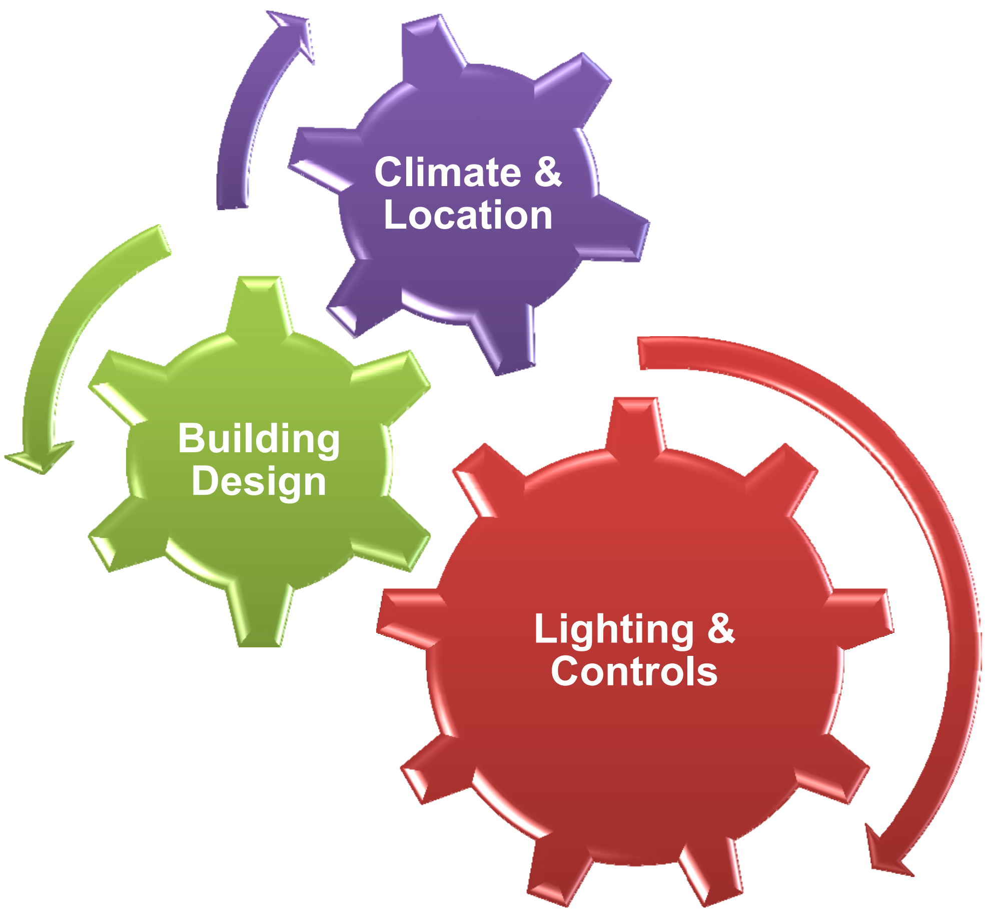
It is important not only to deliver natural daylighting, but also the right type of natural daylighting. Direct sunlight can make occupants uncomfortable and leads to other design challenges.



# Designing with Daylight

# Daylighting as a System

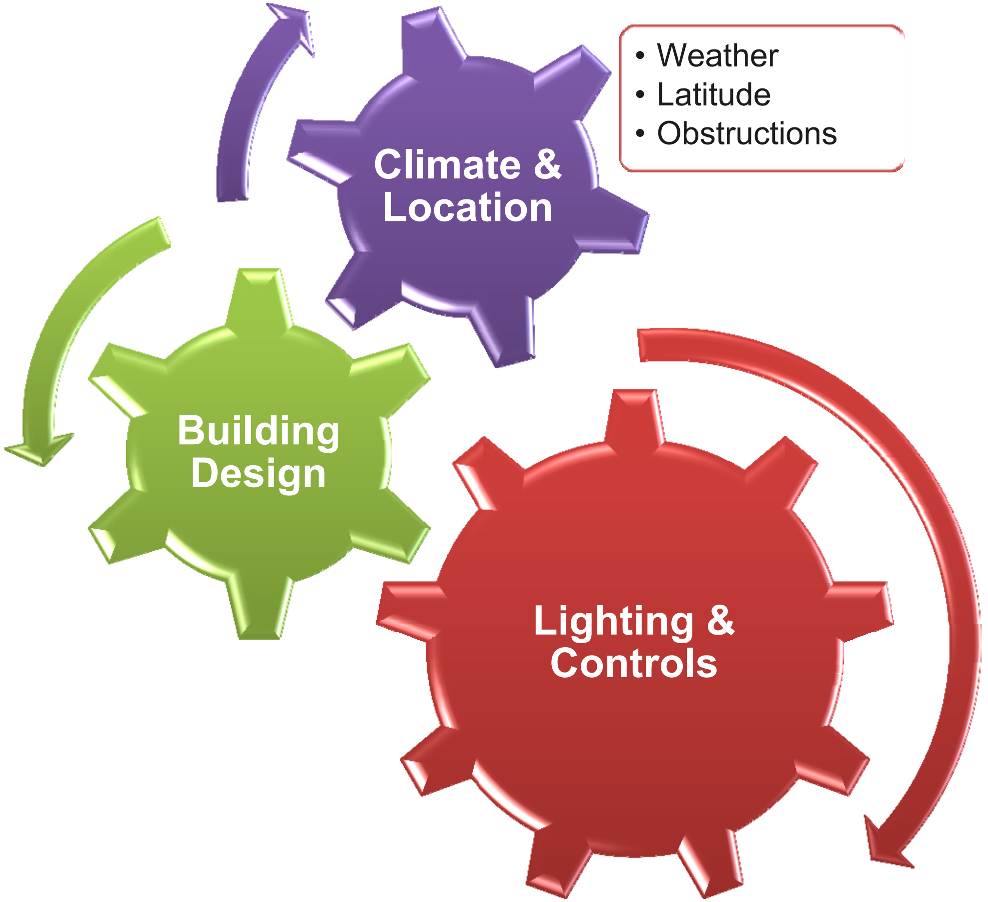
Daylighting should be thought of as a system—building systems working together.



# Daylighting System: Climate and Location

The climate and location will define how much natural light is available.

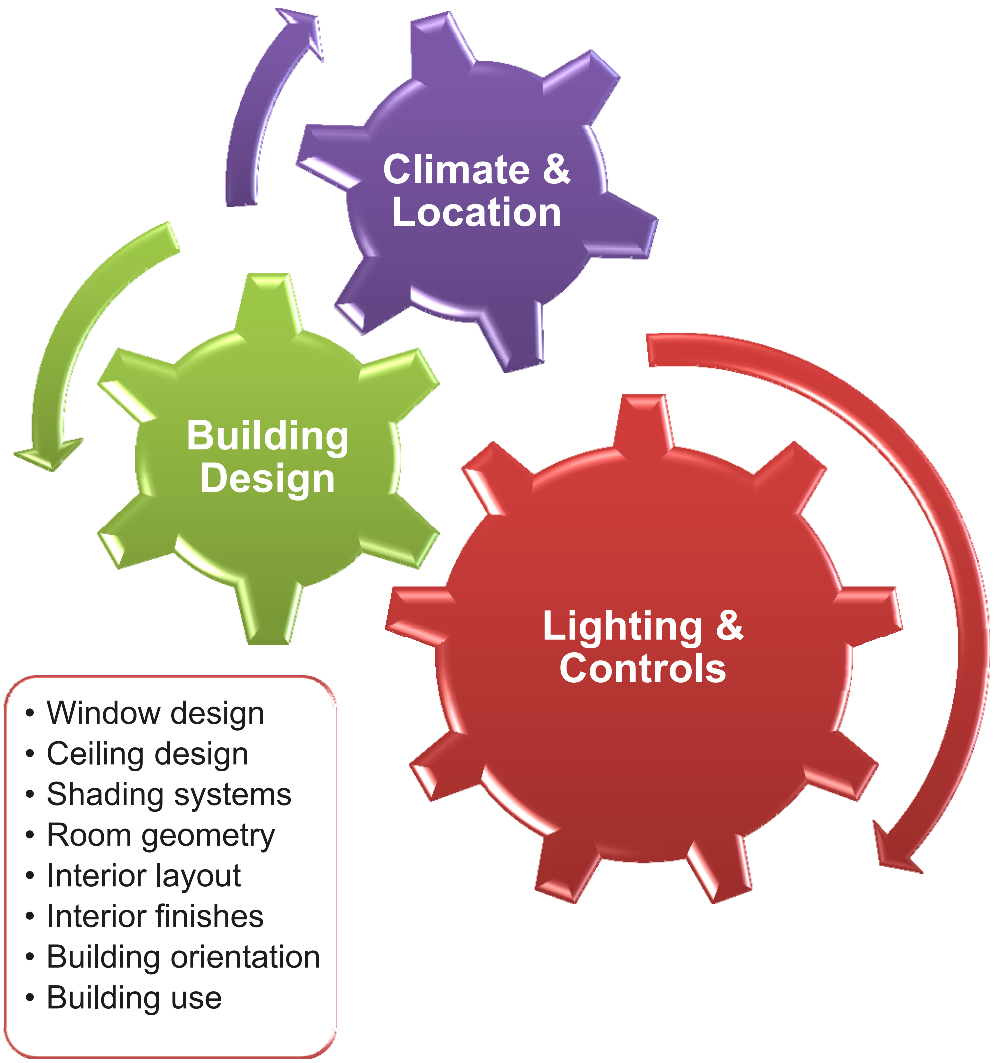
- Weather (clouds versus direct sunlight) will affect intensity.
- Latitude will define how high or low the sun will get in the sky.
- Obstructions such as trees or buildings may also affect the lighting available.



