Baselines and Barriers: Current Design Practices in Daylighting

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ABSTRACT

High-quality daylighting for commercial buildings represents a major opportunity for energy efficiency as well as for attractive, functional design. In this paper, the authors examine the current state of the practice of daylighting design based upon research conducted by Pacific Gas and Electric Company. Three levels of practice reflect the degree to which practitioners emphasize daylighting in projects, the degree to which designers understand and incorporate daylighting design measures, and the degree to which designers employ predictive methods (including physical and computer modeling) to assess and refine their designs. The authors examine specific differences between high-level daylighting practitioners and the others, discussing the differences in terms of barriers to high-level practice.

Introduction: A Brief Historical Perspective on Daylighting

Many share our view at Pacific Gas and Electric Company that *daylighting represents the single largest "new" opportunity for energy savings in commercial lighting today* and for the immediately foreseeable future. Although some dispute this view in absolute terms, all agree that there is tremendous potential for harvesting energy savings with daylighting. Similarly, most agree that high-quality daylighting enhances virtually any interior space. There is a growing body of work suggesting that this "enhancement" includes measurable improvements in the *functionality* of the space for its intended purpose: Pacific Gas and Electric Company-sponsored work by the Heschong-Mahone Group provides documentation of this effect in retail environments (improved sales in daylit stores) and in schools (improved test scores) (Pacific Gas and Electric Company, 1999).

We call our programmatic response to daylight problems, issues and opportunities the **Daylighting Initiative**, an effort begun in 1997. The large gap between the *possibilities* of energy efficient daylighting practice and the *results* of typical lighting designs was our point of departure. The **Daylighting Initiative** has two main objectives: (1) to **increase awareness** of good daylighting practice and (2) to **improve the practice** of daylighting design. A series of efforts is ongoing within this initiative, including the work developed for this paper.

Despite the powerful drivers noted above, few buildings today are designed to take full advantage of daylighting opportunities. In fact, one could argue convincingly that, despite significant advancements in areas such as glazing technology and various CAD-related design and construction tools, we are today *behind* where we were 75 years ago in daylighting design. A literature search on the history of daylighting quickly reveals a common theme: building designers placed greater emphasis on daylighting 75 to 100 years ago than has been the case more recently, starting in the last 40 or 50 years (Benton, 1990).

The explanations for this de-emphasis are fairly well-known: a constellation of reasons forms around (1) the development of relatively efficient and inexpensive electric light sources and (2) the roughly concurrent market penetration of mechanical space conditioning technologies and (3) the building shell and footprint considerations dictated by these developments. In other words, building designers did a better job with daylighting 75 years ago than they do today largely because they had no choice.

So, just what are the key market barriers keeping effective daylighting just beyond our reach? Our view is that there are two main barriers. The first, and subject of this paper, has to do with *architectural design practices*. In short, we count on design practices to make daylight available within the space to displace electric lighting during daylight hours. In addition to the many methods for projecting daylight into a space, good daylighting design of course requires careful mitigation of heat gain. Our current research indicates that most designers do not have full command and mastery of these methods (Pacific Gas and Electric Company 1998(a)).

The second, which we note for completeness but will not address in depth in this paper, relates to *the lack of "off the shelf functionality" for daylighting dimming systems*. Experts can and do routinely make such systems work: there are dozens of successful, well-documented, working buildings with good dimming systems. The problem is that it takes an expert and a significant, often non-commercially viable amount of that expert's time to do so. In brief summary, devices made by different manufacturers do not conform to any standard performance and communications protocols at present: as such, they are difficult to specify correctly and difficult to install correctly (Pacific Gas and Electric Company, 1998(b)).

Much work is ongoing in this latter area, including work sponsored by Pacific Gas and Electric Company. But in this paper, we will address *design practice* issues.

Daylighting Design Practice as a Market Research Issue

In early 1998, at a high-profile gathering of the lighting design community, we asked a seminar presenter--a designer--if he felt that daylighting techniques were fairly well known and commonly applied. He replied to the effect, "Absolutely, there's a whole community of daylighting designers, especially in California." He went on to say that this group knew all about daylighting design, and that, whenever there was the need, it was easy to call upon their services and incorporate their thoughts into a lighting design.

Like so many other things about daylighting, this view is both true and false, and obviously so. It's certainly true that a sub-specialty of skilled daylighting designers exists, but it's certainly false that the practice of daylighting design is commonly applied in buildings and well-integrated into lighting design practice. In fact, daylighting is not even on the "radar screen" of many designers, as was born out by the seminar presenters' lecture: after we asked and he answered the question, his presentation proceeded for more than an hour (we timed it), with dozens and dozens of slides of many different projects until finally, he showed one single example of a daylit space.

