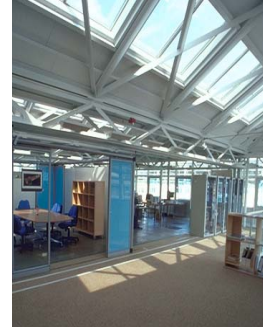





Maximize the use of daylight without glare and provide daylight-responsive lighting controls to ensure 22 - 60% overall energy savings, 35 - 65% lighting energy savings, and 0.45 - 40% productivity gains, for ROIs over 185%

Daylighting is the use of direct, diffuse, or reflected daylight to provide full or supplemental lighting for building interiors. Daylighting helps create visually stimulating and productive environments for building occupants, while reducing building energy costs.

Daylighting, in combination with energy-efficient lighting, can reduce the lighting power density in some office buildings from over 2 W/ft² to 0.2-0.8 W/ft² with consistent or even increased measured lighting levels. As daylight produces less heat per unit of illumination than many artificial lighting systems, daylighting may reduce cooling requirements when it replaces artificial lighting. With innovative seasonal controls, daylight can also provide supplementary building heat without jeopardizing cooling comfort. In addition, a growing number of studies suggest that daylighting increases worker productivity and improves health, enhances student learning, reduces absenteeism, and contributes to higher sales in retail stores.



High performance daylighting systems should be designed to provide enough daylight without any undesirable side effects. Heat gain and heat loss through windows, glare control, and variations in daylight availability must be carefully balanced. A number of design strategies can be applied in new buildings and in the retrofit of existing buildings.

	Conventional Practice	High Performance Daylighting System
 Floor Plans	Deep floor plans.	Shallow buildings or atriums for daylight penetration.
Aperture Location	All orientations; punched, slits, bands	North & South exposures, roof monitor and clerestories.
Glazing	Tinted glass, low shading coefficient, low visible transmittance.	Low e-glazing combining low shading coefficient and high visible transmittance (or high solar transmittance and high visible transmittance in heating dominant climate).
Glare controls	Unshaded glass.	Exterior and interior shading devices, daylight redirection and diffusion.
Lighting system controls	Electric lighting continuously on regardless of space use or daylight condition.	Integrated with occupancy and daylight-responsive lighting controls
Integration	Daylight not integrated with HVAC and lighting systems.	Daylight integrated with HVAC and lighting systems control with demand side management and peak power shaving.

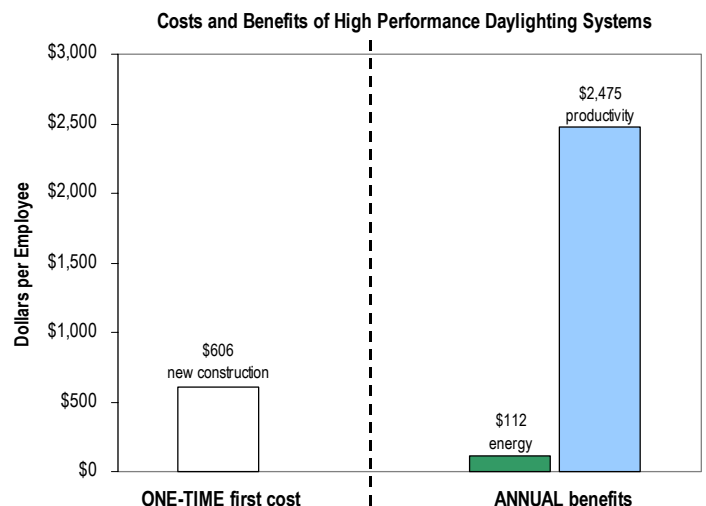
Daylighting Pays!

Eleven studies have shown that innovative daylighting systems can pay for themselves in less than one year due to energy and productivity benefits.

CMU's BIDS™ demonstrates that daylighting yields annual energy cost savings of \$112 per employee (\$0.99 per square foot) and annual productivity gains of \$2,475 per employee, for total savings of up to \$2,587 per employee annually.

With an estimated one-time first cost premium of \$600 per employee (\$1 to \$7 per square foot) in new construction, the ROI for an investment in daylighting is over 185%.