# Daylighting System: Building Design

The building design will define how much light is let into the building and where it goes.

- The size of the windows will determine how much light is brought in.
- Ceiling height and height of the windows will define how far that light is carried into the building.
- Surface reflections will affect how many bounces the light will make into the interior.
- The building orientation and interior layout also help determine how the light will be used and how far it will penetrate into the building.

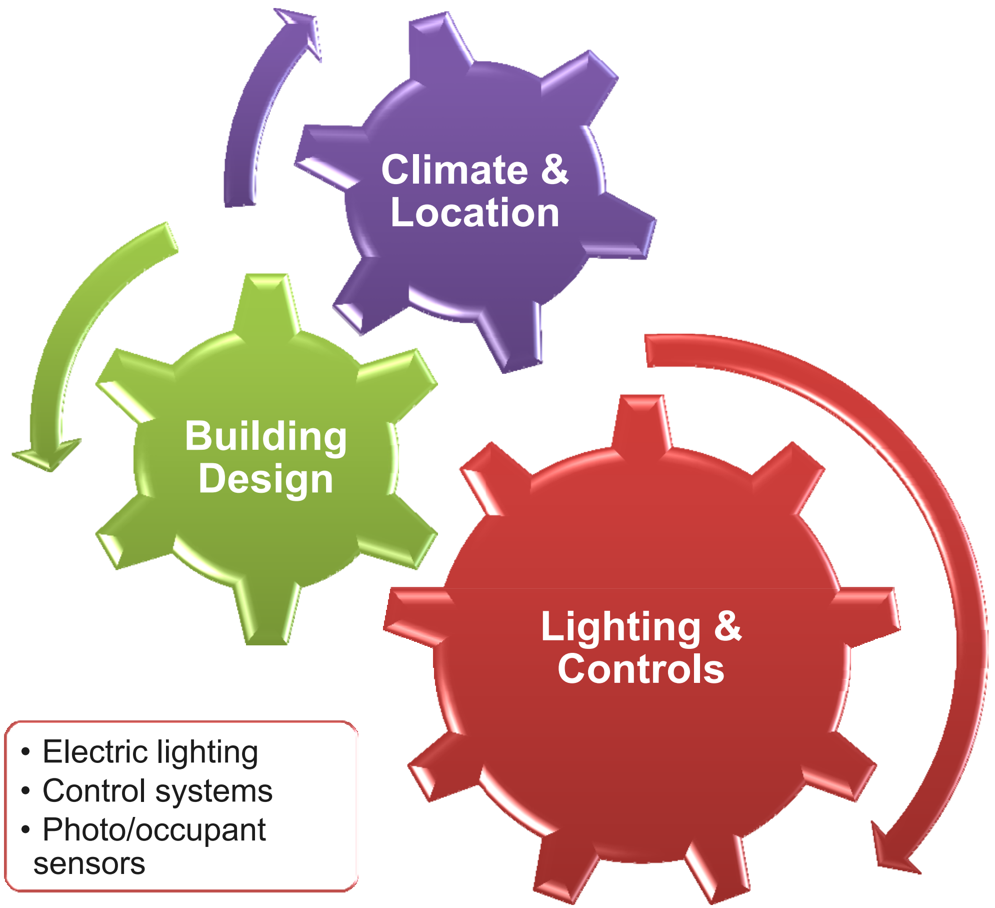


# Daylighting System: Lighting and Controls

The lighting and controls will then determine how much artificial lighting can be saved.

- Lights need to be turned off or dimmed in order to save energy.
- Adjustable dimming ballasts will allow for a reduction from full light levels.
- Sensors will determine how much artificial lighting is needed to maintain a desired lighting level.

To maximize daylighting use and reduce energy use, a systems approach must be used.



# Window Considerations

Windows offer many features that must be considered. They let us connect to the outdoors by providing views to the city, mountains, or landscape. They also let people look into buildings, and are used to determine whether a building is open or occupied. Privacy must also be considered when desired in the day or night. Windows have a large role in defining a building's aesthetics, in both color and look.

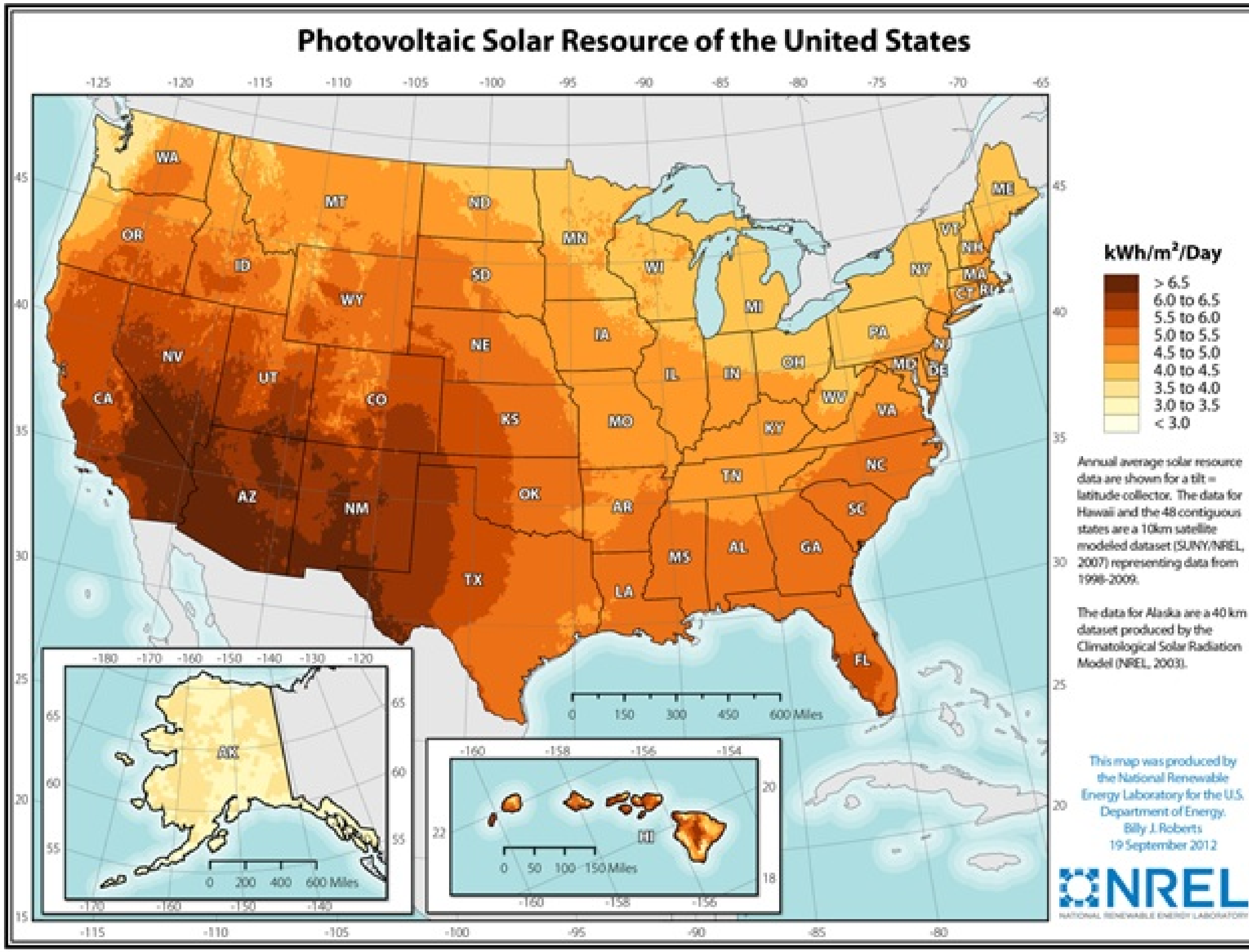
There are also important energy considerations in terms of thermal performance and the amount of solar heat. Occupant safety is another consideration; windows must also protect the building itself from damage or break-ins.

