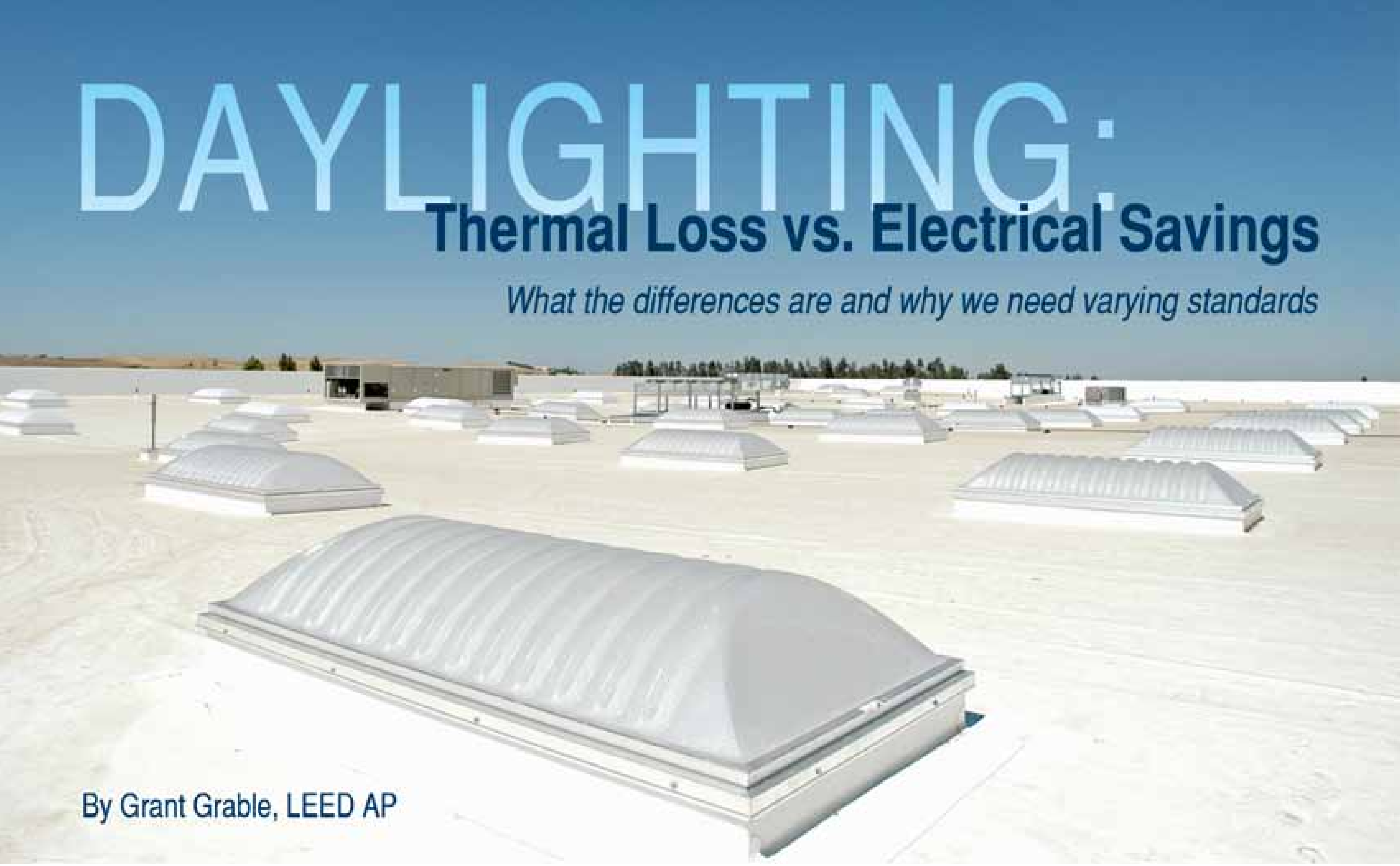
DAYLIGHTING: Thermal Loss vs. Electrical Savings

What the differences are and why we need varying standards



By Grant Grable, LEED AP

Besides decreasing roof surface temperatures, reflective roofing systems also increase reflective light levels for high-performance daylighting applications, increasing their efficiency while putting the roof to work for owners and occupants.