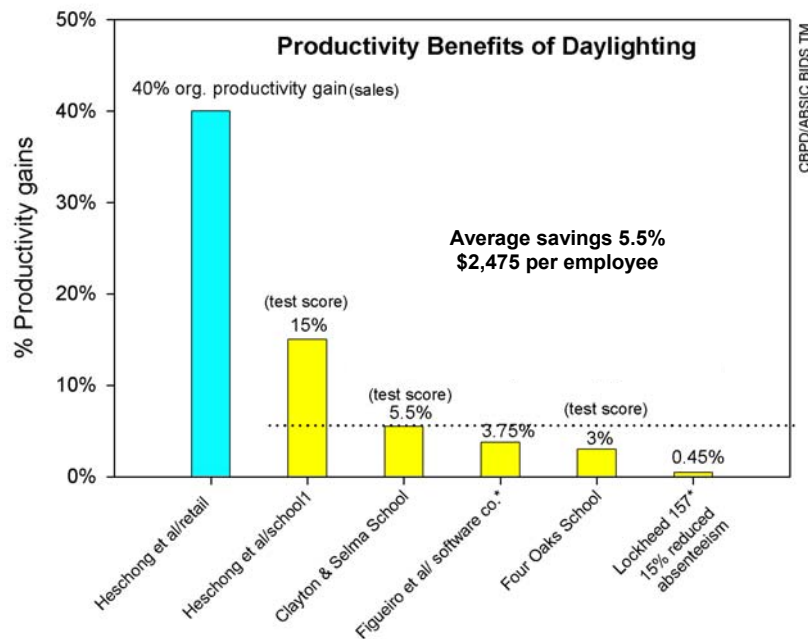
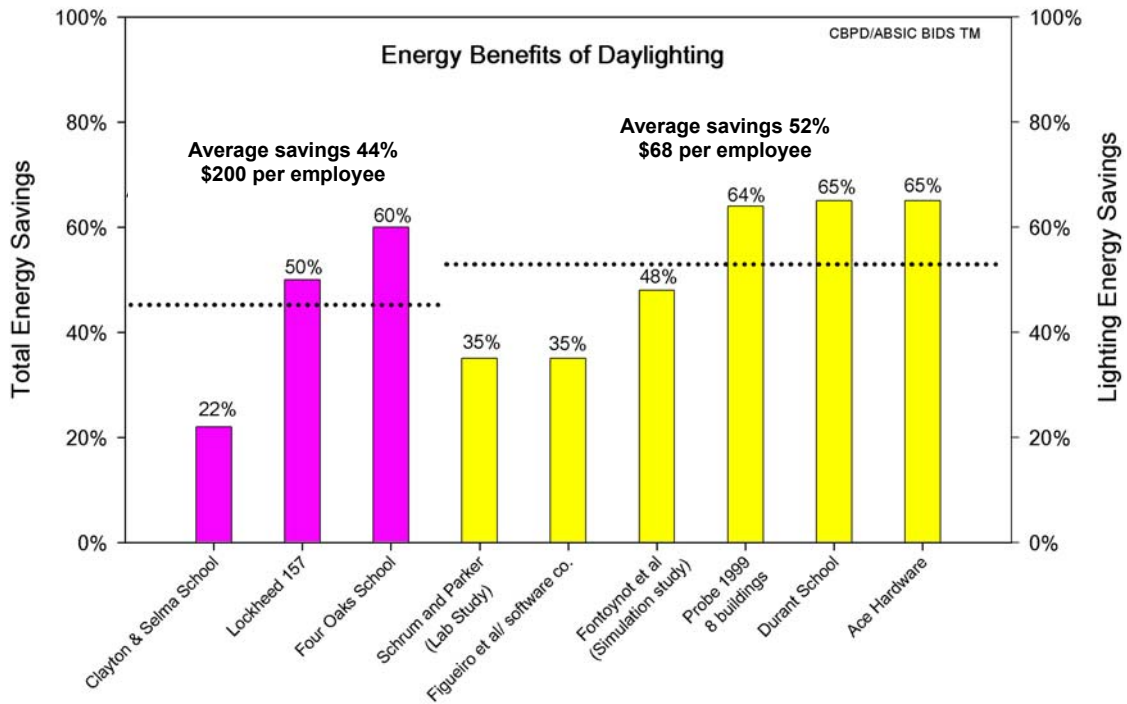
*Using BIDS™ baseline assumptions (national averages)





Benefits of Daylighting

CMU's BIDS™ identifies three case studies that demonstrate an average 44% reduction in overall energy consumption, and six case studies indicating 52% average lighting energy savings due to high performance daylighting systems. Five case studies demonstrate individual productivity benefits from daylighting, with an average improvement of 5.5% annually. Finally, one case study identifies a 40% improvement in organizational productivity due to daylighting, through higher retail sales in a “big box” chain retail store.