The focus of this course is on window considerations that provide natural light with occupant comfort. Daylighting lets light in so the need for artificial lights is reduced or eliminated, but too much direct sunlight can cause glare and heat issues for occupants.

# Climate and Location: Available Sunlight

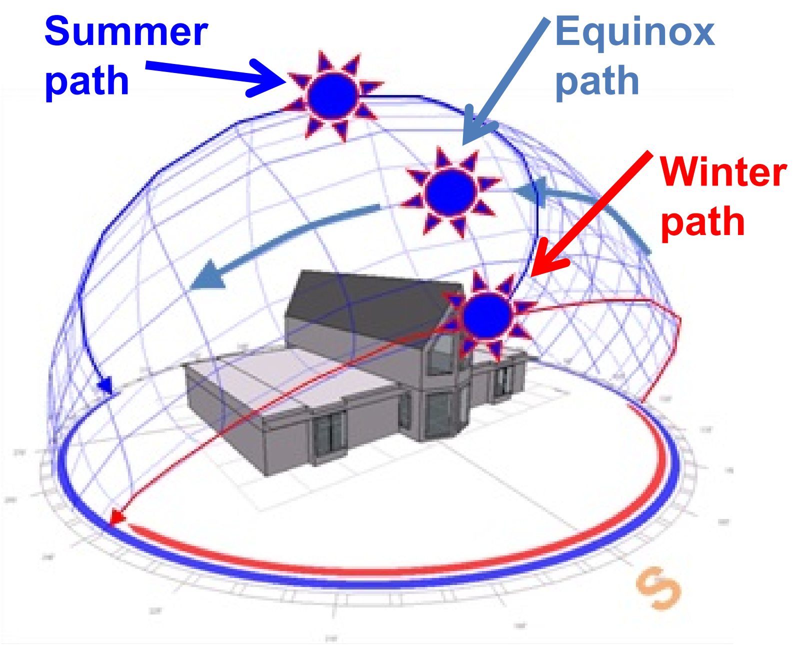
This chart was developed to show the amount of direct sunlight available for photovoltaics but is also applicable for daylighting.

In general, latitudes closer to the equator and clear sky climates receive more sunlight; however, there is plenty of sunlight all over.



# Climate and Location: Solar Position

Latitude determines the solar angles at different times of the year. The further away from the equator, the greater the variation between the summer and winter paths.



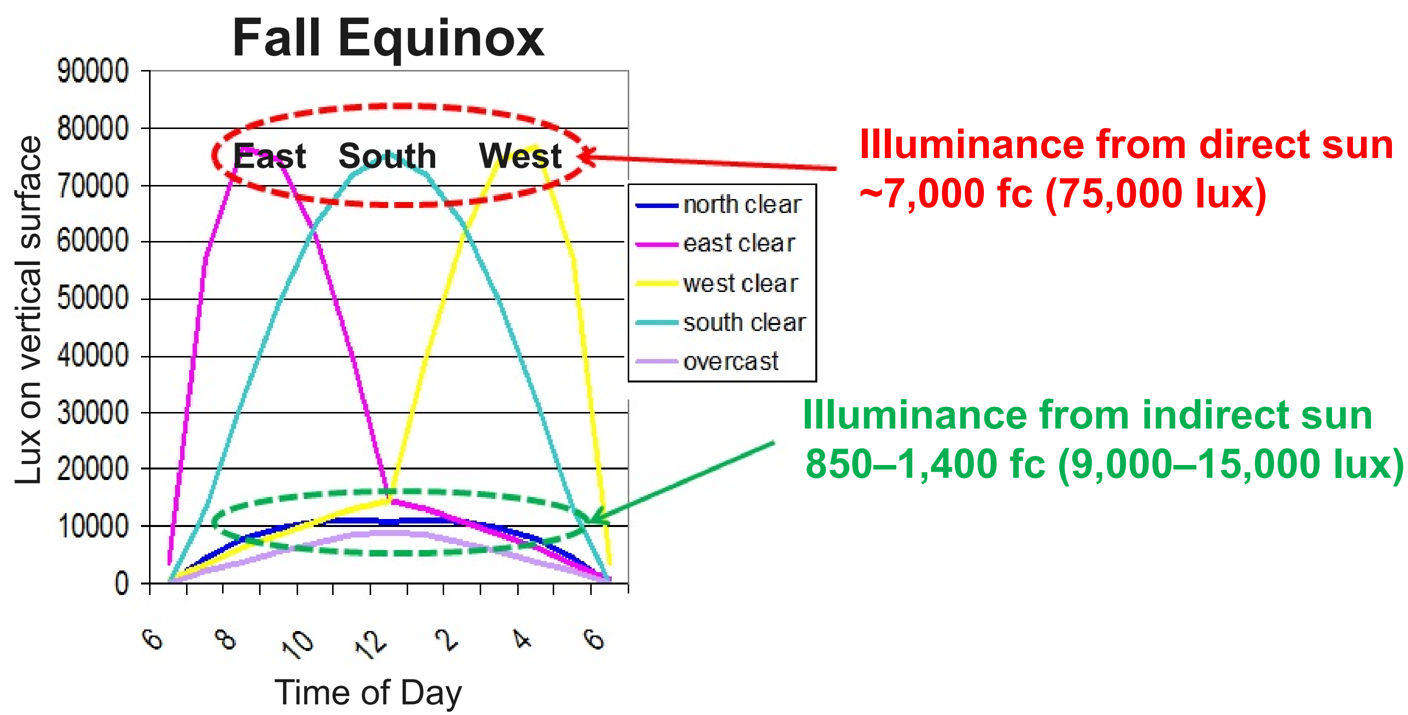

In the northern hemisphere, the sun is low in the sky in winter; low-angle light is more directly in our line of sight and can be uncomfortable. Most sunlight faces the south side of a building in winter. The sun is at its lowest height at the winter solstice, near December 21st/22nd.

In summer, the sun is high in the sky and is more directly on the east and west sides of a building than on the south side. The sun is at its highest at the summer solstice, June 20th/21st.

Spring and fall equinoxes occur near March 20th and September 20th. Around these periods, light hits the east, south, and west sides of a building more equally.

# Climate and Location: Window Orientation

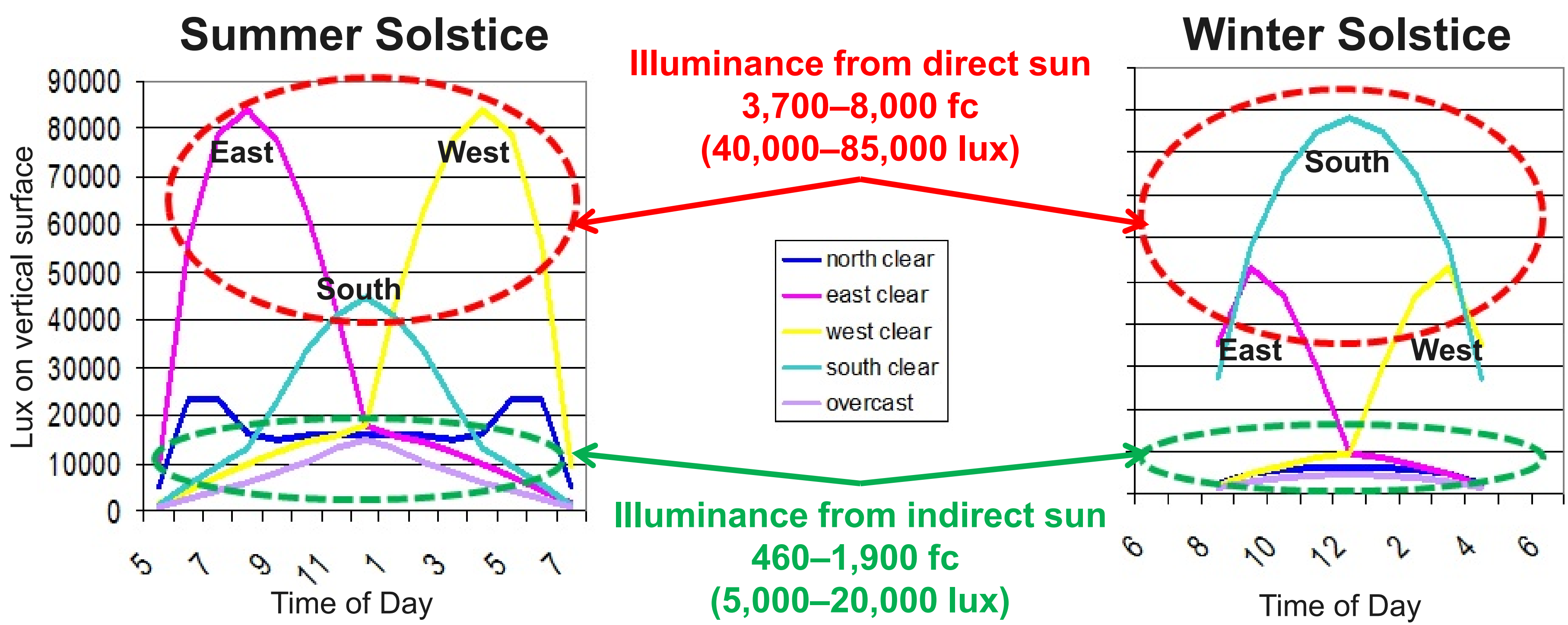
The following examples show the illuminance for a building in San Francisco, California.




