



Introduction to Daylighting
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by

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**HARNESSING THE SUN FOR CREATE DAYLIGHTING
REDUCE OPERATING COSTS AND CONTRIBUTE TO A HEALTHY ENVIRONMENT**

Summary

We think of our sun as providing light and heat, but in fact it has provided much more throughout history. Its symbolic and cultural aspects have guided and provided spiritual inspiration—though for the better part of the last century we lost track of its impacts on everything from our moods and ability to learn to the sun’s impact on a building’s heating and cooling loads.

Daylighting can be thought of as the controlled entry of natural light through windows to reduce or eliminate the need for electric lighting. In recent decades, this was not considered a modern method of illumination; sourcing the sun was one of the least important aspects of construction and maintenance given that utility costs were low, window technology was in its infancy, and we didn’t spend up to 90% of our lives indoors as we do today.

New concerns about carbon emissions, global warming, and sustainable design have brought about a resurgence of the planned use of natural light in buildings. Today, daylighting is more frequently being considered as an integral part of building design, with the benefits of improving our sense of spatiality, awareness to color, and the bottom line.

This presentation is the first in a series about daylighting. It will cover the history of bringing sunlight into buildings, the basic considerations for utilizing daylight within a building's design, and how utilizing daylighting can contribute to credits on a project seeking Leadership in Energy and Environmental Design (LEED) certification, and the benefits of daylighting on HVAC systems. While many other topics are related to daylighting, such as window types and coatings, this presentation will not cover those topics in depth. Case studies will be referenced and illustrated throughout.

An engineer’s understanding of daylighting can become a critical component to the construction and operation of a building. Utilizing the sun’s energy appropriately can contribute positively in many ways, including:

- Reducing the required size of the HVAC system
- Reducing the need for interior artificial lighting
- Reducing costs associated with lighting, heating, cooling, and overall energy costs



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- Imparting a connection with the outside, leading to a greater sense of employee well-being

Introduction

Daylighting is not new; it existed in ancient civilizations out of necessity, and is commonly used today as a design element. Daylighting is, however, receiving renewed attention as an energy saving method being incorporated into homes and commercial buildings under the banner of sustainability. Its resurgence can also be attributed to the charge being placed on architects and engineers to design buildings with materials and methods having improved life-cycle costs, increased energy efficiencies, reduced carbon emissions, and those that impart an improved quality-of-life feeling of connection between the inside and outside for its inhabitants.

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in non-residential buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment.

History of Daylighting

A review of daylighting throughout the ages illustrates the creative ways we've utilized sunlight, how we got off track with modern architecture, and how we are now respecting the power of the sun and utilizing technology to improve the indoor environment.

Ancient Civilizations: Egypt

Egypt's natural blinding sunlight and bleached interiors required builders to devise ways to minimize light introduction into temples and buildings. The limited ability of post-and-beam construction with stone restricted the manipulation of the building material to control sunlight. Working within the confines of the materials, solutions were achieved by adjusting the thickness of the stone walls which served to soften and diffuse sunlight as it came into the building. An additional benefit of using stone was the heat storage it provided, in effect tempering the wide range of temperature fluctuations that can exist in the desert. Clerestory openings were also used to introduce light into the interior of a building,



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particularly near church pulpits, serving to reinforce the idea that the priest's sermons were words coming from the heavens.

Ancient Civilizations: Greece

The Greeks designed their buildings as monuments and temples more for their exterior glamour than for interior use. Greek temples were usually oriented to the east, to portray the interior statutes in good morning sunlight. Mostly post-and-beam construction was used, with timber roofs. Similar to Egyptian architecture at the time, use of stone for construction posed limitations. The Greek response to this was in the use of columns for additional structural support. Use of columns defined ancient Greek architecture, which created colonnades and porticoes that provided afternoon summer shade and winter rain protection. Within the temples were coffered ceilings above the colonnades, which required strong reflected light for viewing.

