DAYLIGHTING collaborative CASE STUDY

Appleton School District • Appleton, Wisconsin

When Bob Zuehlsdorf, Facility Director for the Appleton School District, decided to retrofit the windows in two area elementary schools, he didn't just go with the conventional choices. With the help of the Energy Center of Wisconsin's Daylighting Collaborative he pursued the energy efficient alternative of daylighting—the use of natural, indirect sunlight to supplant electric lighting.

Now, three classrooms in the Richmond and Foster Elementary schools are lit using daylighting principles and serve as examples of what can be done with daylighting—at minimal cost. Teachers love the lighting in the new classrooms and the potential energy savings for the district are substantial.

The Process

Zuehlsdorf had been involved with a window replacement program for several buildings in the district. At that time a typical replacement was plain, insulated glass and dropped ceilings. However, he had noticed over the years that glare was often a problem.

Zuehlsdorf then attended a Daylighting Collaborative training. At the training he learned that daylighting can eliminate glare problems and cut energy costs. As a start, the Collaborative suggested that he retrofit some of the district's classrooms as copyrooms, which are examples of daylighting principles that can be easily implemented elsewhere.

The Rooms

The school district replaced old fixtures, installed new high reflective ceilings, used high-reflection paints, replaced windows, and installed controls to sense room light levels. The classrooms incorporate two types of windows—clerestory and view windows. Clerestory windows are narrow windows located adjacent to the ceiling; they are the primary source of room light. View windows are larger windows located directly below the clerestory. The view windows have perforated roller screens or intra-glass blinds to reduce incoming light during the brightest part of the day—although the blinds are rarely needed.

Richmond Elementary School windows.

The rooms are painted in two tones to enhance downlighting. The ceiling and upper walls are painted bright white; the lower walls are painted light gray. Direct/indirect fixtures supply the lighting (light shines straight down and is also bounced off the ceiling). The fixtures are tied to sensors mounted near the first row of lights near the windows that monitor the incoming light and supply electric lighting as needed to keep illumination levels constant.

Daylighting techniques in the three copyrooms vary slightly. The

two copyrooms at Foster Elementary School have 4-ft. overhangs from the original building that help block direct sunlight from entering the rooms. One of the Foster copyrooms has parabolic light fixtures that are flush with the ceiling. The copyroom at Richmond Elementary School has a sloped ceiling that helps bounce incoming light down into the room.

Human Performance

The copyrooms are having a positive impact on teachers and visitors. "I feel myself relaxing when I walk into this room," says Sheila Omholt, Principal of Richmond Elementary School. "It's a calming, soothing environment." Tracy Groth, who teaches fourth grade at Foster Elementary, notes fewer headaches. And Terri Schultz, the 6th grade teacher at Richmond Elementary School, says her copyroom is "more invigorating and makes the environment a lot more open." All three teachers noted that outsiders often comment on how nice the rooms look.

Omholt recalls a group of teachers and social workers that met in that room. "They were taking off their coats and putting their papers together. And almost to a person they started looking up," she says. "They could notice that something was different. And we could tell them, 'You're noticing our new lighting.'" She further notes that the school board was impressed when they toured the school and that the other teachers have asked for daylighting in their own classrooms.

"The biggest benefit of the copyrooms is that owners can test daylighting," says Daylighting Program Manager Abby Vogen. "People can become familiar with the new light fixtures and the lower light transmittance of the windows. Once people experience the space they understand the lighting benefits of daylighting." Another benefit: According to studies by the Herschong-Mahone group, daylighting can also increase student test scores.

QUOTES FROM SCHOOL PERSONNEL

"The school board was very impressed by the appearance of the room and the amount of light." — Judy Baseman, Principal, Foster Elementary

"A lot of the teachers are asking, 'When can we have daylighting in my room.'" — Sheila Omholt, Principal, Richmond Elementary School

"It's better for my eyes and I have fewer headaches compared to the old lighting system." — Tracy Groth, Teacher at Foster Elementary School

"I feel myself relaxing when I walk into this room. It's a calming, soothing environment."— Sheila Omholt, Principal, Richmond Elementary School

Foster Elementary classroom showing window screens.

Economic and Environmental Performance

Facility Director Zuehlsdorf is committed to energy efficiency and is excited about the prospects for the district. "We have a two million dollar energy budget, so it's a big part of our controllable costs," he said. They recently spent $700,000 for an energy efficient lighting retrofit and have outfitted two other rooms with daylighting windows. He plans to follow with high performance lights and controls later.

"There is a significant decrease in energy consumptions because there are fewer lights, and the lights that are there are dimmed," says Ted Wilinski, project engineer.