During the fall equinox, the illuminance is fairly evenly divided on the east (a.m.), south (noon), and west (p.m.) facings of the building. The illuminance from direct sunlight is over 7,000 fc, which will be very intense and uncomfortable if not addressed. In comparison, during times of indirect sunlight, the illuminance is around 850–1,400 fc, which is much more comfortable to experience.

# Climate and Location: Window Orientation

Compare these graphs of the solstices to the equinox on the prior slide. During the summer, the east and west facings of the building receive intense light for a long portion of the day. The south facing receives less sunlight. During the winter, this situation is reversed: the south receives intense, direct sunlight for the majority of the day, while the east and west facings receive less sunlight. The indirect sunlight is much less intense and quite comfortable compared with the bright and hot direct sunlight.



# Direct Sunlight

High windows or clerestory glass will allow more direct sunlight to penetrate deeper into the building, affecting more occupants in the space.

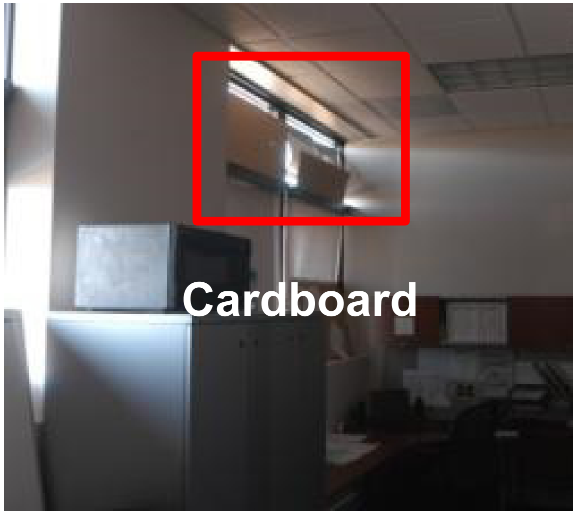
Low sun angles will increase how far this uncomfortably hot and glaring direct sunlight penetrates inside the building.

The light output of a computer monitor or screen is no match for the power and intensity of the sun. The computer screen may appear washed out or be extremely difficult to view.

# Occupant Methods to Address Discomfort

Saving energy is important, but so is occupant comfort. If occupants are not comfortable, they will take action to make themselves so. They will close blinds or shades if they are available, or they will figure out another way to make themselves comfortable. Trash bags, cardboard, and tarps installed in windows have all been used by occupants to combat heat and glare.

This is certainly not how these buildings were designed. Actions such as these bypass designed energy saving features and detract from building aesthetics. Instead of providing natural light to the space, these measures have the opposite effect.


# Controlling Glare: Blinds and Shades

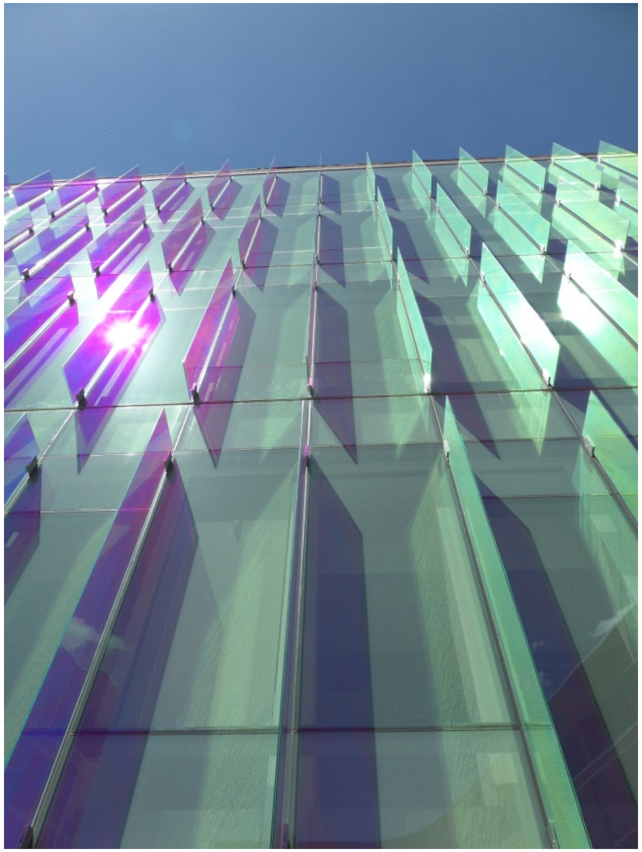
Blinds are provided to address occupant comfort. People have different levels of sensitivity to glare, so the occupant with the lowest sensitivity is generally the one who takes action. Once the blinds are closed, they tend to stay closed for long periods of time. They require someone to take the effort to reopen them. With closed blinds, the window is not bringing in much natural light. Additionally, the view is negatively affected. The exterior of the building then has a “patchwork quilt” or “checkerboard” look to it, as the blinds are randomly closed at various heights.

# Controlling Glare: Other Solutions

There are other ways to control glare such as shading fins, awnings, dynamic glazing that darkens as needed, or window films. In addition to improving comfort, many of these solutions can also save energy by reducing solar heat.

These devices often do a good job at reducing the amount of direct sunlight that reaches into the building, but due to cost, many times they are not included.


Exterior Louvers



Dichroic Fins

# Controlling Glare: Other Solutions

Solar control window films can be a very good option for existing buildings where direct sun is an issue. These films reduce the amount of visual light that is transmitted through the glass and require no occupant action to work. Window films can also improve the exterior appearance of the building by creating a uniform aesthetic, and can save energy by reducing the cooling load needed.

Checkerboard effect of blinds at various heights

Window film providing a uniform look and reduced solar heat

# Building Design: Ceiling and Office Layout

The ceiling and office layout play an important role in providing daylighting deep into a building.

High ceilings will increase the daylighting penetration into the building by allowing the light to bounce further off of surfaces and travel deeper into the space.

Open office designs with low cubicle walls or partitions will also allow the light to travel more freely, unobstructed, deeper into the room. Conversely, high cubicle walls or walled offices will block the light from traveling deeper into the space.

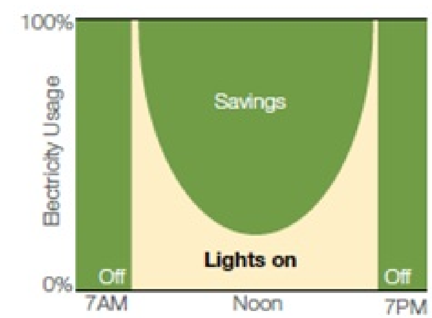
Surface reflections are also important; the higher the reflectance, the more light will be bounced further into the interior. This is particularly important for the ceiling design.


Image courtesy of Armstrong

# Lighting and Controls

To save energy, lights must be turned off or dimmed. Therefore, the lights and controls are important to take advantage of the potential savings. Lights with adjustable dimming ballast can be dimmed at different times of the day or when natural light provides partial lighting to the area.

Photo sensors measure the amount of light to determine how much artificial lighting is required to maintain the desired lighting level. If sufficient daylighting is supplied to the area, the artificial lights can be completely turned off. Sensors are needed at different zones which correspond to different depths within the building, as the amount of natural light will gradually decrease the further you get from the window. Occupancy sensors can also help save energy by turning the lights off or down when no one is present.




Images courtesy of Lutron

Daylight harvesting


# How to Measure Daylighting Performance

# Complexity of Daylighting Measurement

Calculating daylighting can be very challenging as there are many different factors that affect the amount of daylight available.