BIDS™ Case Study Examples of High Performance Daylighting Systems



Lockheed 157 / Thayer 1995 | Romm and Browning 1994

In a 1995 building case study of Lockheed Building 157 in Sunnyvale, California, Thayer identifies 50% savings in lighting, cooling and ventilation energy and 15% reduced absenteeism due to the daylighting design, which integrates north-south orientation, top lit atrium for bi-lateral lighting, window placement, type of glazing, light shelves, and ceilings.

Thayer, Burke Miller (1995) Daylighting & Productivity at Lockheed Solar Today, Vol.9, 1995./ Romm, Joseph I. and Browning, William D. Greening the Building and the Bottom Line. <http://www.rmi.org/images/other/GDS-GBBL.pdf>



108 buildings

Heschong et al 2002a / Retail

In a 2002 multiple building study, Heschong et al identify an average 40% increase in sales in retail stores, a measure of organizational productivity, where skylights provide a significant portion of daytime lighting, as compared to stores with conventional lighting systems and no skylights.

Heschong, L., Wright, R. L., and Okura, S. (2002) Daylighting Impacts on Retail Sales Performance. Journal of the Illuminating Engineering Society, 31:2, pp. 21-25.

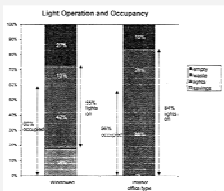


8 buildings

Probe 1999

In a 1999 multiple building study of 8 office buildings in the UK, the Probe team identifies an average 64% lighting energy savings in buildings with effective daylighting due to clear glass and perimeter access, as compared to buildings with deep floor plans and/or tinted glass.

The Probe Team [Bordass, B., Cohen, R., and Standeven, M.] (1999) Final Report 2: Technical Review. Final Report 2 to DETR, August 1999, Probe Strategic Review 1999. <http://www.usablebuildings.co.uk/Probe/ProbePDFs/SR2.pdf>



Software Co. / Figueiro et al 2002

In a 2001 field study at a software development company, Figueiro et al identify a 15% increase in time dedicated to work tasks and a 35% decrease in electric lighting use for occupants of windowed offices, as compared to occupants in interior offices with no access to daylight, in winter months. Given 3 month of winter conditions, this increased performance is 3.75%.

Figueiro, M., Rea, M., Stevens, R., and Rea, A. (2002). Daylight and Productivity: A Field Study. In Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA.



THE NATIONAL IMPACT

Energy Conservation

With a total area of 12 billion square feet, U.S. office buildings use over 86 billion kWh for lighting each year. An estimated 35% of those buildings are already appropriately massed and glazed for daylighting. At the 2003 U.S. average energy cost of \$0.08 per kWh, the potential savings from lighting energy reductions due to implementing high performance daylighting in those 35% of office buildings is more than **\$1.25 billion** each year. Over **15.6 billion kWh** would be saved annually—an amount of energy equal to:

One-fifth the annual energy production of the Three Gorges Dam



3.9 times the annual energy production of the Hoover Dam



The annual energy use of 580,000 U.S. households
 (🏠 = 10,000 houses)



The gasoline used by 782,000 cars in a year
 (🚗 = 10,000 cars)



Energy - Associated Benefits

The annual energy savings of **15.6 billion kWh** achieved by implementing effective daylighting systems in 35% of U.S. office buildings would generate valuable reduction in **emissions** and **water consumption** due to power generation, for a total additional savings of **\$458.8 million annually**, and one-time **peak load** reduction with a value of **\$1.5 billion**.

Peak Load Reduction

1,260 MW
 with an estimated value of
 \$1.5 billion
 (15% peak lighting savings, Choi 1984)

Emissions Reductions

Pollutant	Annual reduction	Annual cost savings
CO ₂	21.8 billion lbs	\$145.2 million
SO ₂	94.7 million lbs	\$221.6 million
NO _x	46.4 million lbs	\$155.6 million
PM ₁₀	2.0 million lbs	\$4.5 million

Water Consumption Reduction

31.4 billion gallons / year
 with an estimated value of
 \$62.7 million annually

Productivity Benefits

Given the average productivity benefit of \$2,475 per employee, the total savings achieved by providing 35% of the U.S. workforce with effectively daylight workspaces is **\$52 billion** annually.