Ancient Civilizations: Rome

When the Romans began their architectural developments, the techniques of daylighting and passive solar heating expanded greatly. By using improved techniques to compress concrete into shapes of round arches and domes, the need for columns was eliminated, and the opportunity to create large areas of light entry emerged. Glazing materials became available for the first time in this era, in the form of simple glass and mica.

Timing and culture merged well in this time period. Unlike the Greeks, the Romans used their buildings' interiors for many purposes: as courts, and for conducting businesses and various other commercial operations. Many of these buildings were rectilinear in shape, elongated east to west to provide maximum southern exposure. The roofs were built to allow for use of clerestory openings or windows that would allow sunlight to reach up to 200 feet into the interior of the building.

Losing Our Way

Prior to the 1800's, the lighting that a building received was a function of its envelope and the daylighting the architecture supplied, with supplemental lighting provided by oil lamps and candles. But beginning with the Industrial Revolution and even continuing today, the connection between nature and buildings diminished. In essence, the connection between respect for place, people, and the cycle of life was lost. This loss went easily unrecognized as modern technologies such as mechanical heating and cooling systems, gas and then



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incandescent lamps, and even interior stairways and central plumbing negated the need to work with the vernacular architecture. Orientation, roof angles, depth and width of buildings, and their ecological footprint as a function of energy efficiencies no longer played a role in the building's development phase. When daylighting was used, it also came a cost: increased glare, extensive heat loss in the winter, and solar gain in the summer.

A Renewed Respect

A series of factors have begun to influence current thinking about land use in general and daylighting in particular. Rapidly increasing energy costs are a major factor, others include:

- The need to increase building operational efficiencies to accelerate the return on investment
- The need to reduce operating costs, lowering the 35–50% of a commercial building's energy demands attributable to its electrical needs
- Data showing improved life-cycle costs for using daylighting by reducing the need for excessive supplementation of electrical fixtures and controls
- Knowledge of the increased job satisfaction that comes from natural lighting which connects workers to the outdoors and leads to increased productivity and improved performance

Daylighting has now come full circle and returned to its original intention, which is to bring in natural indirect light to illuminate building spaces and connect people to the outdoors. In addition to bringing in light for soulful reasons as in ancient Egypt, daylighting is being utilized today to add a sense of connection to the outdoors. This change in the built environment is good for people and the bottom line: it is beginning to restore the sense of people and place, and improve life-cycle costs.

Building Orientation and Design for Daylighting

The challenge of daylighting design is harnessing the incredible amount of energy found in sunlight. On a clear day, the sun provides 8,000 to 10,000 foot-candles (fc) of light. Even through glass, it can provide 5,000 fc on a clear day and 1,000 fc on a cloudy day. Most people working at a desk require a mere 35 fc to read. Compounding the challenge is the fact that sunlight is as much heat as visible light. The sunlight that pours through a typical 4-by-8-foot window section in an afternoon can heat 15 to 30 gallons of water to a adequate shower-taking temperature.



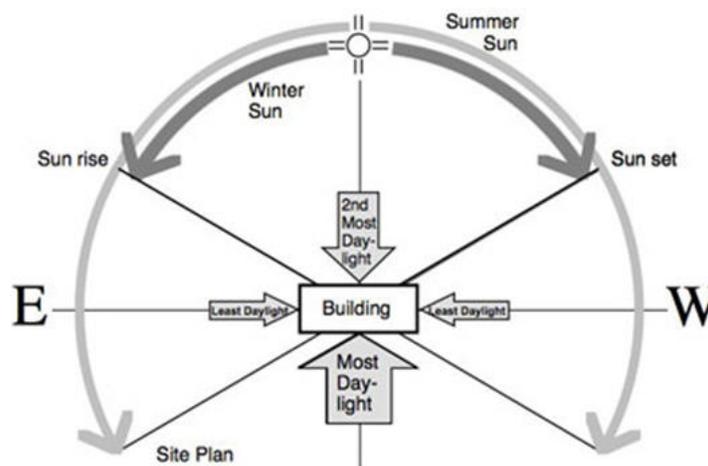
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Daylighting makes use of the luminance distribution from the sun, sky, buildings, and ground. Daylight strategies are determined by analyzing the availability of natural light, which is determined by the latitude of the building site and the conditions immediately surrounding the building, e.g., the presence of obstructions. Daylighting strategies are also affected by climate; thus, the identification of seasonal, prevailing climate conditions (particularly ambient temperatures and sunshine), is a basic first step when considering daylighting design. Once these factors have been determined, tools and calculation software can be used to further refine the building.

