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The Elusive Challenge of Daylighted Buildings
A Brief Review 25 Years Later

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Introduction

As we approach the end of the decade of the 1990s, daylighting is increasingly promoted as a design strategy and building solution that can save energy and improve human performance and satisfaction in indoor spaces. Similar claims were made in the 1970s in the aftermath of the oil embargo. Twenty-five years later, in a world newly concerned about carbon emissions, global warming, and sustainable design, daylighted buildings are again proposed as a "solution." While it is possible to find some examples of well daylighted buildings that have been built in the last 25 years, the fact that there are so few suggests that the optimistic outlook for daylighting needs to be critically (re)examined.

In 1978 and again in 1986 the author examined [Selkowitz 1979, Selkowitz 1986] the gap between the potential benefits claimed for daylighted buildings and the actual achievements in building practice. That gap remains in 1998. The first challenge is to define performance expectations for a daylighted space. Many definitions of daylighted buildings and the associated performance expectations are used interchangeably: *Architectural definition*: the interplay of natural light and building form to provide a visually stimulating, healthful, and productive interior environment; *Lighting Energy Savings definition:* the replacement of indoor electric illumination needs by daylight, resulting in reduced annual energy consumption for lighting; *Building Energy Consumption definition:* the use of fenestration systems and responsive electric lighting controls to reduce overall building energy requirements (heating, cooling, lighting); *Load Management definition:* dynamic control of fenestration and lighting to manage and control building peak electric demand and load shape; *Cost definition:* the use of daylighting strategies to minimize operating costs and maximize output, sales, or productivity. Each of these (and others) is a legitimate perspective, but it is important to be clear about which is being referenced. In this assessment we focus on the energy-related savings definitions, recognizing that there are overlapping elements in each definition.

Daylighting Assessment

In comparing the promise and the reality of what has been achieved in daylighted buildings, we conclude that the positive assessments of technical energy-related savings potentials are largely correct, but that these potentials have not been achieved, in large part because of overly optimistic assumptions that technical, cost, and design process issues could be resolved far more easily than was possible. The failure to achieve the expected energy savings and widespread market penetration results from a set of interrelated, contributing factors and from the relative complexity of the "daylighting solution" itself. In contrast, several other energy efficient building technologies have emerged in the building sector over the last 25 years, with large demonstrated energy savings. Low emissivity windows, unknown in the 1970s, have captured over 30% of current sales. T-8 fluorescent lamps and electronic ballasts are on their way to becoming the defacto standard for lighting fixtures. These success stories share some features in common, and some important differences, with daylighting. Low-E windows and electronic ballasts are essentially drop-in, replacement technologies that are “invisible” to the building user and simple to integrate into architectural specifications, once cost, performance and availability issues were resolved. This was no small feat, requiring 15 to 20 years of continuous R&D as well as marketing effort.

Daylighting has benefited from the availability of new and more efficient glazings and ballasts, but these products alone have been insufficient to produce the desired change in the marketplace. Daylighting is fundamentally a systems integration challenge, involving the building siting and orientation, fenestration design, lighting systems design, control systems selection, and ongoing maintenance. Successful designs are often characterized by a relatively high level of design team skill and experience, additional design effort, the selection and optimization of several different technologies offered by multiple vendors, and added attention to ensure successful installation, commissioning, and maintenance. Most of these characteristics involve added first cost. Many building features are “invisible” to occupants or do not call attention to themselves unless there is a significant failure. But the typical building occupant becomes an immediate evaluator and judge of a daylighted space. Anecdotal evidence suggests that most daylighting designs are not particularly failure-tolerant and the presence of glare or the poor response of a photocell to changing light levels is often enough to move an occupant to disable the system. As partial evidence supporting the importance of these obstacles to good daylighting design, it is interesting to observe that some of the most successful daylighting solutions have been in toplighted spaces where the design optimization task is simpler due to the geometric relationship between source and task, glare control is less difficult, and the fenestration and lighting control hardware is simpler and cheaper.