This little vignette drew us into some of the problems around daylighting design as a practice. In our view, it's both significant and telling that the designer above perceived no particular set of challenges involving daylighting, nor did he perceive any particular opportunity. This view struck a nerve with us: we decided to investigate the view and its implications. We decided to do some market research among practicing architects and

lighting designers and attempt to characterize the practice of daylighting design. We wanted to know how much building designers thought about daylighting in the initial phases of building design.

The following were our research questions:

- If clients ask for "daylighting," what do the designers actually do and what options do they consider to deliver it?
- Do architects consider energy efficiency when they consider daylighting?
- It was fairly easy to hypothesize various elements of a "high level" daylighting practice, but could we identify a population of high-level practitioners?
- Finally, and most importantly, is it reasonably foreseeable that wholesale changes in design practice are plausible over a fairly short time frame?

Could these changes lead to dramatic improvements in daylighting design and dramatic increases in the market penetration of high quality daylighting design?

Top Line Study Results

Going into the study, we developed our questions into a formal hypothesis so that we could divide the sample population into three groups. We decided to designate these Level One, which we characterized as a basic level of daylighting design practice, Level Two, an intermediate level, and Level Three, a sophisticated level. As suggested above, we were particularly interested in learning whether the hypothesized Level Three had an actual population: in other words, is the "high level" of practice merely hypothetical or does it really exist?

We contracted with experienced professional market researchers to do the project. With time and budget restrictions, we directed our researchers to put aside issues of statistical significance, confidence intervals, and so on. These are important issues, but we were most interested in learning first if our classification scheme really did create clusters around the three practice levels (we were not interested in force-fitting the data into three groups). The researchers conducted in-depth interviews that took 45 minutes to one hour to complete.

We found that 58 of our 76 respondents were from the architectural community and that their distribution was as follows: 34 at Level One, 21 at Level Two and significantly, 2 at Level Three. With the exception of the one respondent they could not classify, the researchers found that the remaining 57 fell quite naturally into one of the three groups (there were few "borderline" cases). So, our key findings are that:

1. The classification system works.
2. Most architects practice at a "basic" or "moderately sophisticated" level.
3. There is a small population which practices at a high level.

Descriptions of the Practice Levels

What are the practice levels and what are the implications of those levels regarding energy efficiency? We found the architects could be assigned a practice level based upon whether (and the extent to which) they *typically* do the following:

1. Consider daylight in their overall building design
2. Consider multiple solutions for daylighting design
3. Incorporate daylighting features in their building design
4. Simulate the effects of natural and electric light in interior space
5. Model the energy impacts of daylighting

The five "summary criteria" are important because, if given a choice, most architects and designers consider themselves to be knowledgeable in daylighting design and will self-report that they are reasonably skilled in daylighting. And it's no secret that, generally speaking, clients prefer "bright and cheery" over the alternative.

When considered against the criteria listed, we found that Level One practitioners report that they attempt to be responsive to client requests for daylighting (criteria 1, 2 and 3). At the same time, *an emphasis on daylighting does not drive their overall design process*. They do not possess what one might call "professional mastery" of advanced daylighting techniques and features. Specifically, Level One practitioners:

- do not fully understand advanced glazings and their use in daylighting.
- do not understand dimming systems.
- are not aware of alternative window heights as a design option.

Further, Level One practitioners do not simulate or predict (by way of computer modeling or physical modeling) daylighting performance, either from the perspective of lighting performance or energy efficiency. They are likely to believe that compliance with the current California energy code for buildings, Title 24, will result in an efficient lighting system. Finally, Level One practitioners see "increased cost" as a primary barrier to the increased use of daylighting.

Level Two practitioners are significantly more advanced with respect to all five key criteria. In contrast to Level One, *client requests regarding lighting and daylighting do impact the overall building design.* This group is likely to consider multiple design options, and, at least in part, consider energy efficiency when evaluating options. Level Twos are aware of various advanced daylighting techniques, often specifying advanced glazings, alternative window heights and automatic dimming systems. They do employ physical and computer modeling techniques, although this work is not typically done for the purposes of analyzing daylighting performance. Level Two practitioners tend to think that Title 24 provides a basic, non-remarkable level of energy efficiency. Issues concerning the difficulty of controlling of natural light, not just cost issues, are seen as barriers to the increased use of daylighting.

For Level Three designers, *lighting and daylighting decisions do not simply impact building design; they are fundamental design drivers*. This advanced class of designers makes a conscious effort to balance the impact of electric light and daylight; lighting design features are chosen accordingly. Level Three designers typically consider multiple design options and demonstrate a mastery of all daylighting materials and techniques. This group tends to think of Title 24 as a good minimum for energy efficient design; they typically try to exceed code in their designs.

Perhaps the sharpest contrast between the Level Two and Three practitioners concerns criteria four and five, which have to do with the extent to which they typically *predict* the impacts of their designs from the perspective of lighting quality (criteria four) and

energy efficiency (criteria five). The high level practitioners typically use physical and computer modeling techniques to inform their decision-making in both areas.

