



U.S. Department of Energy
Energy Efficiency and Renewable Energy



Daylighting



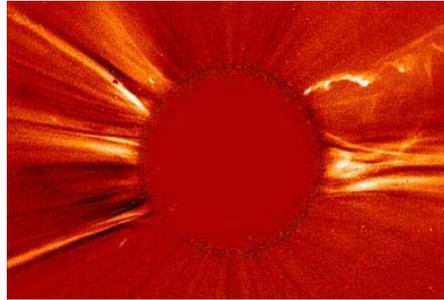
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RBA/ESS





Solar energy

- Most useful when it provides light—lumens, not watts. The sun competes much more favorable against electricity than against cheap gas and oil
- With day-lighting systems, the sun is usually out when it's needed the most, in mid summer when utilities need to shave demand



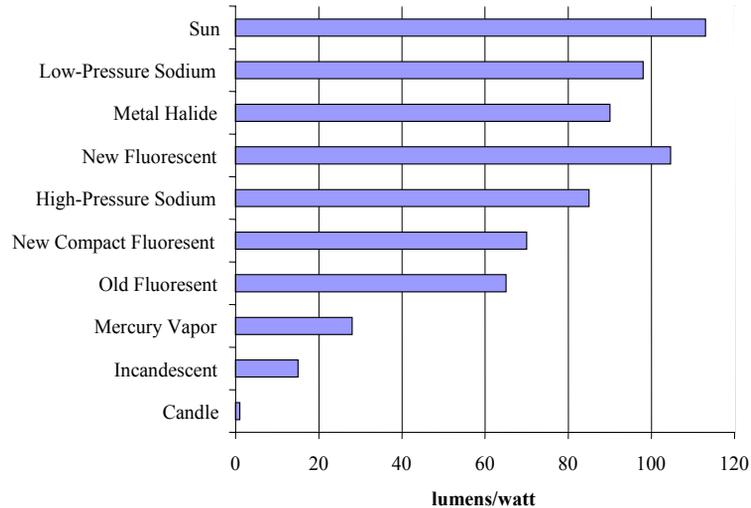
Footcandle

- The illuminance on a surface one square foot in area on which there is a uniformly distributed flux of one lumen.
- The lumens incident on a surface = footcandles x the area in square feet.





Luminous efficacy (Lm/W)

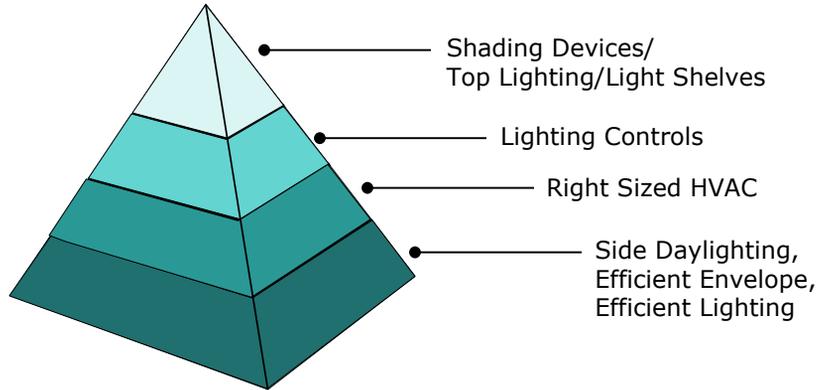


Daylighting...

- Is the use of indirect natural lighting to illuminate the interior of buildings reducing the need for electric lighting



Prioritization – The Daylighting Pyramid



Prioritize Design Strategies Based on First Cost

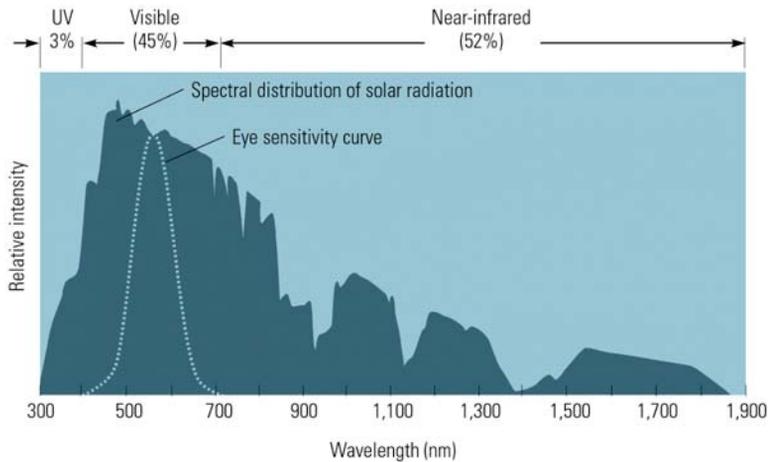


Day-lighting advantages

- The luminous efficacy of direct beam sunshine is about 113 lm/W, and a clear northern sky is 30% better.
- Unlike electric lighting, in the case of day-lighting the “watts” don’t make the meter turn any faster
- Day-lighting not only supplies lumens for free, but also results in a lower cooling load
- Good day-lighting designs lower A/C demand and allow for specifying smaller coolers