Lest one view this assessment too negatively, there are powerful positive forces that reinforce the interest in daylighting. View and connection with the outdoors is a sufficiently strong motive for many people so that they will prefer a thermally uncomfortable perimeter office with windows to an interior space without view. The quality, spectral composition, and variability of daylight are all cited as beneficial aspects of daylight. And a wide variety of claims for daylighted spaces are now being cited, for improved productivity in offices, greater sales in retail spaces, improved academic performance, and health benefits. But to date, there have been few rigorous studies that convincingly support these claims. Despite this paucity of rigorous supporting data, it is difficult to find a “green building” in the late 1990s or any building that professes to incorporate the principles of sustainable design that is not also a “daylighted” building. After several decades where the low-transmittance, reflective glass facade on a compact, monolithic building form was the paradigm of modern architectural design, there is a growing movement to more extended building forms, or more conventional forms with light wells, light courts, atria penetrating the form to admit more daylight, and a shift away from the reflective, low transmittance skin toward a more visibly transparent design solution. These approaches were first popularized in Europe but are increasingly appearing in the US and in Asia. Daylighting strategies seem to occupy a unique and important niche amongst design solutions that provide not only energy and cost savings, but also add amenity and improved functionality, as well as visual quality, to interior spaces.

To further compound an assessment of the state of the art, there have been major changes in the typical office space over the last 25 years as the nature of many office tasks has changed, e.g., computer-based tasks replacing paper-based tasks. The "competing" electric technology has become substantially more efficient, thus reducing potential energy and cost savings. Typical lighting power densities have dropped from $3.0W/ft^2$ to $1.5W/ft^2$ and hours of operation have dropped as better lighting controls have been installed. These two effects, when combined, are reducing typical annual lighting energy consumption from values above $15kWhrs/ft^2$-yr to $5kWhrs/ft^2$-yr. Continued improvements in these technologies and design applications will continue to put downward pressure on the base case annual lighting energy consumption and associated peak power requirements.

Daylighted buildings, as practiced in the late 1990s, have more to tell us about intention and potential than demonstrable accomplishment. Design solutions have been most successful where the technical challenges and integration issues were least complex, particularly in single story, toplighted spaces used for office, retail, and educational purposes. Light distribution is less complex and more uniform that in a sidelighted space and the associated lighting control hardware is simpler and less costly than that needed in typical sidelighted spaces. Glare and contrast differences are more readily controlled. Assessing the successes and failures in a variety of spaces and buildings leads one to conclude that there are common denominators to the problems as well as the successes. Overall, the critical obstacles to widespread daylighting utilization have been a lack of suitable low-cost, high performance components and systems, inadequate attention to systems integration issues in building design practice, a continued focus on first-cost rather than life-cycle costs, a focus on the role of daylighting as a source of illumination to the exclusion of lighting quality and amenity issues, an inability to accurately quantify the non-energy benefits, a lack of accessible tools that allow continuous assessment of daylighting quantity and quality, a lack of credible energy performance data, and inadequate training on the part of building designers.

The Optimist's Perspective

Despite the rather mixed assessment presented above, I remain optimistic that daylighting strategies can, and ultimately will, become a more pervasive and effective element in building design. In order to change building design practice and move us toward this challenging goal, we need to aggressively pursue activities in the following five broad areas:

1. Demonstrate the value of daylighted spaces to owners and workers, with respect to:
    a) amenity and satisfaction
    b) comfort and health
    c) desirability and marketability
    d) reduced operating costs, e.g., energy

2. Create decision-support tools to facilitate design of daylighted spaces, by:
   a) addressing the full design process, from conceptual design through design development
   b) permitting interactive exploration of virtual spaces, addressing both lighting quantity and quality, including occupant response to the luminous environment
   c) assessing daylighting effects under the full range of sun and sky conditions
   d) integrating design of fenestration and room daylighting elements with electric lighting strategy and controls
   e) assessing impact on thermal loads, peak demand, total building performance, energy costs.

3. Develop and commercialize a new generation of cost-effective technologies and systems:
   a) lighting controls—dimmable ballast technology has matured technically and is close to becoming "cost effective" in typical daylighting applications; improved photosensors and control algorithms are needed.
   b) responsive fenestration systems—"smart" window glazings with dynamic control of optical properties (e.g., intensity, direction) are needed to supplement conventional systems.
   c) integrated building energy management systems—linking lighting and fenestration controls with building HVAC, comfort, and metering will improve cost effectiveness and provide larger cost savings.

4. Provide facility managers with the capability to properly manage and maintain lighting in daylighted spaces by providing:
   a) calibration and commissioning protocols
   b) performance tracking tools and diagnostics
   c) systems that are readily adaptable to changing functional task requirements

5. Accelerate market penetration of daylighted buildings
   a) professional education and training
   b) modify codes and standards to encourage daylighting solutions
   c) document and publicize successful daylighted buildings
   d) develop inventive market-based strategies to facilitate items 1) to 4)

A continued and coordinated effort on a global basis to address these challenges will accelerate the beneficial impacts that daylighting can have in terms of energy efficiency, comfort, visual performance, health and amenity in buildings of the 21st century.

References

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