A Gap: Architectural Design and Lighting Design

Thus far we have been reviewing the survey results from the architectural community. In addition to the 58 architects surveyed, 18 lighting professionals were included in the survey. This group was quick to point out that architects make (or fail to make) a set of design decisions impacting daylighting, *decisions which are irreversible by the time this next group gets involved*. Under these conditions, lighting consultants and electrical engineers then do the lighting design, which becomes, *de facto*, strictly an *electric* lighting design.

With the partial exception of the Level Three practitioners, who attempt to integrate building design considerations on many levels, we are left with a "*dis*"-integrated design process. The *de facto* structure of the building design and construction industry forces a daylighting designer to straddle traditional interdisciplinary boundaries in order to do a good job. Put another way, all parties may be *interested* in promoting the use of daylighting, but no one is ultimately *responsible*. Or, to paraphrase Amory Lovins, we notice *systematic disincentives* for interdisciplinary planning: as a rule, one puts one's own time, compensation and reputation at risk when one crosses interdisciplinary boundaries. Yet effective daylighting design requires the crossing of traditional interdisciplinary boundaries.

The situation is not static; the nature of commercial building design practice changes constantly. As building owners, designers and the public at large begin to perceive and articulate that high quality daylighting adds value to interior spaces, prospects for the integration of daylighting practice across traditional practice areas improve. Two other important trends likewise spell promise for daylighting.

First, computer-assisted design (CAD) systems are rapidly becoming a standard in commercial building design work. A Pacific Northwest National Laboratory daylighting study from 1990 contains the statement, "Over 75% of the architects [surveyed] could not *name* a CAD system they had used in the past" (emphasis added) (Hattrup, 1990). Nine years later, we found that almost 90% of the architects, lighting consultants and electrical engineers *use* some type of CAD tool in their commercial design work. We are in the midst of an astounding transformation in the practice of commercial building design, with more to come.

The most important part of this transformation is not that a computer display has replaced pencil and paper, but that CAD systems have created new potential for *design integration*. CAD systems lend themselves well to daylighting and lighting simulation "plug-in" modules, which could greatly reduce the cost and difficulty associated with accurate modeling of daylighting options. As we have seen, the cost and difficulty of such modeling is a key barrier to the practice of modeling. Of course, access to a CAD system with daylighting modeling capability does not turn a designer into a daylighting expert, far from it. Mastery of and experience with the elements of design remain essential. Nonetheless, it is our view that the ability to perform such modeling is an essential element of high quality daylighting design.

Second, fluorescent and HID dimming ballast technologies are moving forward rapidly, as are dimming sensor technologies. Although application, installation and

commissioning issues will continue to challenge designers, there are many successful projects today despite such challenges, with prospects for great improvement.

Summary and Conclusions

Back to today's reality. We have identified a three-tiered scheme as the *status quo* for daylighting design practice. The majority of building designers possess a very basic, ordinary level of skill, awareness and sophistication with respect to daylighting; we characterize these as Level One practitioners. Level Two practitioners possess significantly more awareness and skill in daylighting design than the Level One group, but they do not routinely produce buildings with sophisticated daylighting systems. It is especially significant to note that this group does not typically *predict* the visual performance or the energy performance of the spaces they design. The hallmark of the Level Three practitioners is *mastery of daylighting design elements* coupled with an ability to *predict the performance* of those elements.

If we are to harvest a significant portion of the benefits available from daylighting, what needs to happen such that many more practitioners (and buildings) move into the Level Three paradigm? Certainly, more prominent treatment of daylighting in building codes would have a tremendous impact. Likewise, a renewed emphasis on architectural fundamentals as they affect daylighting is needed, both at the university level for architectural students and professional development/continuing education level for practicing professionals. On a purely technical level, it's clear that the benefits of advanced glazing technologies are not well known and applied by the building design community and that there's a real need for additional training in this area.

Design practice integration across traditional boundaries for daylighting may come to us by way of technical developments in CAD systems, both from the perspective of desktop hardware and system software. For example, the group we define as Level Two practitioners would appear to be highly likely to adopt *daylighting simulation* as a standard area of practice immediately if it were possible for one to learn and to operate such systems quickly and easily (Reed, 1999). On the building technology side, there is great promise (and great need) for the continued development of improved dimming technologies and control systems.

The "value" side of the equation is most likely to be driven by building owners and by the general public. There is a growing body of opinion and evidence that suggests that high quality daylighting improves the quality and functionality of interior spaces: to the extent that this trend accelerates, building owners and occupants are likely to start demanding more daylighting in buildings (perhaps in a manner not unlike public demand for "smoke free" interior spaces).

We started this discussion by voicing our view, shared by many, that *daylighting represents the single largest "new" opportunity for energy savings in commercial lighting* today and for the immediately foreseeable future. Today, daylighting design as an area of practice is poised to make rapid advancements. The views, actions and policies of influential individuals, institutions and organizations with respect to the barriers identified will chart the course.

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