The copyrooms are saving about one peak kilowatt per classroom and reduce electricity use by about 50 percent. The savings are primarily from having less electric light use and would be even more if the schools used central air conditioning, because using natural daylighting prevents heat build up from electric lighting.

Per square foot energy costs could drop 50 percent, to $0.48, for non-air-conditioned facilities (for air conditioned facilities, energy costs could drop to $0.35 per square foot). The Collaborative estimates that, at minimum, the state of Wisconsin could save at least 93 million dollars in utility bills over ten years by adding cool daylighting to schools in need of major renovations—a payback of about four years.

In addition, the daylit copyrooms are saving on environmental emissions. Each room cuts annual nitrogen and sulfur dioxide emissions by about 10 pounds and carbon dioxide emissions by over three tons.

The Evolution of a Classroom

Three different approaches to daylighting are evident at Richmond Elementary School, allowing visitors to compare and contrast approaches to daylighting. The original classrooms were outfitted with clear, single-pane glass (Figure 1). Richmond teacher Terri Schultz comments: "The old windows let in too much sunlight, cold air and even bugs. The majority of the time I had the blinds pulled down. I would characterize the original lighting as harsh."

Renovations were already underway, resulting in the modifications shown in Figure 2. Clear insulated glass in dark, brown frames were used. Though an improvement, the renovations were not ideal. "These window frames are too dark," says Schultz. "And the window patterns cut off the connection the outdoors and is too confining. Plus the daylight is still too harsh."

The Daylighting Collaborative suggested the solution shown in Figure 3—glare-reducing, low-glass; a smaller, energy-efficient lighting system with daylighting sensors; and wall treatments to increase the reflectance of the room near the ceiling. Schultz was assigned to the copyroom and enjoys teaching in the new classroom. "With the new windows, I rarely use the shades," she says. "I like the strong connection to the outside, without all the distractions, and the lights are not harsh."

Figure 1. Original windows and lights at Richmond Elementary School in Appleton, Wisconsin. Notice the unfiltered daylight that produces glare on the desks, and the uneven light on the ceiling from the poorly diffused fluorescent fixtures. Lighting power density: 1.53 W/sf.

Figure 2. Original window renovation at Richmond Elementary School. The high contrast between the dark brown frames and the outside light is less than ideal. Glare is still evident on the two tables near the blackboard. Lighting power density: 1.53 W/sf.

Figure 3. Daylighting copyroom at Richmond Elementary School. Notice the warm, even distribution of light on the ceiling and reduced glare on the desks. The room is evenly lit, with little stark contrast to distract the eyes. Lighting power density: 0.81 W/sf.

Energy and Cost Savings

For this Richmond Elementary School classroom, energy savings come from both lights and air conditioning (884 sf room, unit ventilator at 900 CFM).

	BASE CASE	PREVIOUS RETROFIT	COOL DAYLIGHTING (WITH DIMMING)
Lights (kWh)	2773	2773	471
Equipment (kWh)	890	890	890
Pumps / auxiliary (kWh)	156	103	100
Fans (kWh)	1216	1216	1216
Total (kWh)	5035	4982	3664
Peak kW (September)	2.2	2.2	1.6
Electric savings	$402	$396	$292
Savings	$512	$285	$275
Total utility savings	$914	$683	$567

Lighting

	Richmond:	*Foster West:*	*Foster East:*
Lighting system	Pendant mount direct-indirect	Pendant mount direct-indirect	Troffers
Lamp type	T-8		
Controls	On/off with manual dimming Occupancy sensor and photo sensor override		
Lighting power density—Before retrofit	1.53 W/sf		
Lighting power density—After retrofit	0.81 W/sf		

Windows

Casement: Wausau Windows Series 3250

GLAZING	CLERESTORY	VIEW WINDOW
Model	Viracon VE3-85	Viracon VE3-40
Color	Light gray	Light gray/amber
Shading coefficient	0.38	0.22
Visible light transmittance	38%	18%
UV light transmittance	11%	4%
U-value	0.32	0.32
Coating	Low-e	Low-e

More Window Details

Window-to-wall ratio	Richmond: 79%	Foster: 33%	
Overhangs	Richmond: none	Foster: 4 ft	
View window coverings	Richmond: Perforated roller screens	Foster East: Perforated roller screens	Foster West: Between-glass Venetian blinds
	(Blackout shades available for entire window in all 3 rooms)		