Building Orientation Considerations

The best siting of a building for daylighting is for the short sides to be facing east and west, and the long sides north and south. The sun's daily path across the sky from east to west allows for north-facing exposure in the early morning and the late evening during mid-summer, when the sun is highest in the sky.



Source: Whole Building Design Guide.org

Case Study:

Building: Pennsylvania Department of Environmental Protection, Cambria Office Building

Location: Ebensburg, Pennsylvania

Project Details: 34,500 ft² office space, completed fall of 2000, LEED 2.0 Gold Certification



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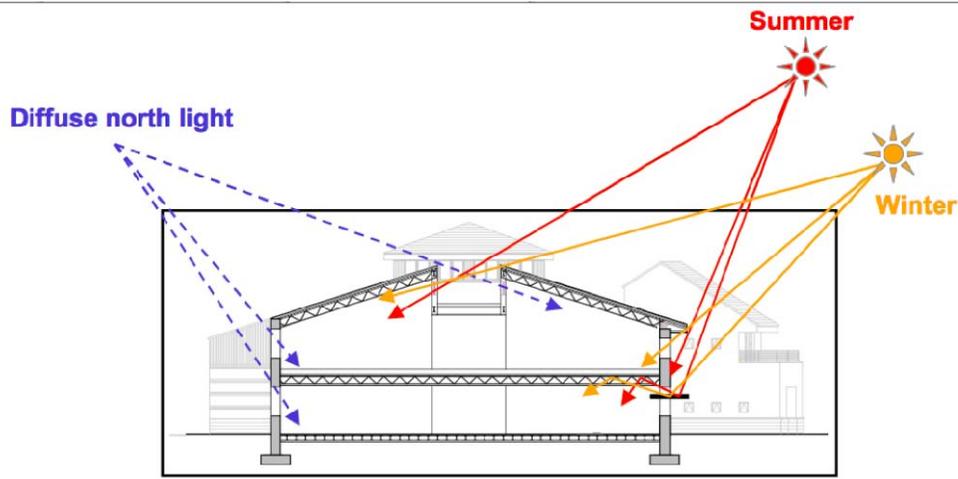
Notes: Daylighting used in this building provided minimal savings because of the solar array used, but still contributed to the overall layout and use of the building.



The goal of this building was to create a productive work environment and minimize its environmental impacts. The design team chose an array of features to complete the high-performance building, including “efficient wall and roof insulation, high-performance windows, ground-source heat pumps, an under floor air distribution system (UFAD), energy recovery ventilators (ERVs), daylighting, motion sensors on restroom lights, and an 18.2-kW photovoltaic (PV) system for on-site electricity production. “ For best daylight penetration into the building, roof lines were sloped for maximum utilization of the high mounted roof windows, and the second floor was designed as an open space around the perimeter with the offices placed interiorly so as to not block access to daylight. Actual design features are illustrated below:



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Daylight features of the Cambria Building

Tools and Calculation Software for Modeling Daylighting

The first step in determining the natural and supplemental lighting that will best suit a building is to utilize calculation tools (which predict the impact of daylighting on a building's performance) and, if possible, room modeling. Data provided by these tools is critical to effective daylighting, and should be gathered at the outset of the design process.