The sun is a near perfect “black body” but many wavelengths are somewhat absorbed in passing through the atmosphere



Source: Kreith and Kreider



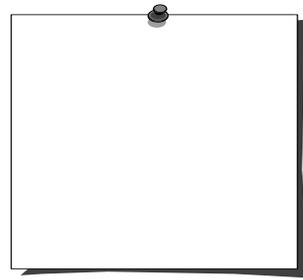
Fenestration terms used in day-lighting

- Visual transmittance (V_t): the percentage of light in the visual spectrum that passes through a window
- Solar heat gain coefficient (SHGC): the fraction of all solar energy (throughout the solar spectrum) that passes through a window
- Recent glazing options include fairly high V_t and fairly low SHGC...yielding more light than heat.

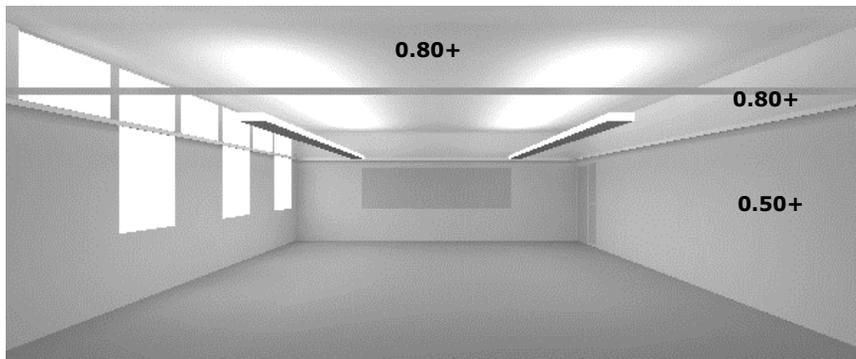


Reflectors

- **Specular** (bathroom mirror)
- **Diffuse** (flat white paint on drywall)
- **Spread** (the less shiny side of aluminum foil; aluminum paint)
- Each is useful in creating good lighting environments



Interior Finishes - Reflectance



Minimum Reflectance Values



Key objectives in day-lighting design

- Designing spaces to use controlled natural light (reduce glare and address low solar angles)
- Using day-lighting to provide the primary illumination within a space (where possible)
- Optimizing the use of natural and electric lighting



Day-lighting design pitfalls



- Buildings architecturally “designed” without careful attention to fenestration
- Incorrectly designed windows and/or skylights
- A building with good daylight illumination but with electric lights burning away



Beam sun light is not useful directly (but it can be spread over white surfaces such as ceilings to produce pleasing diffuse light)



Evolution of windows in the classroom

- 50 years ago, most schools (and workplaces) used day-lighting
- In the late 1960s and 70s, windows were considered:
 - A distraction for children
 - An energy liability
 - A maintenance liability
 - A security liability
- The “Open Classroom” of the 1970s was often a windowless classroom, in a big, open-plan building
- “Energy conservation” retrofits have often removed daylight in an effort to save energy and reduce maintenance



Basic principles of solar orientation

N



Worst Exposure

- North and south ends provide minimum interior light
- East and west sides tend to introduce too much light and heat
- East and west sides require complex shading systems
- Shading often requires blocking view glazing



Basic principles of solar orientation

N



Ideal Exposure

- North side can introduce a maximum of diffuse daylight
- South side can be passively shaded most of the year without blocking view glazing
- East and west sides can have minimal fenestration



Day-lighting design principles

- Allow **no** direct sun penetration that can fall on viewers' eyes ,except in circulation spaces.
- Diffuse the light broadly through diffuse reflectors, glazing, and/or shading.
- Introduce daylight as high as possible.
- Use light-colored surfaces.
- Keep brightest surfaces out of line of sight.
- Provide blinds or louvers where there is potential for glare and for audio-visual control.