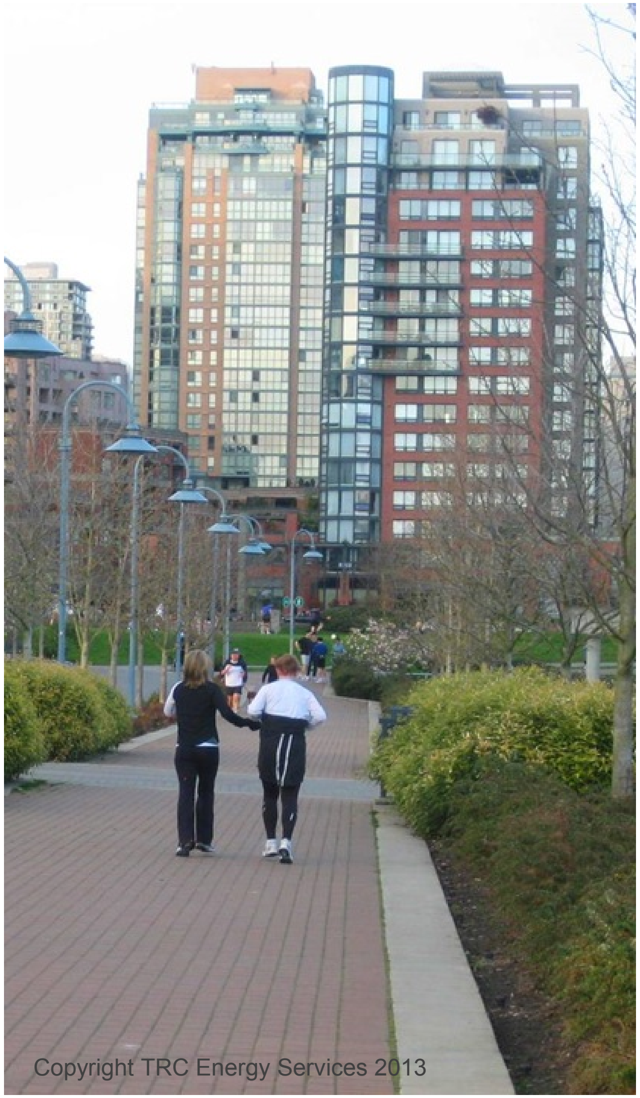
- The building's location in terms of latitude has an impact; for example, the amount of daylight in Alaska compared to Arizona differs greatly.
- The angles and directionality of the sun change throughout the day and year, making accurate measurements more difficult.
- A climate that has mostly clear days will vary from one with variable cloudiness.
- Orientation of the building affects the angles and times the sunlight hits the windows.
- How occupants or automated systems use blinds for glare and heat control also has a large effect on the amount of natural light.

We will next discuss several metrics used to calculate daylighting in a space.

# The Old Metric: The Daylight Factor

Previously, the daylighting world used the daylighting factor, a simple calculation of the ratio of light inside to light outside. The outdoor light measurement is based on an unobstructed, uniformly overcast sky. Therefore, it predicts illuminance only on days when there are no shadows; it does not account for building orientation or latitude, or the use of blinds.

This method does not take direct sunlight into account. As every building should receive direct sunlight, this metric does not take into consideration an extremely important aspect, as direct sunlight needs to be taken into account for occupant comfort.



# LEED v4 (2014)

LEED allows three methods for calculating illuminance levels.

- Site measurements: After the building is completed, illuminance is measured at desk height in a fully furnished office. Actual light measurements are made any time between 9 a.m. and 3 p.m., collected twice about six months apart, and must be between 300 and 3,000 lux over a specific floor area. Three LEED points are available.

- Computer modeling: One computer modeling option allows for task level illuminance measurement at a single point in time, at 9 a.m. and at 3 p.m. on a clear equinox day. There are two LEED points available.

- Dynamic annual simulation modeling: The second computer modeling option can earn up to three LEED points by providing a summation of hourly annual illuminance. Spatial daylight autonomy (sDA), a metric describing annual sufficiency of ambient daylight levels in interior environments, is added to annual sunlight exposure (ASE), a metric that describes the potential for visual discomfort in interior work environments.

# Why Dynamic Modeling?

Accurate daylight design must consider hourly variation in the sun's position, as well as shading and redirection, and weather variations throughout the entire year. Measurements need to account for the behaviors and preferences for how blinds are operated in response to daylight.

Using hourly weather measurements such as the typical meteorological year (TMY) data to model cloud cover allows an understanding of how the design will perform for the year and at what days or times there may be issues.

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# Dynamic Modeling Metrics: UDI, sDA, cDA

Usefully daylight illuminance (UDI) is a metric that is designed to maximize “useful light,” both by calculating daylight performance and taking glare into account in one metric. Light less than 100 lux is not bright enough so is not counted. Additional light over 2,000 lux is determined to be too bright, and this light is also not counted. Light between 100–2,000 lux is deemed “useful daylight.” UDI reports the percentage of floor area that achieves useful daylight 10 hours per day, 250 hours per year, signified as a subscript fraction: $_{10/250}$.

Spatial daylight autonomy (sDA) is the percentage of the floor area that receives 50% daylight autonomy of 300 lux or greater for at least 50% of the year. This metric is integrated in automated analysis tools.

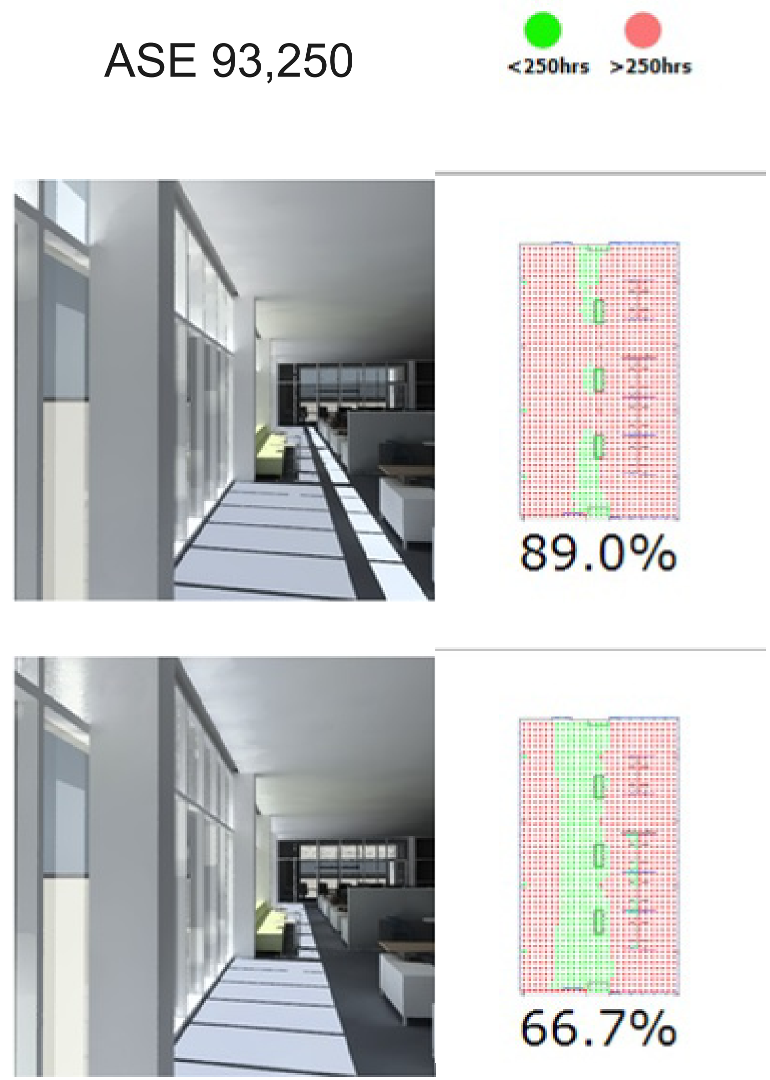
Continuous daylight autonomy (cDA) is similar to sDA but also gives partial credit for daylighting levels under 300 lux.

# Dynamic Modeling Metrics: ASE

Annual sunlight exposure (ASE) calculates the risk for direct sunlight in the space, before blinds or shades are deployed to block sunlight. It measures the percentage of the area that is exposed to direct sunlight, defined as greater than 1,000 lux, for more than 250 hours per year ($_{1,000/250}$).

In the upper image, 89% of the space receives more than 1,000 lux for more than 250 hours per year.

The lower example has daylight redirecting window film applied, and the number is reduced to 66.7%. The smaller the area of floor space with direct sunlight, the better.



# Current Daylighting Products

# Daylighting Strategies

Different daylighting solutions are available for different design and aesthetic considerations.

Toplighting uses light from the roof, such as via skylights and roof windows (monitors). This strategy works on the top floor of a multi-story building and for a single-story building.