The analysis is based on the use of a heliodon, a device that tests the varying angles of a beam of light onto a flat plane. The results of the analysis will be affected by the latitude and longitude of the building site, the time of year (as the sun's angle in the sky varies throughout the year), and the time of day that the light will hit the building. Daylighting should be simulated throughout the time of day when the building will be occupied. Various software options and tools are available, offered under names such as Radiance Synthetic Imaging Systems, SkyCalc, and Lumen-Micro which serve to:

- Predict light levels for spaces under various types of sky conditions and seasons
- Determine daylight patterns for a room based on the wall orientation, room geometry, and the size of the window openings
- Assist in optimizing energy efficiencies

If simulation modeling is not an option, data exists for analyzing solar activity regionally from resources such as the International Daylight Measurement Program <http://idmp.entpe.fr>



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which has monitored daylight every minute at more than 50 stations since 1991; and the U.S. Naval Observatory <http://aa.usno.navy.mil/index.php>.

Hourly energy modeling was conducted for the Cambria building using Department of Energy data, with predicted energy savings and three-year analysis post occupancy from the various modalities as illustrated below.

Estimated Energy and Cost Savings

Fuel	Design Use (kBtu)	Design Cost (\$/ft ²)	Baseline Use (kBtu)	Baseline Cost (\$/ft ²)	% Savings	
					Energy	Cost
Total building energy use	851	0.77	1,597	1.54	47%	50%
PV energy production	82	0.25	0	0		
Net building energy use	768	0.52	1,597	1.54	52%	66%

Cost, Site, and Source Energy Savings Summary

	Cost		Total Site Energy		Total Source Energy	
	\$/ft ² ·yr (\$/m ² ·yr)	Percent Savings	kBtu/ft ² ·yr (MJ/m ² ·yr)	Percent Savings	kBtu/ft ² ·yr (MJ/m ² ·yr)	Percent Savings
Baseline	\$1.80 (\$19.38)	43%	57 (642)	40%	180 (1,800)	40%
As-Built	\$1.02 (\$10.89)		34 (386)		108 (1,226)	

The best method for determining the effects various energy saving techniques will have is via actual scaled room modeling. A miniature room built in an environment similar to the actual building can effectively simulate what will be found full-scale. One well-documented



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example of modeling occurred when the New York Times headquarters building was constructed in 2004 in Manhattan. The company responsible for the daylighting design, MechoShade, constructed a 4,300-square-foot prototype of a 51-story tower. The mock-up office was used to test the various aspects of the building's design that would be affected by daylighting design, including HVAC needs, interior lighting, room colors, and physical layout.

Building Design Considerations

A key strategy to sustainable building design is to approach it via a team effort within an integrated design process. Daylighting design should compliment and enhance the architectural design of a building, as well as work in unison with mechanical and electrical systems to optimize their efficiency.

For effective daylighting, the following design concepts should be considered:

- Increase the feeling of space by providing daylight zones throughout the perimeter of the building
- Keep room depths shallow
- Provide an opportunity for daylight penetration from a high area. The higher the light enters the space, the more uniformly it can be distributed.
- Slope the ceilings away from the sun-entering windows to allow for more direct light into the space by providing a larger surface area off which the entering light can reflect. With this orientation, light can enter deeper into a space without causing intense brightness or glare
- Filter daylight by adequate use of curtains, louvers, light shelves, or window treatments
- Prevent direct daylight on critical task areas

Materials - The Modernization of Daylighting

As technological advances have provided for a better understanding and use of the science of daylighting, it is also able to advance even further by the use of glazing materials and window treatments which can be adjusted automatically according to the sun's daily pattern.

Glazing is simply the transparent part of a wall by which light can enter. It has two



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purposes: providing a view out and allowing daylight in. Glazing can be as simple as a single pane of glass allowing full light to enter, or as elaborate as designs imbedded into the glass such as prisms to defuse light or direct it precisely into a space, gas-filled double panes to create high-R (insulating) factor and/or low-U (reflectance) factors. When considering what type of glazing to use, it is important to understand the behavior of the entire building, including orientation, external light shelves, reflectance of external spaces such as parking lots and sidewalks, the design of the interior space (cubicles or offices on the perimeter, and internal design (illuminance of paint and desk surfaces).

