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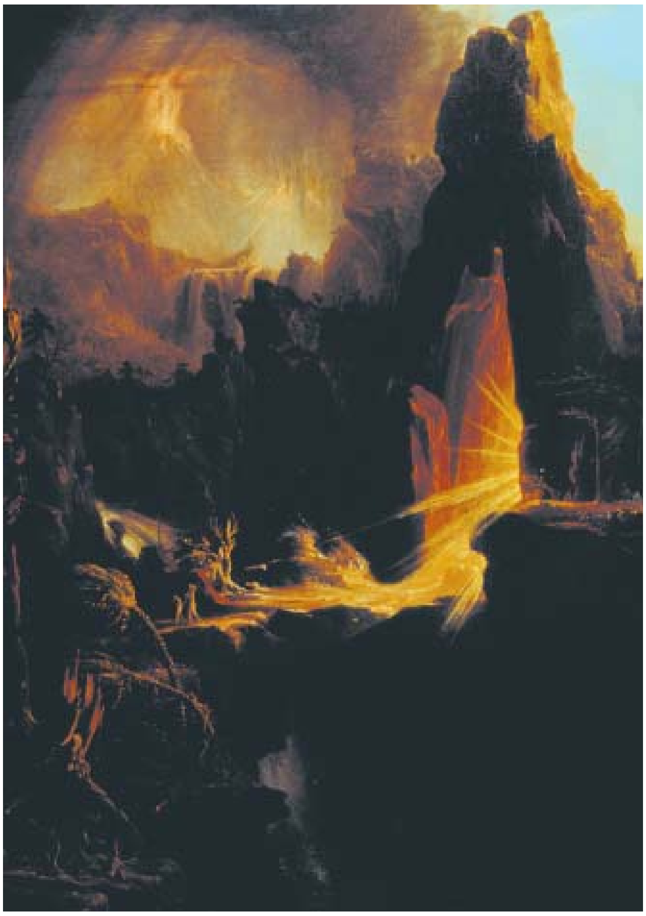


Expulsion from the Garden of Eden, Thomas Cole, 1832, Collection of the Museum of Fine Arts, Boston, MA

Daylight By Design

Studies from the Betterbricks Daylighting Lab in Seattle illustrate how daylight can be integrated into site and building design

By Joel Loveland

The way we think of Nature thus daylight greatly influences the form and substance of our daily lives, the buildings we design and therefore how they sustain the nature of place. Daylight until recently hasn't been considered a contemporary way to illuminate a building because we have learned to cast the nature of place and with it daylight, out of most buildings we design and build today. Designing a building so that it tells the daily and seasonal stories of daylight is essential to the daylighting of a building. This is a traditional task that architects and the lighting design communities of the last century, largely have forgotten.

Research in the U.S. of the 1940s through the 1960s indicated the best way to work was under uniform electric light. Little or no benefit was given to daylight as a source of illumination or even the role of windows. Research, mainly epidemiological in nature, in the last decade that looked at the productivity of large groups of students, shoppers and in a much more limited sense, office workers, has shown that immense gains in productivity can be correlated to a well-designed daylight-illuminated learning, retail or workplace environment. A great deal of research in the last five years has focused on the effect of daylight on students, shoppers and workers' health and productivity. These studies have uniformly indicated the positive effects of daylight.

Through these same observations, however, came the realization that the direct rays of the sun caused students to learn less and for workers to be less productive. The role of sunlight in critical visual task areas such as the office or classroom stems from its tendency to overheat a room and cause glaring disability. As much as daylight can increase the learning in a classroom, the direct beam of sunlight can cause similar decreases. If a well-designed daylighted workplace can cause a 20 percent increase in productivity over a baseline, in a non-daylight-illuminated building, sunlight can cause near-equal decreases in productivity, resulting in nearly a 40 percent swing.

With the realization of the critical importance of a healthy, productive and explicitly daylight-illuminated workplace came the synergistic effect of saving energy if the electric lights were off when the daylight was available. Additionally, because we know that sunlight generally decreases our ability to work effectively, well-designed daylit buildings will be shaded from the penetration of sunlight. This will additionally reduce the cooling energy use of a typical building by 10-20 percent.