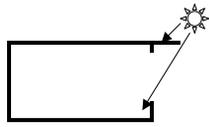
Other day-lighting design considerations

- Natural ventilation
- Visual communication
- Noise control
- Radiant comfort - hot and cold surfaces
- Safety and security
- Air and water leakage
- Condensation
- Maintenance and replacement

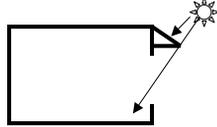


Day-lighting schemes

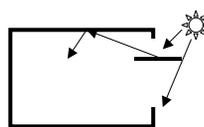
Sidelighting



Window w/ Overhang

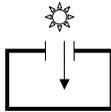


Window w/ shading

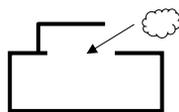


Window w/ light shelf

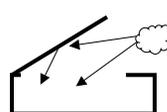
Toplighting



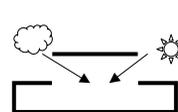
Skylight



Clerestory



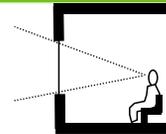
Sawtooth clerestory



Monitor



View windows

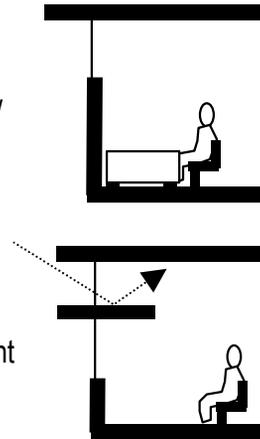


- Provide access to exterior views through view windows for all interior spaces where students or staff will be working for extended periods of time.
- View windows are often inefficient at supplying working daylight to the space since light levels diminish with the square of the distance from the window.. However, areas where many buildings will be multi-story, side lighting is the only option for lower floor spaces and should be designed to provide as much useful daylight as possible with the least problematic glare.
- Operable view windows provide emergency egress and natural ventilation.



Clerestories – with or without light shelves

- Clerestories can be used in all school spaces to provide deep penetration of daylight.
- A light shelf is a horizontal panel placed below high clerestory glazing (generally with a view window below it) that improves light distribution.
 - Daylight reflects off top surface onto the ceiling.
- Use light shelves or louvers to improve daylight distribution, block direct sun penetration, and minimize glare.



Skylights

- Proper sizing needed
- Modern skylights using prismatic refractors and other technologies help control glare
- Skylights are:
 - Effective all day long
 - Effective under sunlight or cloudy skies
 - Comparatively inexpensive
 - Relatively independent of building orientation



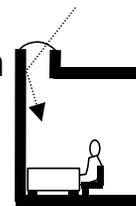


Skylights in Salida, CA middle school



Wall wash top lighting

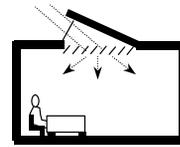
- Use wall wash top lighting for interior classroom walls to balance daylight from window walls, brighten interior classrooms, and make them seem more spacious.





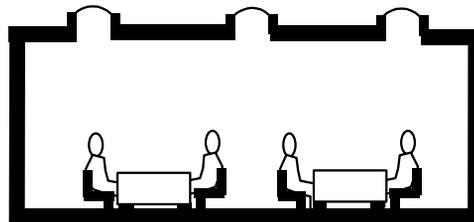
Central top lighting

- Central top lighting is accomplished by a central monitor or skylight (or cluster of skylights) that distributes daylight evenly across the room.



Patterned Top Lighting

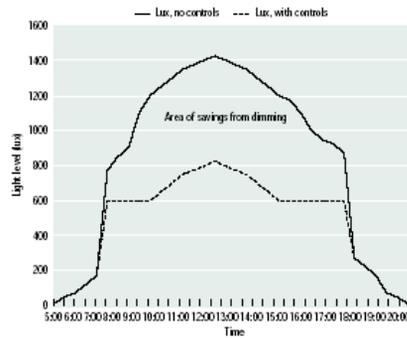
- Use patterned top lighting in interior spaces that need even, low glare illumination across large areas like gyms, cafeterias, and libraries.





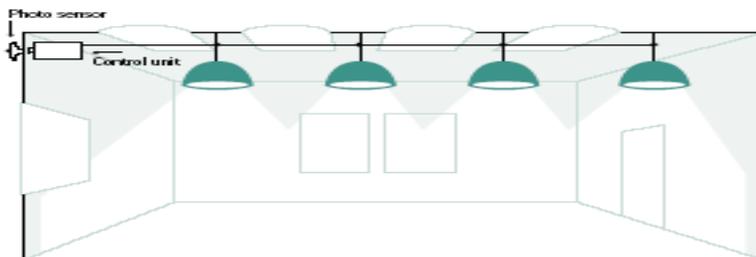
Dimming

- A necessary condition for an effective day-lighting system
- Dimmable electronic ballasts are cost effective
- Well-designed systems respond to sunlight and occupancy