Daylighting is the use of natural light as a main illumination source from a myriad of glazing devices in both vertical and horizontal positions within a building. The use of daylighting stems from the beginning of time, and there have always been similar concerns regarding proper design, light output, glare, and even heat. The quality of light and the value to the human eye and visual acuity have never been argued. The light in the shade of a tree has been measured at 600 - 800 foot candles (6,000 - 8,000 lux), yet the eye is never more relaxed than when it's introduced to these lighting levels. It is the light that our eyes were made for.

However, over time, the value of daylighting through a building's roofing system (often referred to as "toplighting" in the U.S.) has taken on debate from an energy perspective, pitting thermal efficiency of a system against electric light energy reduction provided by the system. Today, code bodies are torn between thermal efficiency mandates and the use of commissioned lighting control with properly diffused, highvisible-light-transmission skylights as to which properties provide the greatest performance measurements for total building energy efficiency.

THERMAL PERFORMANCE AND ENERGY SAVINGS

In June 2008, the U.S. Department of Energy's (DOE) Building Technologies Program published a research paper titled "Commercial Building Toplighting: Energy Saving Potential and Potential Paths Forward," which covers the energy savings benefits from toplighting systems in a multitude of climate conditions and locations throughout the U.S. For this report, the DOE contracted with TIAX, LLC, which enlisted information and assistance from a breadth of respected lighting, controls, and daylighting professionals around the country. The thorough report looks into why skylights, in conjunction with lighting control, should be considered. Additionally, the report focuses on total building energy savings and what the key factors are for a subsequent system.

High-performance school design requires high-performance daylighting solutions that have been proven to increase student performance and decrease absenteesim.

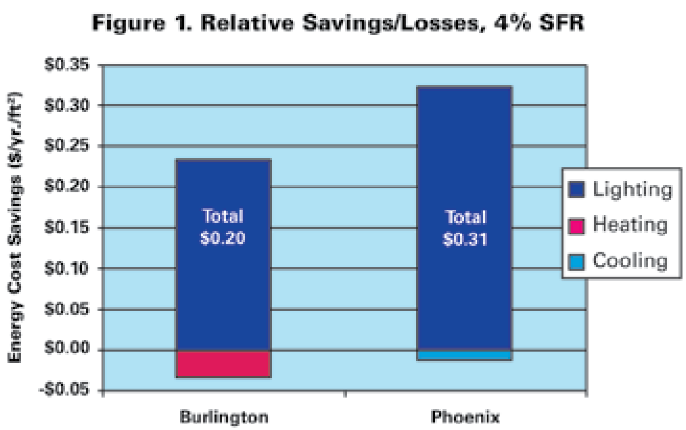


Figure 1

What the DOE identifies is really the crux of the argument. If a skylighting system is being designed for use in a building absent of lighting control, then thermal performance value should be the highest consideration. After all, any thermal value (whether in thermal loss or gain) that deviates negatively from that of the building envelope and roofing system will provide a negative energy impact to the building—either in increased cooling loads or heating loads. However, what would be the primary motivator for including less thermally efficient building products through a perfectly well-insulated roofing system? If thermal performance were the main motivator and the only energy savings opportunity, an energy professional would argue that all toplighting products should be removed from the facility, as they will never equal the insulated value of the roofing system.

However, globally we're now seeing growing mandates for thermal performance of toplighting systems with little to no mandate for performance around the light output properties (let alone the missing key ingredient mandatory for any true energy savings through daylighting—commissioned lighting controls). In many cases around the world, building codes are being established with higher effective skylight-to-floor ratios to compensate for the reduced visible light transmission occurring from decreased values in solar heat gain (SHGC in the U.S. or G-Value in Europe) as well as decreased conductance (U-value). For instance, the European Directive on the Energy Performance of Buildings (2002/91/EC) under the 2006 Building Regulations Approved Document L2A, *Conservation of Fuel and Power in New Buildings Other Than Dwellings*, states that rooflights are limited to 20% of floor area. The area-weighed average U-value of all the rooflights must not exceed 2.2 W/m^2K, while the U-value in an array must not exceed 3.3 W/m^2K, provided the average U-value overall does not exceed 2.2 W/m^2K. As these high skylight-to-floor ratios (SFRs) between 10% to 20% have shown, the rise in thermal mandates has driven the increase to SFRs in order to be able to meet light output needs for the space.