A more efficient strategy for multi-story buildings is sidelighting. This technique brings light from the side of the building to deep into the building and is usable on all above-ground floors. Some examples of sidelighting include:

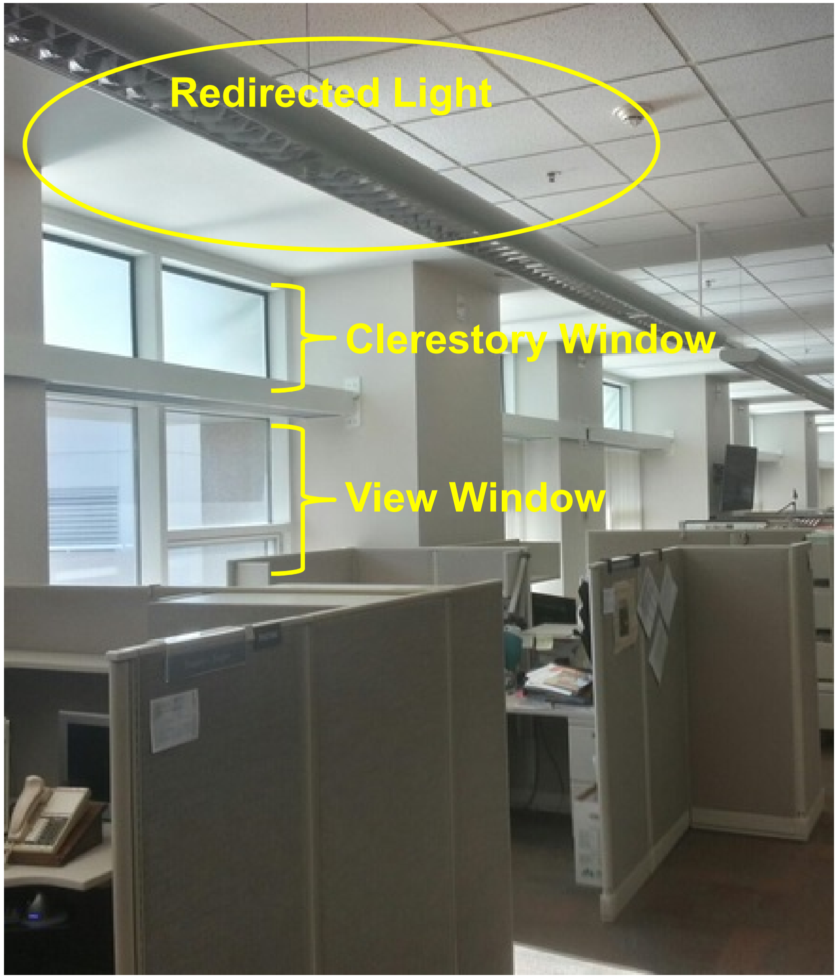
- clear or diffuse clerestory windows
- light shelves
- daylight redirecting blinds
- daylight redirecting films, and
- ducted light systems.

# Sidelighting Window Design

A window can be thought of in terms of its different functions.

A clerestory, or daylighting, window starts at door height and above, approximately 7.5 feet above the finished floor. It serves to provide daylight and ideally redirects sunlight to the ceiling. The higher the clerestory glass (and ceiling), the deeper the penetration of light.

A view, or vision, window is 3–7 feet above the floor. It serves to provide a connection to the exterior, and can be optimized for comfort, privacy, and glare control with blinds or film.




Sacramento Municipal Utilities Department

# Clear Clerestory Glass

Clear clerestory glass works well for indirect sunlight. However, the discomfort from direct sunlight will cause occupants to close blinds (and often leave them closed) or take other measures if blinds aren't available, such as putting cardboard over the glass—thus negating any benefits of having a window in the first place.

The higher the glass, the more occupants will be negatively affected by the direct sunlight, especially at low sun angles.

Diffuse glass can be used, but it spreads the light out instead of redirecting it, so glare and heat will likely still be an issue. Diffuse glass generally provides very little increase in the daylighting penetration but can be slightly more comfortable than clear glass.

Fritted glass is another option. Fritted glass blocks the light, which can help increase comfort, but direct sunlight will still pass through the clear areas of the glass. As a daylighting technique, it has limited value because it is blocking or wasting useful daylight.

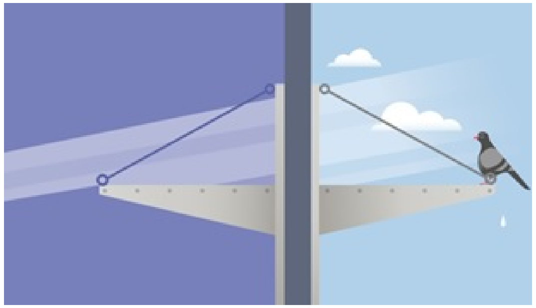
# Light Shelves

Light shelves redirect light up to the ceiling so the light can bounce off the ceiling to increase the daylighting penetration. When the sun angle is high, they also prevent direct sunlight from reaching occupants.

They can be installed on the interior or exterior of a building, between the vision and clerestory glass. This technique also preserves the view out of the upper window when viewed from deep in the interior.

# Light Shelves

The effectiveness of light shelves can vary. Generally, the redirected light is equal to the incoming angle. When the sun is at a high angle, most of the light is redirected close to the window. At low angles, sunlight may bypass the shelf and cause glare.



Low-angle light bypassing shelf

Light shelves reflect the light onto the ceiling like a mirror. This redirected light can be concentrated on one section of the ceiling, causing very bright areas and dark areas which can make the space seem much darker than it actually is.

Light shelf directly below sprinkler head

Light shelves require periodic cleaning to remain effective as they rely on reflective surfaces that must be clear of dirt to work properly. Light shelves can also make it difficult to reach the existing clerestory window for cleaning.

Because light shelves are cantilevered, they require structural load considerations. Light shelves can also cause interference with light fixtures and sprinkler systems and are therefore difficult to retrofit in an existing building.

# Daylight Redirecting Blinds

Daylight redirecting blinds are similar to light shelves in that they redirect light to the ceiling. They are usually made of reflective metallic material and can have a curved shape.

They can be installed inside an insulated glass cavity or on the interior of the building. Usually they are fixed, but adjustable and automated options are available for a higher cost.

Redirecting blinds can be installed as easily as regular blinds or window treatments. Since they do not interfere with light fixtures or sprinkler systems, they can be installed as part of remodeling.

# Daylight Redirecting Blinds

Daylight redirecting blinds have the look of a highly metallic blind. They often block any view to the outside. Direct sunlight will also generally not bypass the blind.

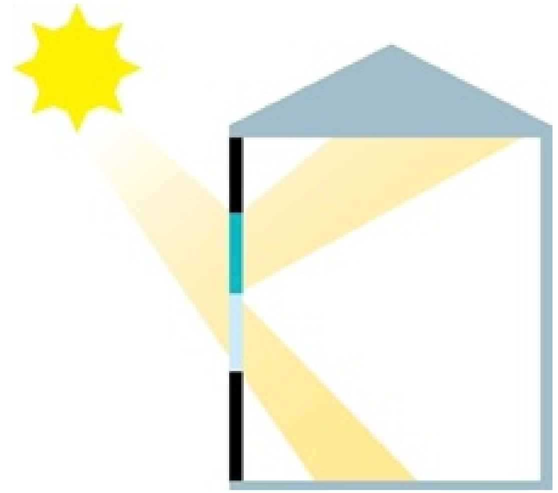
If the blind is installed on the interior, it requires dusting or cleaning similar to a light shelf, or dirt will decrease the effectiveness.

Glare can be an issue at certain solar angles, depending on the blind design.

# Daylight Redirecting Film

Daylight redirecting film is a newer technology now being used. It redirects the light up to the ceiling like a light shelf, but without the low-angle light bypass problems of light shelves and with no special cleaning or maintenance needed.

It is easily installed and can be used in new construction or existing buildings.

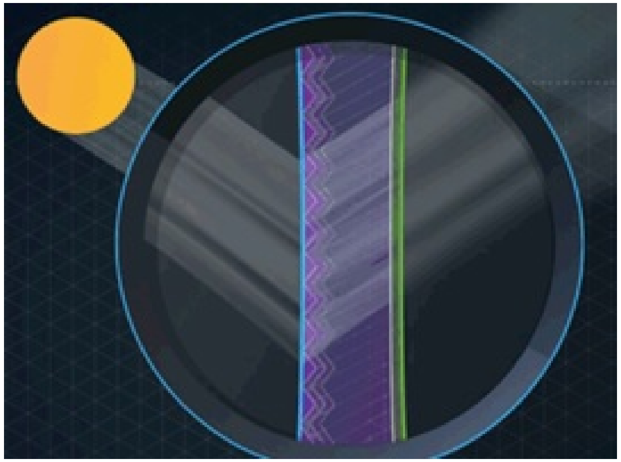


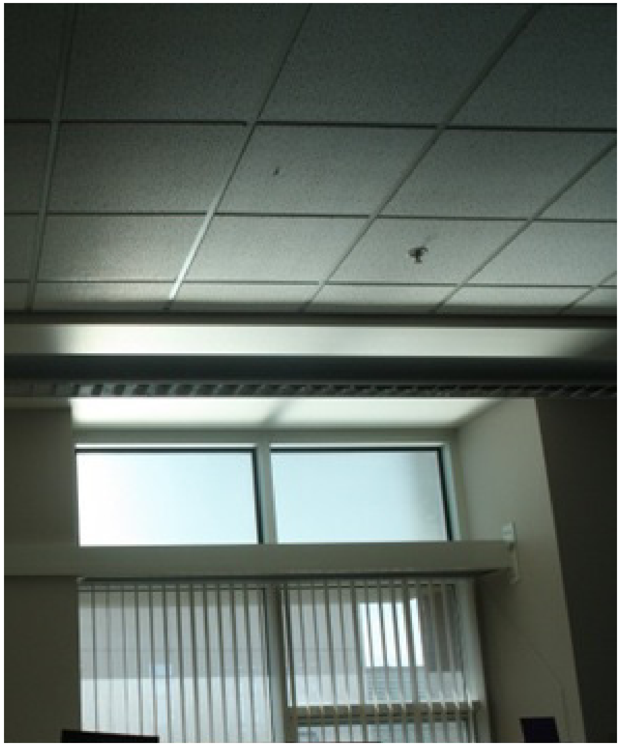
Without film

With film

# Daylight Redirecting Film

The film is made up of microstructures that optically redirect light up to the ceiling. Light is then diffused to spread light more evenly on the ceiling and increase comfort.





