

B. DAYLIGHTING AND WINDOWS

1. General

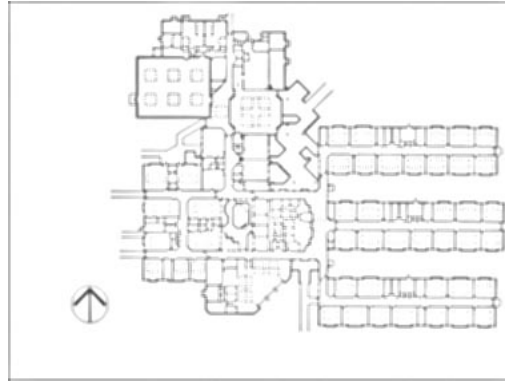
- a. Of all the high performance design features typically considered, daylighting may have the greatest impact on Wake County facilities. Optimum daylighting design significantly reduces energy consumption and also creates improved learning and working environments. Daylighting has been shown to result in increased attendance, improved grades for students, and increased productivity of the occupants. When properly designed, windows, clerestories, and roof monitors can provide a large portion of the lighting needs without undesirable heat gain or glare.
- b. Electric lights produce more waste heat energy than daylighting, for the equivalent lighting effect. Waste heat must be removed in warmer months through ventilation or air conditioning, using additional energy. Sunlight, on the other hand, is a cooler light. Reductions in cooling loads due to daylighting strategies often enable designers to downsize air conditioning systems, reducing the initial cost of equipment. High performance windows help to minimize heat gain in warmer months and heat loss in colder months. Although windows can create glare and skylights may cause overheating, properly designed daylighting strategies can reduce both lighting and cooling energy consumption. Glare can also be controlled through good design practices.



Effective Daylighting strategies reduce both lighting and cooling loads.

2. Building Orientation and Solar Access

- a. By elongating the building design on an east-west axis, the potential for cost-effective daylighting is maximized.
- b. Consider daylighting strategies using south- or north-facing glass. This makes unwanted, excessive radiation much easier to control. An elongated building that has its major axis running east-west will also increase the potential for capturing winter solar gain as well as reducing unwanted summer sun that more often strikes on the east and west surfaces. Exposed, eastern- and western-facing glass should be avoided wherever possible because it will cause excessive summer cooling loads. South glass should incorporate properly sized overhangs, lightshelves or shading techniques that limit radiation in warmer months and prevent direct sun at critical cooling times of day.



To optimize solar access, develop a building plan elongated along an east-west axis.

- c. Verify that other exterior design elements or existing site features do not negatively affect the daylighting design.
- d. Make sure other building elements are not inadvertently shading glazing areas that are designed as daylighting elements.
- e. Consider the reflectance of the materials in front of the glazing areas. The use of lighter roofing colors can reduce the glass area needed for roof monitors, while a light colored walkway in front of a lower window may cause unwanted reflections and glare inside areas of a building.

3. Daylighting Design Strategies

- a. Because lighting is a significant component of a building’s energy consumption, efforts to use daylighting should be given a high priority.
 - 1) Good daylighting design can reduce the electricity needed for both the lighting and cooling needs of a building. Daylight provides a higher ratio of light to heat than electrical sources. This ratio, known as lighting efficacy, is much higher for daylight than for electric light sources, meaning that daylight provides more light and less heat, greatly reducing cooling loads. The following chart compares the efficacy of various light sources.

Lighting Efficacy	
Lighting Source	Efficacy (Lumens/Watt)
Beam Sunlight / Diffuser Skylight	110-130
High Intensity Discharge (high pressure sodium, metal halide)	32-124
Fluorescent	55-90
Compact Fluorescent	50-60
Incandescent	10-20
Sunlight provides more lumens/watt than electrical lamps Source: Lawrence Berkeley National Laboratory Lighting Market Source Book for the United States	

- 2) Consider daylighting apertures to limit the amount of direct beam radiation entering during the hottest part of the day in the cooling season. This would mean that east- and west-facing glass should be minimized. South-facing vertical glazing is typically better because roof overhangs can be designed to effectively admit low-angle winter radiation for daylighting while excluding excessive higher-angle sunlight in the warmer months. North glazing is second best because it doesn't create overheating problems during the cooling seasons but it also doesn't provide any passive heating benefits.
- 3) Consider using a well-designed overhang to mitigate the potential drawbacks of summertime solar gains through south-facing glazing. An oversized overhang on the south is not recommended on daylighting apertures since it can also block significant amounts of diffuse radiation in addition to the direct beam.
- 4) Develop a daylighting design with primary emphasis on south- (typically best) or north-facing roof monitors and a secondary emphasis on south-facing lightshelves. Lightshelves can significantly enhance the natural lighting uniformity within a space and also provide good lighting in narrow rooms (less than 16 feet to 20 feet). Lightshelves may also be the only practical option on multiple-story buildings.