However, extensive studies have been performed on the value that lighting control mandates, along with toplighting, have done to minimize SFRs for a space, which decreases thermal impact and, in many cases, even reduces air conditioning in the process. In section 4.6 of the DOE commercial toplighting report, it states that the primary factors influencing the economics of toplighting are climate and building type (primarily due to lighting power density, schedule, and light well needs); appropriate skylight technology selection is also crucial.

The key performance attributes of a skylight for daylighting are good diffusing properties (to aid in light distribution and avoid glare) and high visible transmittance (VT). Of special note in this report, as stated by the DOE, "Other desirable properties that are much less important for daylighting applications are a low solar-heat-gain coefficient (SHGC in U.S., G-Value in European standards) and low conductance (U-value)." The DOE report illustrates the rationale for this prioritization in a graph, re-created here as *Figure 1*.

The report also states, "Reduced lighting energy use ranks as, by far, the greatest factor in the annual savings at economically optimum SFRs. The reduction in lighting energy use is directly related to VT; i.e., the higher the VT, the lower the total skylight area needed to achieve a given lighting energy savings. However, total skylight area reduces cost and energy losses." The report goes on to identify that, "To further minimize energy losses, in most climates, the SHGC and U-value of the skylight should be as low as possible. However, because heating and cooling energy losses are small relative to lighting energy savings, if reducing

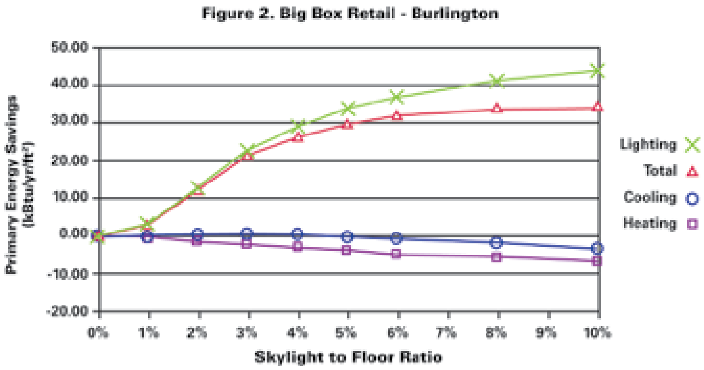


Figure 2

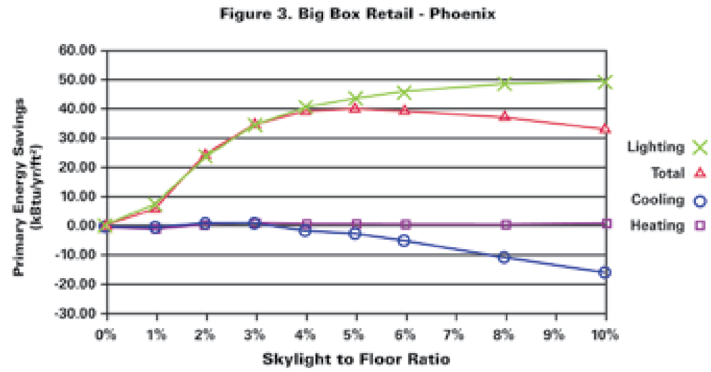


Figure 3

SHGC (G-value) or U-value results in any significant reduction in visible transmission (while maintaining high diffusion, ≥90%), it is generally not a beneficial tradeoff at SFRs in the range expected to be economically optimal, i.e., below 5%."

GOING TO EXTREMES

The report investigates this theory further by documenting the extreme climate conditions in the United States. The area determined to have the lowest amount of solar load and highest heating degree figure in the United States was Burlington, VT. The area with the highest amount of solar load and highest cooling degree figure was Phoenix, AZ. The report documents the results in total building energy savings from lighting, cooling, and heating based on several building types and illustrates the findings in the report, re-created here as *Figures 2* and *3*.

Figures 2 and *3* show that light energy savings truly do compensate for any thermal loss or gain (even in extreme climates) and, in fact, are the main driving factor to any energy savings for the space.

The DOE proves that toplighting solutions that maximize visible light transmission with diffusion and the mandate for commissioned lighting control to maximize electric lighting reduction would produce 0.4 quads of electricity reduction in the U.S. alone for buildings that should be daylit. The report contains a chart shoing the primary energy savings potential for buildings by climate zone, shown here as *Figure 4*.