Additionally, interior louvers and blinds can be used to accentuate the benefits of architectural daylighting by manual or sensor-related adjustments throughout the day. Manual adjustments provide a sense of control for a room's occupants, a benefit of a healthy building. Sensor-related systems allow for changes related to the solar impact on a fenestration at any point of the day, and serve to create constant, uniform introduction of light into a building. See Appendix 1 for illustration.

There are many creative ways to bring sunlight into an interior space, but the basic methods can be categorized as roof monitors, clerestory, sawtooth, skylight, and atriums as window-types, and roof and overhangs, shading, or light shelves as interior daylighting aids. Other options include the use of reflectors and light ducts. See Appendix Two for examples for examples.

Daylighting and Energy Maintenance – Case Studies

As discussed, daylighting is just one contributor to the reduction of a building's overall energy use, and like all other design aspects, should be evaluated early on in the design process. The best way to show the reduced energy costs contributed by daylighting, siting, lighting, envelope, air distribution systems, solar arrays, structural design, etc. and the resulting reduction of HVAC systems from these various energy-saving design applications is via case studies. Three will be illustrated below, which have used daylighting for various reasons though with positive financial and environmental benefits.



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Building: BigHorn Home Improvement Center

Location: Silverthorne, Colorado

Project Details: 18,400-ft² hardware store retail area and a 24,000-ft² warehouse

Overall Energy Savings: 53%

Notes: Using renewable energy was a key goal for this project, and owner minimized internal gains by incorporating extensive daylighting connected to a switching arrangement with the fluorescent lights. The building envelope was designed to allow for natural ventilation to meet cooling loads and a radiant floor system with natural gas-fired boilers was installed to the heating system. CO sensor controls were installed on the roof-mounted exhaust fans, which reduced the need for a continuous fan. Solar collectors and gas radiant heaters heated the warehouse. The numerous modalities used in this project provided increased the overall cost by 10% over conventional building methods, and a 54% increase in energy performance. One unusual finding was in the warehouse heating energy, which is the same as the As-Build Model and approximately the same as the As-Built Baseline Model. The reason for this was two-fold:

1. Due to the low heating set point, the required heating load became very small the heat gain provided by the additional lights and fans in the baseline building warms the space above



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the heating set point

2. The solar collector adds a small but useful amount of heat to the space through the warm air delivered to the space and by conducting heat from the hot air space through the wall into the warehouse.

Cost, Site, and Source Energy Savings Summary

	Cost		Net Site Energy		Net Source Energy	
	\$/ft ² ·yr (\$/m ² ·yr)	Percent Savings	kBtu/ft ² ·yr (MJ/m ² ·yr)	Percent Savings	kBtu/ft ² ·yr (MJ/m ² ·yr)	Percent Savings
Baseline	\$1.08 (\$11.63)	53%	63 (720)	36%	156 (1,770)	54%
As-Built	\$0.51 (\$5.49)		40 (450)		72 (820)	

Total and Effective Electrical Energy Charges by End Use

Load	Total Energy Cost		Effective Charge (\$/kWh)	
	9/1/2001– 8/31/2002	9/1/2002– 8/31/2003	9/1/2001– 8/31/2002	9/1/2002– 8/31/2003
Retail Lights	\$3,145.41	\$3,036.65	\$0.0713	\$0.0773
Warehouse Lights	\$757.34	\$1,307.10	\$0.2055	\$0.1559
Exterior Lights	\$1,081.49	\$1,828.04	\$0.1620	\$0.1875
Lighting Display	\$1,619.70	\$2,992.26	\$0.0623	\$0.0761
Forklift	\$1,549.74	\$753.65	\$0.4841	\$0.2598
Miscellaneous Loads	\$2,833.93	\$3,535.63	\$0.0442	\$0.0507
Pumps	\$248.80	\$274.63	\$0.0427	\$0.0467
Total	\$11,243.14	\$13,734.53	\$0.0721	\$0.0785

The complete case study (Deru, Torcellini, and Pless 2005) is available at <http://www.nrel.gov/buildings/pdfs/34930.pdf>



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Building: National Renewable Energy Laboratory (NREL) Thermal Test Facility (TTF)