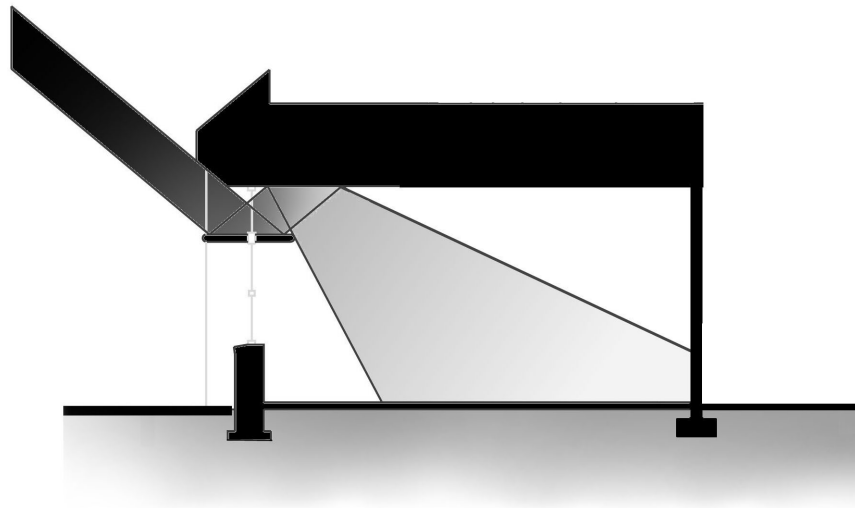
4. Roof Monitors and Clerestories

- a. Roof monitors should be considered to typically perform two critical functions: they provide uniform light within the room, and they eliminate glare.
 - 1) Design daylighting strategies to meet the different lighting needs of each major space while accounting for:
 - a) differing lighting level requirements by time of day; and
 - b) the ability to darken particular spaces for limited periods of time.
 - 2) If south-facing roof monitors are employed, they should:
 - a) employ baffles within the light wells to totally block direct beam radiation from striking people, reflective surfaces, or computers;
 - b) block high summer sun with exterior overhangs; and
 - c) reduce contrast between very bright surfaces and less bright areas.
 - 3) Optimize the design of roof monitors to enhance their benefits.
 - a) Minimize size and maximize transmission of glass to reduce conductive losses and gains.
 - b) Develop an overall building structural design that integrates the daylighting strategies and minimizes redundant structural elements.
 - c) Consider clear double glazing or clear double glazing with argon for south-facing windows.

- d) Choose light-colored roofing materials in front of roof monitors to reflect additional light into the glazing.
- e) In roof monitor/lightwell assemblies, consider incorporating white (or very light-colored) baffles that run parallel to the glass and are spaced to ensure that no direct beams can enter into the space. These baffles should be fire-retardant and UV resistant. Using light-colored translucent baffles reflects the sunlight into the space and eliminate contrast from one side of the baffle to the other.
- f) At the bottom of the lightwell, consider providing a transition between the vertical plane surface and the horizontal by introducing a 45 degree transition, if possible. This will decrease the contrast between the higher light level inside the lightwell and the horizontal ceiling.
- g) Ensure that the walls and ceiling of the roof monitor are well insulated and incorporate appropriate infiltration and moisture barriers.

5. Lightshelves

- a. Consider the use of lightshelves made of a highly reflective material that can bounce the sunlight that strikes the top of the surface deep into the building. The reflected sunlight will hit the ceiling and, in turn, provide light for the room. This is an effective strategy for rooms up to 20 feet deep and can be employed in multi-story buildings or where roof monitors are not possible.



Using lightshelves on south-facing windows allows natural light to bounce deep into the room.

- b. Select durable materials, capable of carrying the weight of a person, for both interior and exterior lightshelves.
- c. Consider aluminum exterior lightshelves as a good compromise between good reflectance, little or no maintenance, and cost.

- d. Consider incorporating white painted gypsum board on top of interior lightshelves. Aluminized, acrylic sheets applied to the top of the shelf allow light to bounce further back into spaces and can improve performance in deeper rooms without top lighting.
- e. Use blinds as a strategy to enhance the performance of lightshelves.
- f. Consider controlling the windows located above and below the lightshelves independently. On the south façade, daylighting can be enhanced by incorporating vertical blinds that focus radiation to the perimeter walls within a space and away from people within the space.

6. Lighting Controls

Lighting controls can ensure that occupants always have adequate light while energy efficiency is maintained. Enhance the economic benefits and provide for smoother transition between varying light conditions by implementing multi-staged or dimmable lighting controls.