Building Specifications

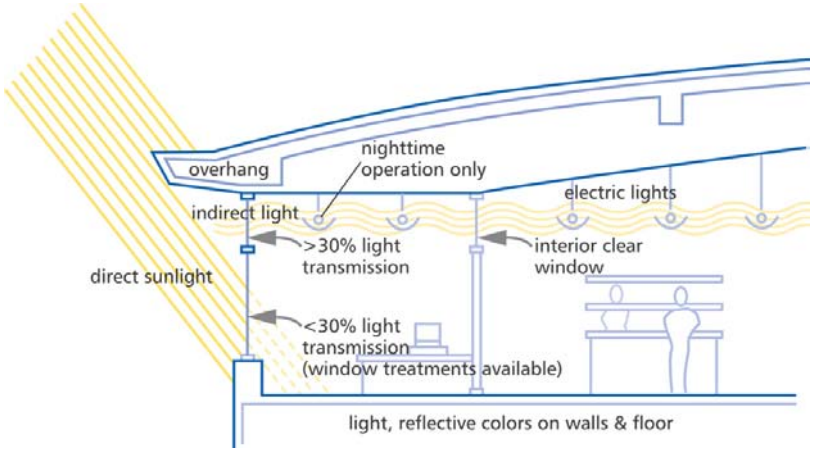
	FOSTER	RICHMOND
Building type	Elementary school	Elementary school
Date constructed	1955	1953
Location	305 East Foster Street Appleton, WI	1414 East Johnson Street, Appleton, WI
Hours of operation	7 AM – 3:30 PM	7 AM – 3:30 PM
Size (unconditioned)	49,696 sf	38,196 sf
Peak energy use	82 kW	76 kW
Annual energy use	187,200 kWh	193,200 kWh
Annual energy use per square foot	3.8 kWh/sf	5.0 kWh/sf
Annual energy cost	$62,000	$50,650
Estimated annual utility costs per square foot (without daylighting)	$1.2/sf	$1.3/sf

More Building Details

HVAC (Heating, Ventilation, and Air Conditioning)	System: Unit ventilators served by steam (no air conditioning) Capacity: 900 CFM
Window supplier	Corocoran Glass and Paint, Inc., Greenville, WI
Lighting supplier	Enterprise Lighting, Green Bay, WI; Crescent Electric Supply Company, Appleton, WI
Architect/lighting designer	Richard Best, Miller Wagner Coenanen McMahon, Neenah, WI
Window treatment supplier	Julien Shade Shop, Appleton, WI
Energy analyst/consultant	Ted Wilinski, Wilinski Associates, Inc.
Building owner/operator	Robert Zuehlsdorf, Appleton Area School District

How Cool Daylighting Works

Cool daylighting is an integrated approach that uses natural light to reduce the need for electric lighting, while also reducing solar heat gain and glare.



Successfully daylit buildings use the following four principles:

❶ **WINDOW PLACEMENT.** Too much light directly in the field of view is uncomfortable. Ideal window design uses a clerestory to let in light high (where it can bounce off the ceiling) plus lower view windows to provide a view. The amount of glass increases with height, bringing in more useable light into the room while reducing glare.

❷ **BRIGHTNESS CONTROL.** The sun, clouds, sky, and reflected light can overwhelm the eyes. These bright sources must be controlled through the use of overhangs and window blinds. This is especially important for view windows.

❸ **LIMITED LIGHT TRANSMISSION.** Even when direct light is controlled, the sky can supply an overwhelming amount of light. This leads to glare—one of the chief reasons that daylighting fails. To control glare, high performance glass is used. Visible light transmittance is limited to 0.38-0.60 for clerestories and 0.18-0.25 for view windows (depending on design conditions).

❹ **EVEN LIGHT DISTRIBUTION.** The human eye does not like large visual contrasts. Several daylighting techniques help distribute light evenly:

Direct-indirect lighting. This type of fluorescent lighting provides direct downlighting and indirect light bounced off the ceiling.

Daylighting sensors. Sensors in the ceiling detect luminance levels and turn off lights as needed to keep light levels constant. Lights near the windows are dimmed, while lights near the back of the room are on more often. This prevents the "cave effect", where the back of the room appears poorly lit because the contrast between the back and front of the room is too great.

Wall treatments. Lighter colored paints are used for the ceiling and for the wall near the ceiling. Slightly darker paints can be used below. This helps create a bright canopy of light out of the field of view.

THE DAYLIGHTING COLLABORATIVE

The Daylighting Collaborative is a group of utilities, product manufacturers, and other organizations who are dedicated to bringing daylighting into mainstream design and construction.

Offers training, education, and demonstrations of daylighting in order to demonstrate that daylighting can be realized with little or no first cost increases, while increasing human, environmental, and economic performance

Promotes flexible, tested techniques that are repeatable in a wide variety of buildings and that do not depend on having to hire daylighting experts to implement

Has helped implement cool daylighting in dozens of buildings in Wisconsin

Contact the Energy Center of Wisconsin at 608.238.8276 x139 or visit **www.daylighting.org** for more information.