Open loop dimming

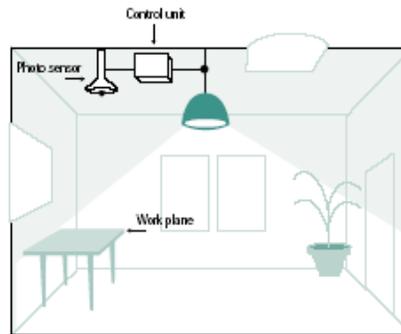
- Least expensive dimming option
- Many lights may be dimmed with a single simple sensor that senses only exterior light
- Applicable in atria, gyms, meeting areas





Closed loop dimming

- Sensor monitors natural and electric light, dims electric to set point
- Applicable in classrooms and offices
- Systems are improving, becoming simpler and less expensive



Day-lighting examples





Day-lighting on both sides



Integrated sidelighting





Top lighting



Sidelighting





Overview – benefits of day-lighting

- A pleasant and appealing environment
- A natural interior environment with excellent color rendering
- Improve academic performance
- Significant energy and demand savings



Daylighting Studies

- Daylighting in Schools
 - PG&E/Heschong Mahone
 - www.h-m-g.com
 - students spending one year in a daylit school progressed
 - 20 % faster on math tests
 - 26% faster on reading tests
- Skylighting and Retail Sales
 - PG&E/Heschong Mahone
 - www.h-m-g.com



Daylighting Studies

- Daylighting in Schools – Re-analysis
 - CEC/NBI/Heschong Mahone
 - www.newbuildings.org
- Daylight and Productivity
 - Lighting Research Center 9/01
 - www.lrc.rpe.edu

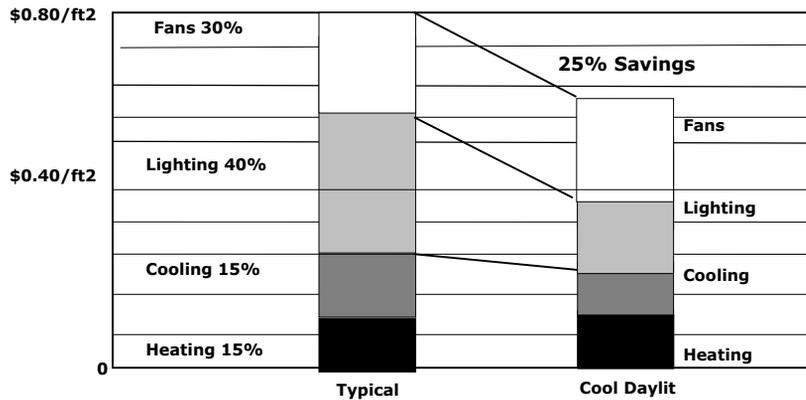


North Carolina study

- In Johnston County, North Carolina, students attending daylit schools outperformed students in non-daylit schools by 5 to 14%.
- Daylit schools saved average of 64% less energy than typical schools in same county



School Energy End Uses – Potential Savings

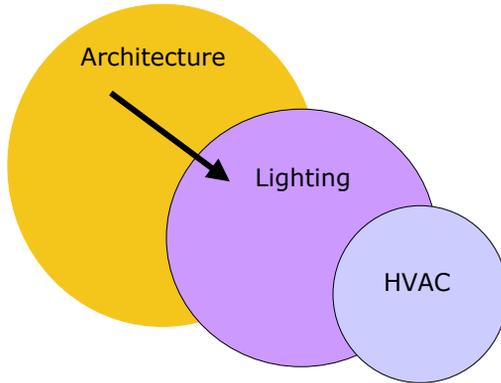


Daylighting and energy use...

- **Cool daylighting** is a holistic, design strategy that facilitates the effective utilization of daylight to reduce the need for artificial illumination, without increasing **COOLING LOADS** or causing **UNWANTED GLARE**



Work from “Macro” to “Micro” Scale



Architecture sets the stage for...

Successful lighting and HVAC



It Doesn't Stop With Lights

- Less artificial lighting = lower heat gain to spaces.
- Less heat gain to spaces = less cooling demand.
- Less cooling demand = less fan and pumping energy.





Daylighting Aperture Placement

- Question:
Why are electric lights generally not placed on walls?



Daylighting Aperture Placement

- Answer
The amount of light (illuminance) is important, but brightness (luminance) is equally important. We want footcandles, but without excessive contrast and glare.



What is WRONG with This Picture – Congress Elementary School (BEFORE)?



What is RIGHT with this Picture Congress Elementary School (AFTER)?





Its up to you....

- Failure to capitalize on these benefits can lead to wasted and costly lost opportunities, and unnecessarily reduced performance occupants, *for the lifetime of the building!*