Location: Golden, Colorado

Project Details: 10,000-ft² (930-m²) steel-frame building that is typical of many small professional buildings, industrial parks, and retail structures

Overall Energy Savings: 51%

Notes: For this building daylighting provided most of the energy saving; daylight harvesting and lighting design reduced lighting energy by 75%. The overall goal was, via an integrated design process, to see how various technologies could be used to reduce energy consumption, particularly in a dry climate. Daylighting provided for the reduction of lighting needs, thus the size of heating and cooling ductwork that was needed. The two-stage evaporative cooling provided sufficient cooling capacity for less energy than conventional cooling systems, and a stiff exterior finish was used to assist in reducing the envelope heat transfer.



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Cost, Site, and Source Energy Savings Summary

	Energy Cost		Site Energy		Source Energy	
	\$/ft ² /yr (\$/m ² /yr)	Percent Savings	\$/ft ² /yr (\$/m ² /yr)	Percent Savings	\$/ft ² /yr (\$/m ² /yr)	Percent Savings
Base Case	0.74 (7.97)	52%	49.1 (558)	41%	131 (1488)	49%
As-built	0.36 (3.88)		28.9 (328)		66 (752)	

Energy Use and Costs: Final Design Model versus Base-Case Model

End use	Base-Case Model		Final Design Model		% savings
	MMBtu/yr (GJ/yr)	\$/yr	MMBtu/yr (GJ/yr)	\$/yr	
Lights	199.5 (210.5)	\$3,771	17.2 (18.1)	\$804	78.7%
Space Heating	46.1 (48.6)	\$177	68.9 (72.7)	\$265	-49.7%
Space Cooling	22.9 (24.2)	\$433	5.8 (6.1)	\$109	74.8%
Heat Rejection	6.0 (6.3)	\$113	0.0 (0.0)	\$0	100.0%
Pumps	5.8 (6.1)	\$110	1.3 (1.4)	\$25	77.3%
Fans	10.5 (11.1)	\$198	5.2 (5.5)	\$98	50.5%
DHW	17.8 (18.8)	\$76	17.8 (18.8)	\$76	0.0%
Exterior Lights	14.9 (15.7)	\$282	14.9 (15.7)	\$282	0.0%
Plugs	73.5 (77.5)	\$1,389	73.5 (77.5)	\$1,389	0.0%
Total w/o Plugs, DHW, and Exterior Lighting	291.0 (307.0)	\$4,802	124 (130)	\$1,301	-57% (energy) -73% (cost)
Total	397.2 (419.0)	\$6,546	230.2 (242.9)	\$3,045	-42% (energy) -53% (cost)



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The complete case study (Torcellini et al. 2005b) is available at
<http://www.nrel.gov/buildings/pdfs/34832.pdf>



Building: Adam Joseph Lewis Center for Environmental Studies, Oberlin College

Location: Oberlin, Ohio

Project Details: A two-story, 13,600-ft² classroom and laboratory building. The building contains four classrooms, a small auditorium, atrium, staff offices, and kitchenette.

Overall Energy Savings: In year 3, cost savings were 48% compared to the base case; estimates of savings to 64% when the solar array can consistently provide 85% of the energy were calculated.

Notes: The objective of this project was to design an integrated building utilizing innovative technologies and to serve as an incubator for students of the school's Environmental Studies Program. The goal was to build a zero energy building, using all electric systems so that on-site energy generation would be able to offset all of the energy consumed. Design elements included daylighting to reduce lighting loads, natural building ventilation to offset cooling loads, a ground-source heat pump system, wastewater processing on-site to eliminate the need to divert to the municipal sewage treatment plant, and a huge 60-kW PV array on the roof to supply solar electricity to supply energy to the building.