The DOE report suggests that code changes for "big box" retail and warehouse facilities could help expand daylighting opportunities and save energy. The report states, "Codes limiting solar heat gain and U-value should be loosened for skylights used with lighting controls." It also recommends codes require skylights in certain applications and that rating systems should be updated "to reflect performance in a toplighting application."

As the DOE has documented, there is a major energy consumption difference in buildings that only implement skylights for visual effect and those that utilize commissioned lighting control to minimize the use of electric lighting during daylight hours. As noted above, codes limiting solar heat gain and U-value need to be loos-

INSULATION VALUES OF BUILDING ENVELOPE COMPONENTS

The term "U-value" may seem foreign to many in the roofing industry, as the usual measure for the insulation value of a product is described as "R-value." However, with skylights, U-value is used to quantify heat loss through plane elements of the building envelope. U-value is defined as the overall thermal transmittance of a particular construction element (typically a window, door, or skylight), including the effect of surface resistance. It depends upon the thickness and thermal conductivity of its component layers and, in the case of air cavities, the emissivity of the surfaces. As a measure of U-value, the lower the number, the better the insulation value. Basically, U-value is the reciprocal of R-value.

There is an easy calculation to determine the R-Value of a window or skylight:

1 ÷ U-value = R-value

Once this formula is used with different skylight systems, it is quickly apparent that even some of the well-promoted thermally efficient skylights have a fraction of the R-value that the building's roofing system has. A skylight will never equal the insulation value of a roof and still allow for light to pass through it, so its only value is in the quality of light that passes through the product. After all, it is called a "skylight," not "sky insulation."

Toplighting 5% of the roof area or less with skylights and using lighting controls can eliminate the need for electric lighting at this new Walmart by 70-80%, on average, during daylight hours. In 2003, the California Energy Commission's study on daylighting and retail sales proved that by the most conservative estimate, the predicted increase in sales was at least 19 times greater–and more likely 45 to 100 times greater—than any energy saved through its implementation.

Daylighting is just as applicable in architectural roofing applications as in conventional low-slope applications.

ened for applications where toplighting with lighting controls are utilized and commissioned properly. In the U.S., building energy codes have even been established that mandate daylighting with lighting controls for certain building types. For instance, in ASHRAE 90.1-2010, buildings over 10,000 sq. ft. (929 square meters) with 15-ft. (4.572-m) or higher ceilings with a connected light load of 0.5 watts per sq. ft. (5.38 watts per square meter) or greater have to utilize daylighting and commissioned lighting controls that are focused on high VT with diffusion with more relaxed requirements for U-value and SHGC (G-value). The IECC 2012 code is following this prescriptive as well.

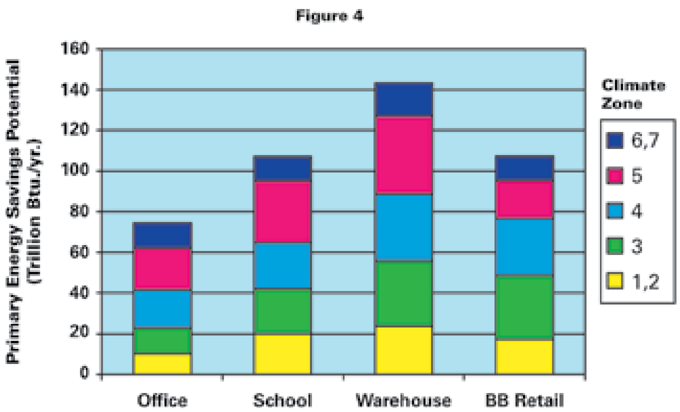


Figure 4

As building energy codes evolve worldwide, the true energy saving benefits of passive solar lighting through daylighting and lighting controls are being discovered. The worldwide daylighting opportunity through reduced electric energy use—of which 74% of all electricity usage is for buildings with 30% to 50% of this value being from electric lighting alone—is staggering. Globally, the environmental impact through reduced carbon output is also as dramatic. The distinction to daylighting with lighting controls needs to be separated from the installation of skylights for aesthetics. The impact to the world would be both economically feasible, as well as sustainable as a renewable energy solution, harnessing the ultimate power of the sun. After all, there is no greater efficiency than "off."

Editor's Note: This article was originally published by Environmental Design + Construction Magazine *in February 2012 and is reprinted here with permission.*

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