Buildings that take the best advantage of diffuse, well-shaded daylight for illumination in critical task spaces can often reduce their electrical energy use by more than 40 percent through the reduction of electric lighting requirements and especially important peak-cooling demand.

The United States Green Building Council's Leadership in Energy and Environmentally responsive building Design has placed daylight in a pivotal role in the LEED standard. A well daylit building that controls the electric lights with the availability of daylight will be well on its way to being certified as a silver-rated sustainable building. The use of *daylighting* as a building's primary source of illumination can provide as many as one-quarter to one-third of the needed credits to attain Silver Certified status.

The old days: unvarying electric light at the British Columbia Hydro offices (*Journal IES*, 1959)

What Is Daylight? Or Daylighting?

Daylight is the light of day, but in most commercial or institutional buildings where critical visual tasks are dominant, it's the light of day—without sun, or at least the direct rays of the sun. Daylighting is the design of buildings using the diffuse rays of the light of day as the primary light source in critical task areas. There are several useful ways building science has momentarily simplified, reduced and commodified daylight, and therefore the sky. This allows a designer to begin to sort out the myriad of conditions one considers when working with complexity of the real light of day. A simplified test condition can be the shadowless overcast sky defined by the Commission Internationale De L'Eclairage, the International Commission on Illumination (CIE). This shadowless sky is often called the standard international overcast, and is generally three times as bright at the zenith as it is at the horizon.

This sky and its light are a very common condition in Cascadia, the region north of the California border and east of the Cascade Mountain ridge. This CIE overcast sky is the general condition for approximately 200 days a year in the cities of Portland or Seattle. The standard overcast sky is a reference condition, which is most often used for testing various building design configurations under one of two worst-case design conditions, a seemingly dark and perfected gray. The cloudless condition, also used for testing and also unreal, is the diffuse clear sky – without sun, even darker than the overcast. It's the "big blue" sky. When have you seen a perfectly clear sky – without the sun? Never. Why is this useful? If you combine it with the luminous intensity of the direct beam of the sun, then you begin to have a real sky. In regions in the Pacific Northwest such as Boise, ID the clear sky is the dominant condition, and getting to know the various effects of the range of luminous conditions towards and away from the sun is critical. While the surfaces of a building towards the sun will be bathed in tens of thousands of lux, the surfaces away from the sun, facing only the perfect blue sky will be darker than an overcast day at noon in the winter.

Building science has deconstructed daylight into simplified conditions, the clear sky's diffuse sources of light, from the "big blue," and its direct source—directly from the sun. Where the Standard Overcast Sky is fairly simple to understand and reflect in a building's geometry, the clear diffuse sky with the added geometry and intensity of the direct rays of the sun are nearly infinite in complexity. These are testing or modeling conditions that provide glimpses of real, but never a moment of truth until modeled or experienced in a built space.

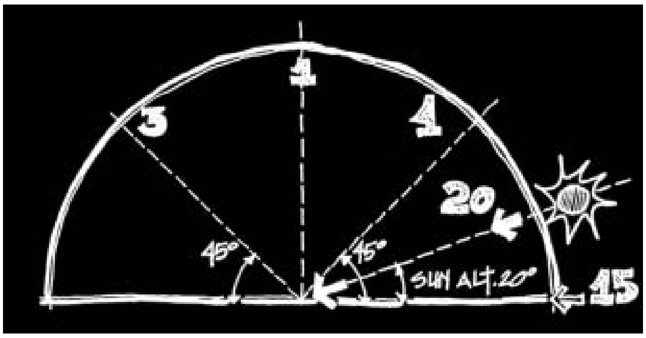
The Pacific Northwest architects highlighted in this article live the light of day. They work with it analytically, simulating their design decisions in the BetterBricks Daylighting Labs of the Pacific Northwest, deconstructed into overcast sky simulation rooms and heliodon sun simulators. Most importantly they integrate the real patterns of the light of day in the experience of light in their designs.