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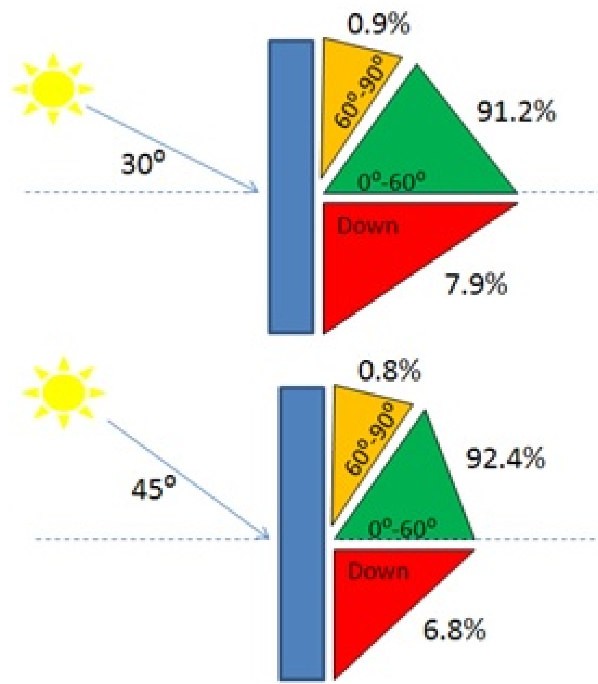
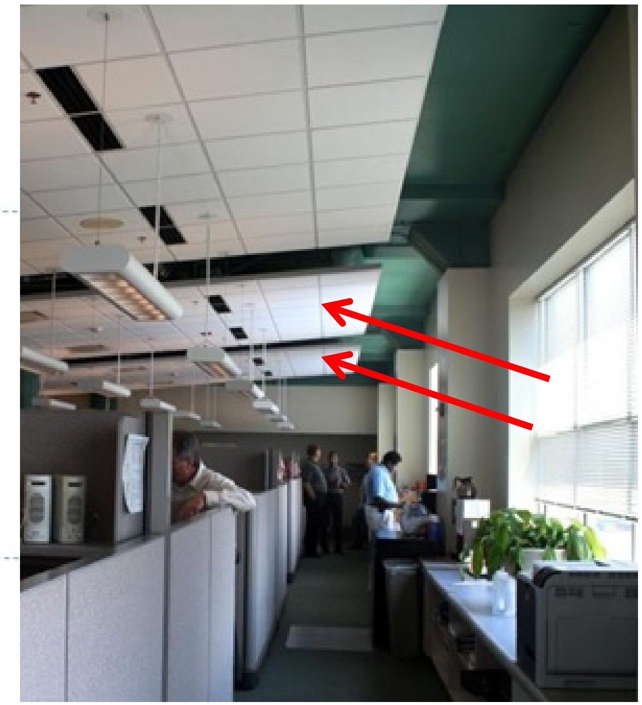
The film has a look similar to frosted glass. Direct sunlight cannot bypass the film, but is instead redirected. Additionally, the film has also been shown to redirect natural light that is not direct, such as that on a north facing or a facing opposite the sun.

# Daylight Redirecting Film

Daylight redirecting film has been designed to redirect the light deep into the building. On average, over 80% of the daylight is redirected upwards. This light is spread at different angles to provide more even illumination than a traditional reflective light shelf.



The film can be combined with solar control film to also reduce the amount of heat. Blinds can be installed to further control the amount of light if needed.

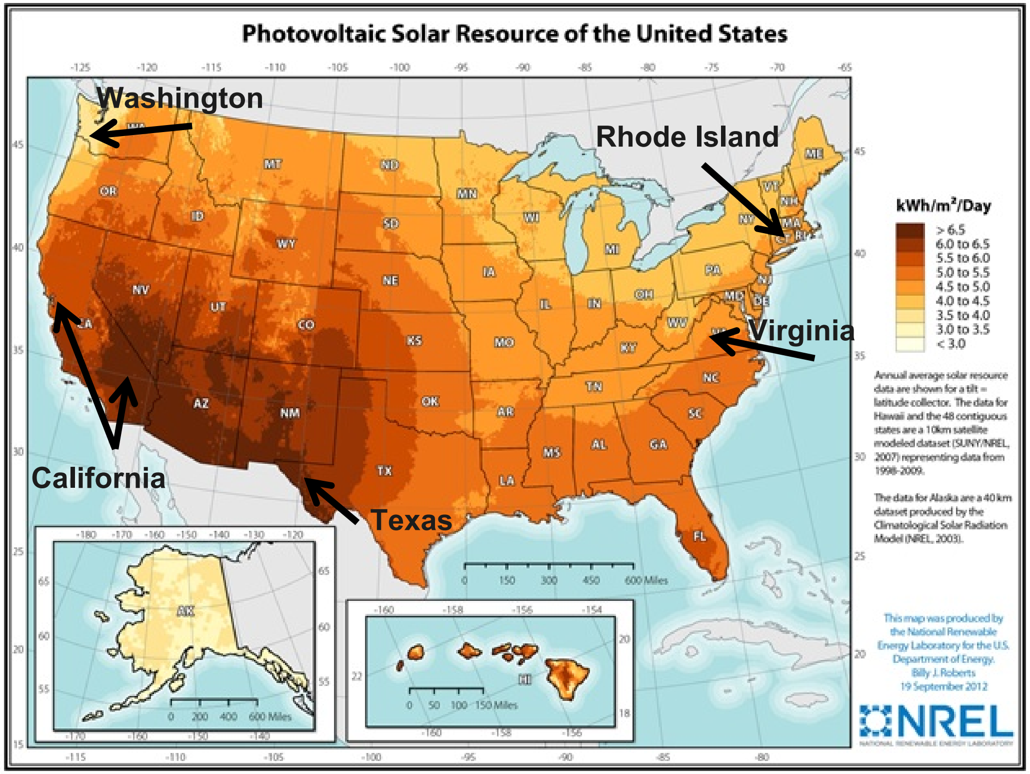
On average, 1' of treated window extends the daylight zone 8' into the room, so 2' extends about 16' into the space.

# Daylight Redirecting Film Case Studies

# U.S. Department of Defense

A study of the U.S. Department of Defense was conducted to evaluate the performance of daylight redirecting film. Film was installed at six locations throughout the U.S. The study was performed by TRC (formerly Heschong Mahone Group) from solstice to solstice to understand performance throughout the year.

Photosensors were installed in an area with film and an area without film to show the difference in lighting levels of the two situations. Four types of sensors were used: ceiling illuminance, curtain/blind status, outside illuminance, and work surface correlation sensors.



# U.S. Department of Defense

Daylight redirecting film was installed on the upper portion of the glass on the far bays; the ceiling light difference is clearly visible at right in comparing the foreground area without film to the area with film in the background.

The increase in illumination was then shown at varying depths from the window as well as times of the year. The table shows an increase in illuminance of 50 fc at 22 feet from the window in the winter season. Most offices are designed to achieve approximately 40 fc, so 50 fc is sufficient for many offices. An increase of 20 fc was also noted as far as 35 feet from the window.

| Distance from Window | Winter Illuminance Increase | Equinox Illuminance Increase |
|---|---|---|
| 8.5 ft | 250 fc | 100 fc |
| 22 ft | 50 fc | 20 fc |
| 35 ft | 20 fc | 10 fc |

# U.S. Department of Defense

The average spatial daylight autonomy increase was 11%, with the highest being 25%. This depends on the design factors and conditions we have described previously, such as latitude, orientation, and climate.

An average peak demand lighting energy reduction of 13% was observed, and in addition to the lighting savings, a 30% energy savings was noted due to cooling load reduction from not having the artificial lights on.