- 1) Provide sensors mounted in a location that closely simulates the light level (or can be set by being proportional to the light level) at the work plane
- 2) Implement a fixture layout and control wiring plan that complements the daylighting strategy
- 3) Provide means to override daylighting controls in spaces that are intentionally darkened for special uses or presentations..

7. Interior Finishes

- a. The color of interior finishes will have a dramatic impact on the lighting requirements within the space.
 - 1) Consider using white (or very light colored) paint inside the lightwell area.
 - 2) Apply carpet or other floor coverings that are as light as is practical for maintenance. This will greatly enhance reflectance and require less glazing to produce the same light levels.
 - 3) If there are television monitors, computers, or whiteboards in the classrooms, consider locating them so as to minimize glare.
 - 4) Enhance the daylighting by considering placement of south-facing windows with lightshelves close to perpendicular interior north-south walls.

8. Skylights

- a. Consider skylights if they can be specifically designed to avoid overheating during the cooling season and perform well with minimum maintenance.
 - 1) If skylights are used, specify those that incorporate:
 - a) motorized, louvered systems that seasonally and hourly adjust to allow the optimum amount of radiation to enter the glazing; and
 - b) a means to reduce glare and diffuse the radiation once inside the space.

9. Windows

- a. Windows have a significant impact on energy consumption. The characteristics of the windows and their location, orientation, design, and purpose will determine, to a great degree, the level of energy-efficiency the facility achieves.
- b. In all cases, windows should be made of high-quality construction, incorporate thermal breaks, and include the appropriate glazing for the particular application. To determine the optimum glazing for each application, the designer should conduct computer simulations that compare options. The US Department of Energy’s DOE-2 program is one of the better analytical tools available for this purpose.

Solar Transmission Values for Typical Glass Types		
Glazing Type	Solar Transmission	Equivalent U-Value
Clear, Single	75%-89%	1.11
Clear, Double	68%-75%	0.49
Low-e, Double, Clear	45%-55%	0.38
Low-e, Tinted, Grey	30%-45%	0.38
Low-e, Argon	45%-55%	0.30

Considering the transmission values of glass by orientation can greatly reduce cooling loads.

- c. Analyze and select the right glazing for each orientation, location, and purpose. If windows are:
 - 1) Oriented east and west and not externally shaded, the best choice is to use a tinted glazing with low-e or low-e with argon.
 - 2) Well-shaded by building elements (e.g., overhangs) or north-facing, tinting is not advised since it restricts the transmission of diffuse radiation.
 - 3) Located close to the floor, comfort becomes a more critical issue and low-e or low-e windows with argon glazing are appropriate.
 - 4) Designed as daylighting components above lightshelves or in roof monitors, the best option is typically clear double glazing or clear double glazing with argon.

Window Selection Considerations		
Application	Exposure	Type
View Glass (non-daylighting apertures)	South	clear double, low-e with argon
	North	clear double, low-e with argon
	East/West, unshaded	Tinted, double, low-e with argon
	East/West, shaded	clear double, low-e with argon
Windows Above Lightshelves	South	Clear double or clear double with argon
High Windows above view glass	North	Clear double or clear double with argon
Roof Monitors	South	Clear double or clear double with argon

The intended application and exposure of a window determines appropriate window selection.

- 5) For non-daylighting apertures, consider selecting spectrally selective, low-solar gain, low-e glazing glass.
- 6) If no other external shading is implemented, tinting glazing can be considered as a means of reducing excessive solar gain.

10. Exterior Window Treatments

The most efficient means of appropriately restricting unwanted solar gain from entering glass areas is to block the radiation before it gets to the glazing.

- 1) Properly-sized, fixed overhangs on south-facing roof monitors and lightshelf glazing block a large portion of the mid-day summer sun while still allowing the lower winter sun to reach the glass.
- 2) Incorporate overhangs or other design elements above east- and west-facing glazing so that they effectively block the morning and afternoon sun.
- 3) Consider the advantages of using seasonally adjustable or stationary awnings, solar screens, shutters, or vertical louvers when fixed overhangs are not possible or are impractical.

Light Transmission Values

0.9	Standard Double Glazing
0.5–0.9	Internal Venetian Blinds—Drawn
0.4–0.8	Internal Curtains—Drawn
0.4–0.8	Internal Roller Blinds—Drawn
0.7	Heat-Absorbing Glass
0.6	Tree Providing Light Shade
0.5	Internal Blind—Reflective Backing
0.4	Solar Control Glass
0.2	External Blinds—Drawn
0.2	External Shutters—Closed

Transmission of light is greatly impacted by the type of window treatments used.

11. Interior Window Treatments

If exterior window treatments can not effectively control the seasonal and daily variations in radiation (and resulting glare), or if it is necessary to be able to darken the particular space, blinds or shades may be considered.