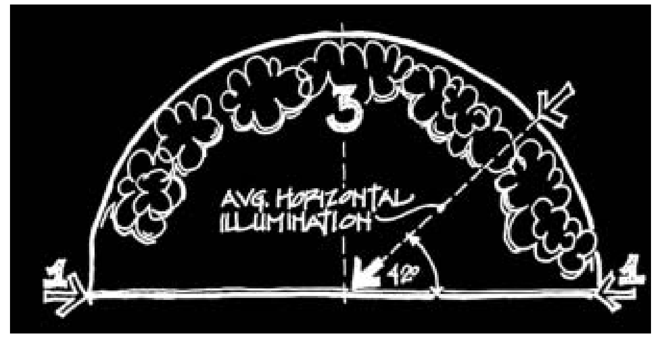
A Language Of Landscapes, Windows And Rooms Of Light

The landscape, the place of building, reverberates with the nature of daylight. Our place on the surface of the

PHOTOS: JOEL LOVELAND, UNLESS INDICATED OTHERWISE

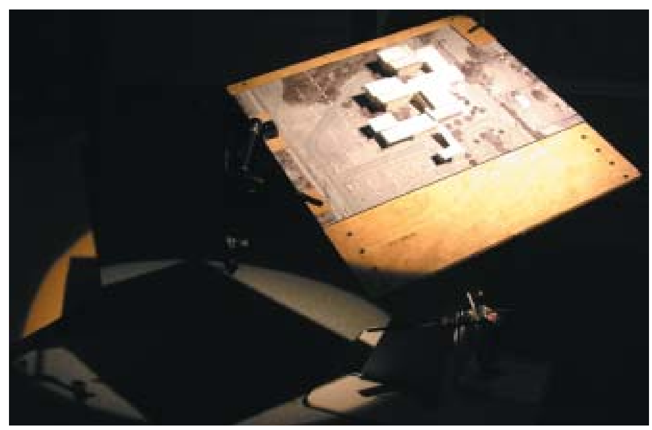
(left, top and bottom) This building in Portland, OR—nicknamed the "world's tallest basement"—symbolizes design that de-emphasizes windows in favor of artificial light.





DIAGRAMS: MARIETTA MILLETERT

(top, left) Clear sky diagram.
(top, right) Diagram of overcast sky.
(middle, right) Daylighting model at the BetterBricks lab.
(bottom, right) Sun simulator in the BetterBricks lab.



Earth, its relationship to the light of the sun is fundamental to daylighting. This placement, our place or orientation to the sun, and more precisely, its seasonal and diurnal metered motion across the sky is the most critical concern in daylighting a building. Since in commercial buildings, the sun is generally not an asset but a liability to be avoided, finding a place in the landscape to accommodate a building that reflects the periodicity of the sun is critical – finding a landscape that exposes itself to the most consistent and therefore controllable sun positions, north and south, and conceals itself from the difficult to avoid and deeply penetrating rays of east and west. The sky is the first order source of light and concern for the daylighting of buildings.

Of equal importance are the second order sources of daylight, the form of the immediate landscape and how it shapes the light available to a building. Urban or rural, flat, rolling or canyoned with high-rise buildings, it is these landscape surfaces that become assets in reflecting additional light from high in the overcast sky to the surface window planes of the building. These same altered profiles of the horizon can obstruct the penetration of the suns rays, or reflect and diffuse them, so as to become an additional luminous surface, an unexpected light source in the landscape. These sources can be assets, bringing additional diffuse light to a building's fenestration, or liabilities, reflecting the unwanted rays of the sun unexpectedly into critical task environments. A well daylighted building is modeled carefully at its conceptual design stages, at the site scale, for a landscape's luminous assets and liabilities.