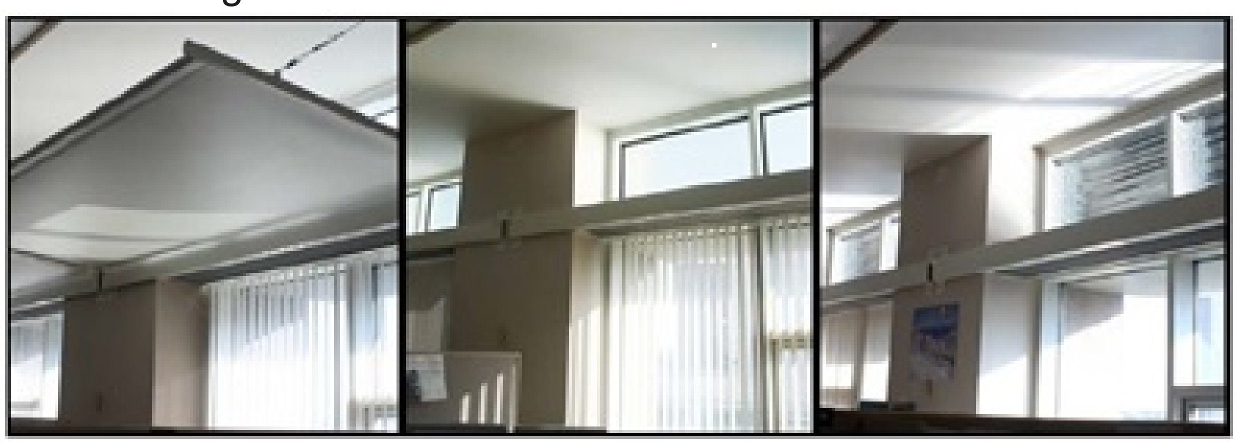
★ Please remember the **exam password LATITUDE**. You will be required to enter it in order to proceed with the online examination.

# Sacramento Municipal Utilities Department

Another study was performed at the Sacramento Municipal Utilities Department (SMUD). The study included a comparison of various daylighting products such as daylight redirecting film, a light shelf/sail, and daylight redirecting blinds. The analysis was conducted by TRC, formerly Heschong Mahone Group.

Light was measured at different distances from the window. The daylight redirecting film provided the most light deep into the building. Occupants reported that the maintenance required for the film is likely to cause the fewest issues, as it is the same as for standard window glass. Most occupants preferred the aesthetics of the film over the light sails and blinds.

Light sails Film Blinds



# Sacramento Municipal Utilities Department

The table shows the lighting illuminance by the different products and the percentage of light each provided to achieve sufficient lighting (30 fc). For example, 100% means no artificial lights are required, as enough natural light is available to do common work tasks. The daylighting zones refer to the distance from the window. Each zone represents approximately 8 feet, so the second zone is approximately 16 feet from the window. Daylight redirecting film provided the most light deep into the building.

| | Reflective Blinds | | Light Sails | | Daylight Redirecting Film | |
|---|---|---|---|---|---|---|
| Daylit Zone | Illuminance (fc) | % of 30 fc setpoint | Illuminance (fc) | % of 30 fc setpoint | Illuminance (fc) | % of 30 fc setpoint |
| First | 57.5 | 100+% | 58.9 | 100+% | 74.0 | 100+% |
| Second | 36.4 | 100+% | 37.0 | 100+% | 45.1 | 100+% |
| Third | 23.9 | 80% | 16.0 | 53% | 26.7 | 89% |

# Sacramento Municipal Utilities Department

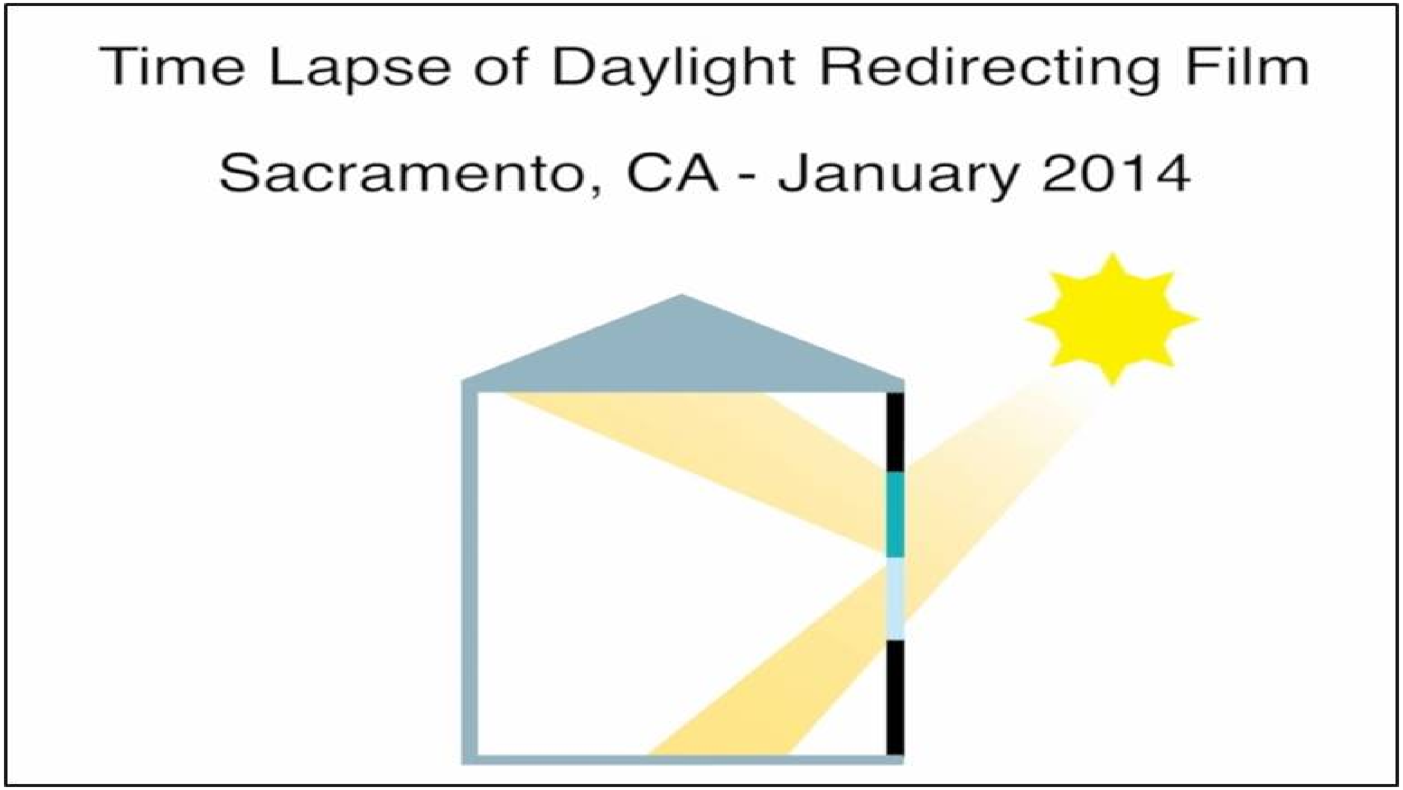
This photo shows the SMUD office. The office had light shelves installed, but the occupants had issues with discomfort/glare at certain times of the year. After the study, the building occupants and managers liked the daylight redirecting film so much, they asked to replace the light shelves with daylight redirecting film.

Before

After

# Time-Lapse Video

The following video will show a time lapse during the course of a day in this area. Pay particular attention to the shadows of smoke detectors and sprinkler heads on the ceiling that show the light being redirected to the ceiling.




Click on the image to view the video; there is no audio.

# Summary

# Summary

Natural light is vital to us all. As we spend more time indoors, the need to properly design for daylighting in buildings is becoming increasingly important. Natural light helps reduce artificial lighting use and will save energy when coupled with proper lighting controls.

Energy savings are just the tip of the iceberg. The benefits of office productivity, patient recovery times, student test scores, increased purchase behavior,...far outweigh the energy savings.

Daylight must be considered as a system; each part of the system must be thought through or issues may arise. Direct sunlight is uncomfortable. It causes us to feel hot and can be too bright and cause glare, especially at low angles of the sun.

Dynamic modeling is the best way to understand how a daylighting product will perform throughout the year. There are a variety of tools and consultants who are able to provide this type of service to understand the performance.

# Summary

There are many different daylighting strategies to bring natural light into the building. Different solutions have a variety of advantages and disadvantages. The solution must be looked at for both performance as well as glare.

Daylight redirecting film:

- redirects up to 80% of the incoming light back up to the ceiling
- allows light to penetrate up to 40' into the interior of the building
- needs no additional maintenance or special cleaning
- will extend the daylight zone 8' into the interior for every 1' of treated vertical window
- is very cost effective compared with other daylighting solutions, and
- has been shown to save up to 52% of the lighting energy compared with baseline lighting energy use.

# Conclusion

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