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Measured Whole-Building Results: First, Second, and Third Year of Operation

	Measured Site Use Intensity kBtu/ft ² (MJ/m ²)	Measured PV Production Intensity kBtu/ft ² (MJ/m ²) ¹	Percent of Building Load Met By PV	Measured Net Site Use Intensity kBtu/ft ² (MJ/m ²)	Measured Source Use Intensity kBtu/ft ² (MJ/m ²)	Energy Cost Intensity \$/ft ² (\$/m ²)
First Year (from Utility Bills)	47.5 (539)	1.6 (18)	3%	45.9 (521)	148.1 (1,682)	1.21 (13.02)
Second Year	30.6 (348)	14.9 (169)	49%	15.7 (178)	50.6 (575)	1.17 (12.59)
Third Year	29.8 (338)	13.4 (152)	45%	16.4 (186)	53.0 (602)	0.85 (9.15)

1. PV production normalized by building floor area for comparison to site use intensity

The complete case study report (Pless and Torcellini 2005) is available at <http://www.nrel.gov/buildings/pdfs/33180.pdf>

Daylighting for LEED Certification

Economics and sustainability meet in the LEED rating system, developed by the U.S. Green Building Council (USGBC). Its mission is to provide a standard, through a point-earning process, which serves to brand buildings as high-performance, sustainable, and energy-efficient. Using the sun as a source of renewable energy has been recognized by USGBC as a feature of a well-designed building; with good planning, modeling, design, and application daylight points can be achieved.

In April of 2009, USGBC introduced version three (v3), and with it LEED 2009, which includes advancements to the rating systems.

Still the most common LEED certification sought is based on the New Construction rating system. An emerging LEED rating system is the Existing Buildings Operation and Maintenance system (EBOM), which addresses the whole building, including exterior maintenance and systems upgrades. While there are other rating systems, this discussion will focus on these two.

Each rating system contains prerequisites and performance-based achievement levels required to obtain credit points and ultimately a level of distinction. There are 100 possible base points, and



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with LEED 2009, the possibility for an additional 6 points in the credit categories of Innovation and Design and 4 points for Regional Priority. The four levels of certification are:

- Platinum: 80 points and above
- Gold: 60-79 points
- Silver: 50-59 points
- Certified: 40-49 points

The six credit category categories where points can be earned are:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation in Design

LEED credits can be associated with daylighting, though it can also impact the functionality of a building in various ways. LEED points that can be directly impacted by daylighting include:

Category	Credit	Comments
LEED NC		
Energy and Atmosphere	Prerequisite 1: Fundamental Commissioning of Building Energy Systems	Lighting and daylighting controls are considered energy-related systems.
Indoor Environmental Quality	8.1: Daylight and Views: Daylight	Achieve a minimum of 25 fc in at least 75% of regularly occupied spaces.



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	8.2: Daylight and Views: Views	Provide a direct line of sight for 90% of regularly occupied spaces, 30 to 90 inches above the floor. Utilize proper glazing to minimize glare, and provide interior/exterior shading or photo-cell controls.
LEED EBOM		
Indoor Environmental Quality	2.2: Controllability of Systems: Lighting	For a minimum 50% of occupants, provide a level of lighting that can be controlled to suit task needs.
	2.4: Daylight and Views	For a minimum 50% of occupied spaces, achieve a base of 25 fc; achieve via simulation or prescriptive path.

The indirect use of daylighting can affect other potential credits. For example, with EBOM, daylighting may affect the following Energy and Atmosphere credits:

- Prerequisite 1: Energy Efficiency Best Management Practices
- Credit 1: Optimize Energy Efficiency Performance
- Prerequisite 2: Minimum Energy Efficiency Performance
- Credit 2: Existing Building Commissioning

Conclusion

History is full of examples of how civilizations have built buildings with sunlight as a dominant factor in the architectural design, of how we lost sight of its importance as technology allowed us to override its benefits, and of how we are now embracing it again with the use of advanced technology to provide a sense of well being for those utilizing interior spaces.