A building's surface is the third layer of opportunity and/or defense. As one looks for a landscape that mirrors the light, they must begin to shape the building's surface, in order to tell the story of the light. The story of North and South light, therefore North and South building surfaces, is one of daily consistency and seasonal variation. East and West are treacherously changing minute-by-minute, deeply scarred by the sun. This fenestrated layer of daylighting design is a matter of the proportioning and detailing of a building's surfaces as they correlate to the nature of light on that surface. These early design decisions must express the pattern of the daylight and the timing and type of human use behind the building's window wall. How serious these decisions are taken has the greatest potential to make life within the workplace either pleasant or a disaster.

At its simplest, daylighting design is beginning to understand and utilize a vocabulary of windows, skylights and roof monitors as phrases of the narrative of light. Each opening to the landscape offers a different pattern of light and equally varying pattern of interior life. Let these most intimate of architectural forms be the last diffusing layer of opportunity in the design of a building as a light fixture.

Lessons Learned from the BetterBricks Lab

The Seattle BetterBricks Daylighting Lab, sponsored by the Northwest Energy Efficiency Alliance, and operated by the University of Washington's Department of Architecture, has had the opportunity to watch and work with some of the most innovative architects in the Pacific Northwest. Autumn/winter 2002-2003 marked the first time when, after three years, we had a significant number of buildings, which have been completed and that illustrate the good work of these design teams. What follows are some of the lessons learned from these projects:

• Don't trade less (building area) for better (performance)

A well-designed daylight illuminated school building can be built within a typical school construction budget and can save 40-60 percent on its overall electric lighting operations costs. A typical daylight illuminated (high performance) classroom, gymnasium, lunchroom and library in this context will save 60 percent of lighting operations expenses.

• Don't overglaze for daylighting

Typical window to wall area in most commercial buildings is limited to 25-30 percent of the wall area through the value engineering process. We have found that window areas in this range can provide adequate daylighting, depending on the room geometry. The daylighting work being completed last autumn indicates that window area doesn't need to exceed 25-30 percent of wall area, 10-20 percent of floor area. The most critical caveat to this statement is: the orientation of the fenestration to the path of the sun. Many of us think we know the story. The effects of the sun, its path in the sky and the opposite path of the light in a room, but what we discovered is there are some interesting surprises.

• Let the building and its windows tell the story of the daylight

South sun, or south-facing windows, within 15 degrees, are generally the best because the sun moves on a daily basis, more horizontally and therefore can be protected by an exterior projecting horizontal overhang.

The northern sky or north-facing windows can be a great daylight asset in the temperate sub-regions of the Pacific Northwest, Cascadia, West of the Cascade Ridge. North light is much more problematic in colder and sunnier regions. This is true for very different reasons. When the problem is cold, there is generally too much heat loss through a North window, except when the internal metabolic rate of the building is exceptionally high. In the dominantly clear sky regions of the PNW, the North light is good for daylighting, but very limited. Seldom does the sun get on a North façade, but the clear northern sky is very dark. Daylighting from the North requires larger windows or higher window-to-floor area relationships.

West sun or west-facing windows, in an occupancy that is concentrated like a common traditional school day 9AM to 3PM (or) 8AM to 2PM and especially where the sunny periods of the year correspond to Daylight Savings Time, can be good when shaded as we would shade a south window. Rather unbelievably, West sun, or windows can be designed much like South.

An East window can only be shaded effectively in the landscape by vegetation, or in an urban setting by tall adjacent buildings. Otherwise forget east. This is especially true in hotter and sunnier regions, unless heavily shaded by the landscape. The glare from the low eastern sun angles is nearly impossible to protect from, especially in DST, April-October. Overheating from the eastern windows in the AM can be very problematic if it's too hot outside to provide cooling from forced or natural ventilation with outside air.

• Refine the window

The development and detailing of the window is key to daylighting success. Designing a room or a classroom with a large window(s) equal to what would otherwise be sufficient window area to provide good daylighting of the room is not enough. Placing a single large horizontal shade is generally not a viable solution to eliminate the glare and overheating of the sunlight. The window must be shaded with fixed architectural elements, whether they are exterior overhangs, interior lightshelves or, vegetation. The period for this shading should be closely timed to balance sun time/position and clock time/hours of use. These can be as much as 90 minutes out of phase, generally with the sun traveling behind clock time, therefore delaying the impacts of sun on the western surfaces/windows of the building in the western portions of the PNW. Carefully select specific glazing types for each light exposure, combining the most appropriate values of visible light transmittance (VLT), Solar Heat Gain Coefficient (SHGC) and U-value for the

PHOTO COURTESY: BOORA ARCHITECTS

The Dalles Middle School, Dalles, OR, demonstrates how south-facing windows with horizontal overhang shading can facilitate daylighting.

PHOTO COURTESY: BOORA ARCHITECTS

The Riverview Elementary School, Lebanon, OR, puts light where people need it the most through perimeter daylighting and skylights.

assembly. Lastly, layer the appropriate interior shading systems with your window design.

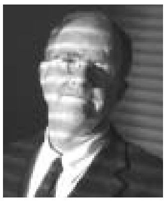
• Put the daylight where people need it most (i.e. where they spend the most time)

This will most often be in critical visual task area such as classrooms, gyms, offices etc., rather than circulation spaces. An effective daylight illuminated school such as Seattle's Wilson Pacific School, built in 1953, concentrates well-balanced and controlled daylight from the North and South in the classrooms. It is received into the corridor through high windows that borrow the light into the corridor. On a typically late fall overcast day in Seattle around 12 PM, the illumination in the classroom from daylight alone is 30-50 footcandles (300-500 lux) while the corridor is illuminated with 10-15 footcandles (100-150 lux). This corresponds very closely to well accept national standards for illuminating these spaces. Unfortunately, more often than not, daylight is brought into corridors and borrowed into classrooms. This makes the corridors very bright, thus making the classrooms seem dark.

Riverview Elementary School in Lebanon, OR, designed by BOORA Architects borrows on this tested strategy. The classrooms were designed to be illuminated with daylight from two-sides, both at the perimeter and with clerestories or skylights along the back wall. This generous daylighting scheme borrows light into the corridors as in the Wilson School scheme. As with many schools today, there is an occasional need to use the classroom for auxiliary teaching. In this case, a pair of classrooms are pushed out to the south, and the corridor is widened as a shared space. The clerestory daylighting that would normally enter the back of the classroom now enters the widened corridor, creating an inviting pool of daylight in contrast to the generally darker corridor illumination.

Breaking New Ground

Most architects claim to consider daylight as a primary concern when designing a project, but few actually test their design decisions. The design teams of the Pacific Northwest are breaking new ground by incorporating daylighting consideration into the earliest stages of the design process, and testing them at the BetterBricks Daylighting Lab facilities in Seattle and Portland. They recognize that their decisions will affect the productivity and energy efficiency of generations of students, teachers and office workers. Architects such as Heinz Rudolf, Partner at BOORA Architects in Portland are firm believers in daylighting design. Speaking about their iterative design practice, Rudolf described the process of considering lighting early and analytically at the daylighting labs, "the only way to see what is really happening in a daylit space under various seasonal conditions is to model it. I believe that every important daylighted room should be modeled... if we don't model the daylighting in our spaces, we're just guessing. Having this expertise available saved the design team a great deal of time and expense."



About the Author: Joel Loveland is the director of the BetterBricks Daylighting Lab Seattle. The lab is funded by the Northwest Energy Efficiency Alliance and operated by the University of Washington, Department of Architecture. The lab has a staff of two full-time resident daylighting consultants, six part-time research assistants that have worked on more than 150 daylighting projects a year since late 1999. Loveland is a graduate in the professional architecture degree programs of Arizona State and UCLA. He is currently an associate professor in the Department of Architecture at the University of Washington where he teaches design studio and courses related to sustainability, the nature of light, landscape and architecture. Loveland is the author of *Daylight, Window Room: The Building as a Light Fixture*, which will be published in the summer of 2004 by the University of Washington Press and co-author of the Second Edition of *Inside-out, Handbook for Passive Environmental Controls*. Chris Meek and Kevin Van Den Wymelenberg also assisted and contributed in the writing of the article.