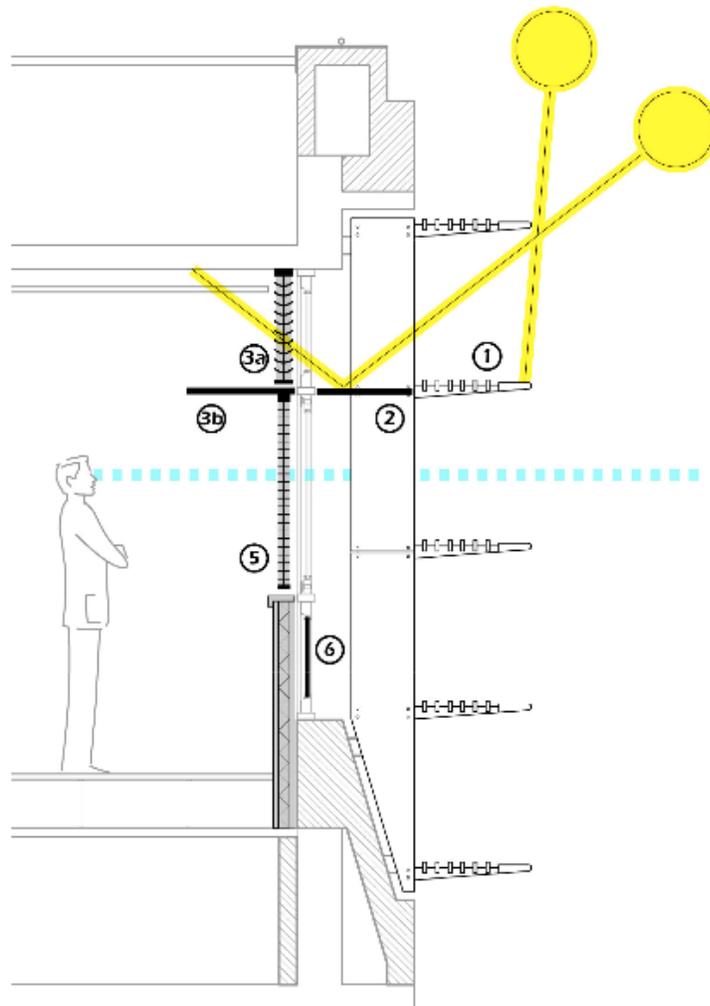
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Understanding how daylighting can contribute to a building's sense of comfort and work in tandem with other technologies to reduce energy use and costs, is vital to a successful project, making it a place where people want to live and work productively and thrive.

Appendix 1 – Methods of Bringing in Daylighting



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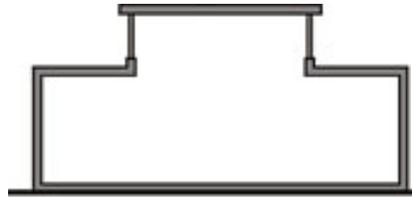
Legend

1. Five Louver Option: The number of louvers are determined to best shade and prevent glare.
2. Exterior Lightshelf: Solid, attached to the exterior louver, serves to bounce daylight into a space
3. A) Daylight Louvers: Adjustable blades that help bounce daylight deeply into a space. Can be attached to sensors. B) Interior Lightshelf: Can be used instead of daylight louvers, depth of shelf deflect direct sun on work surfaces during daylight working hours
5. Interior Miniblinds: Frequently the only option during low sun angle times
6. Spandrel Glass: Located below the work surface and can be insulated to improve envelope efficiency



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Appendix 2 – Types of Roof Openings for Daylight Capturing



A



B



C

Legend

A – Roof Monitor

B- Sawtooth Roof

C- Skylights

Source: gbtech.emsd.gov.hk

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Appendix

1. Use of modern materials and methods to bring daylighting into a space



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Legend:

1. **Five Louver Option:** The number of louvers are determined to best shade and prevent glare.
2. **Exterior Lightshelf:** Solid, attached to the exterior louver, serves to bounce daylight into a space
3. **A) Daylight Louvers:** Adjustable blades that help bounce daylight deeply into a space. Can be attached to sensors. **B) Interior Lightshelf:** Can be used instead of daylight louvers, depth of shelf deflects direct sun on work surfaces during daylight working hours
5. **Interior Miniblinds:** Frequently the only option during low sun angle times



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6. **Spandrel Glass:** Located below the worksurface and can be insulated to improve envelope efficiency