Daylighting and Night Darkening

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The sun rises every day in the east and sets in the west. While local climate determines the number of clear or cloudy days during the year, the sun can help light our offices, schools and homes, even on cloudy days, proving that renewable natural resources are abundant.

At night, how many of us can see the Milky Way? Even when atmospheric conditions are clear, it might as well be cloudy because of the sky glow created by outdoor and stray lighting. With heightened concerns about security and proliferating marketing lighting on commercial and retail buildings, outdoor lighting levels have steadily increased. Unfortunately, sky glow and glare have increased with them.

This article reviews techniques for maximizing the use of natural light inside of buildings and minimizing the impact of electric light on the environment. Understand-ing these techniques can help code officials in their reviews of designs that incorporate these important strategies for meeting energy code requirements.

Daylighting Techniques

Including quality daylighting in building designs may appear too expensive in a first-cost analysis. When longer-term benefits such as energy savings are considered, however, it can easily be seen as a good investment, and research has shown that these savings are dwarfed by the financial benefits of increased productivity and profitability. For example, a series of studies performed by the Heshong Mahone Group found that grocery stores which incorporated skylights had a 40-percent increase in sales and students in schools that had the most daylight had 20-percent higher math scores and 26-percent higher reading scores. Finally, it is worth noting that when combined with other integrated design

techniques, daylighting may not even increase initial construction costs.

The first such technique is to take advantage of daylight through proper building orientation. An east-west orientation minimizes solar heat gain and glare in the morning and late afternoon. Glazing on southern exposures provides a potential daylight contribution of up to 45 percent, and northern exposures produce glare-free, quality lighting.

The second integrated design technique is to take into account the sufficiency of daylighting so that electric lighting never duplicates, but only supplements daylighting. On cloudy days, for example, daylight appears "flat" so some direct lighting is required to add shadows. Fortunately, less lighting is required in most interior spaces at night. If a building's electric lighting system is designed only to meet the needs for cloudy days and nighttime activities, then less equipment is needed; and if we consider that many large buildings have cooling loads even in winter because of the internal heat generated by electric lighting, people and equipment, daylighting offers potential energy and cost savings throughout the life of a building.

The final technique is to control electric lighting. The key is combining personal controls with automatic controls. Personal controls give occupants the ability to turn on/off or dim the lights according to individual needs. Automatic controls include daylight and motion sensing and building energy management control. Personal controls can be used in areas such as offices, classrooms or conference rooms where people work, meet or teach, whereas automatic controls work well in public areas such as hallways, restrooms, lunchrooms and lobbies.

A combination of personal and "invisible" automatic controls works best. A good basic approach is to provide individual offices and classrooms with manual dimming controls that have upper, maximum limits when daylight is plentiful and occupancy sensors. Public areas also can be effectively and inconspicuously controlled with daylight and occupancy sensors.

Building-wide automatic energy management systems should not be programmed to control lighting unless there is the potential for energy shortage and non-critical loads should be able to be shed or reduced, in which case the lighting can be turned off or dimmed as needed. If properly designed, lighting controlled by light and occupancy sensors will automatically minimize both daytime and nighttime lighting loads as a subsystem of the building energy management system.

Energy Modeling and Coordination

A mechanical engineer can establish real-time lighting loads by calculating loading when the control strategies are in place. Daylight availability on peak demand days will also help in control strategies and energy predictions. The California Energy Commission's recently updated *Advanced Lighting Guidelines* includes information on successful control strategies and a guide to typical control percentages.

Once determined, the lighting load profiles can be input into a building energy modeling program such as Energy10 or DOEII that combines envelope, daylight contribution, lighting loads, lighting controls and HVAC data to produce an energy profile that can be used to analyze the effects of different design strategies.

The advantage of such integration is the recognition of actual loads. Ideally, mechanical peak loads are reduced, saving money on the HVAC system and offsetting the costs of enhanced glazing techniques and lighting controls.

Electric Lighting Design

The lighting designer or electrical engineer should design for visibility, with lighting levels or "illuminance" being only one of a multitude of factors. For example, the Illuminating Engineering Society of North America's (IESNA) *9th Edition Lighting Handbook*, which ranks visual environment factors in importance for particular area use, points out that many times glare, daylight availability, and modeling of faces and objects are far more important than actual lighting levels. The New Buildings Institute's *Advanced Lighting Guidelines* also provides in-depth guidance on the human factors for typical applications and combines quality design techniques with maximum energy savings.

All of these tools are readily available—it is just a matter of using them effectively with a qualified team of designers. To assist in this, the International Association of Lighting Designers has a referral service listing professional independent lighting designers by locale and/or specialty.

Night Darkening

Light pollution is a combination of direct uncontrolled light and high levels of reflected light going up into the atmosphere. This stray light reflects off of atmospheric water particles and particulates causing sky glow, leaving only the brightest stars visible in the night sky. Light trespass is the neighbor-to-neighbor complaint of "lighting

shining in my window." It is also caused by extremely bright outdoor retail lighting. Most communities with outdoor lighting ordinances focus on light trespass issues, which fortunately ameliorate the majority of light pollution problems.

IESNA's *Lighting for Exterior Environments* explains the issues surrounding light pollution and light trespass and provides maximum light values in order to guard against serious trespass. These values, arranged by specific environmental zones for curfew and non-curfew times, are not recommendations for good design but intended to limit bad design.

Security Lighting

There is a widely held belief that higher lighting levels contribute to higher security. This has led to the doubling or tripling of existing lighting levels for retail outlets and service areas like gas stations, fast-food establishments and automated teller machines. But when does security lighting stop and marketing lighting begin?

For some perspective, consider the following. The illuminance of full moonlight is 0.01 foot-candles. At night, that of most urban streets is 0.5 to 1.0 foot-candles and of non-retail parking areas is 0.5 to 1.5 foot-candles. Trends in retail lighting are illuminating parking lots at 5 to 10 foot-candles, gas stations from 80 to 150 foot-candles and car dealerships in the 50- to 100-foot-candle range (typical interior office lighting is 30 to 50 foot-candles). Lighting levels like these produce light trespass and light pollution. They can also create a real safety hazard for motorists, whose vision can take as long as several minutes to fully readapt to the darker surroundings.

In order to examine these issues, the California Energy Commission is performing an assessment of existing exterior lighting within the state to obtain data on lighting levels, uniformity, glare and energy use. Subjective evaluations are also being performed to establish security and safety perception for different lighting situations. The results of the study should help reveal the relationship between lighting quality and quantity.

Environmentally Sensitive Design

The safety aspects of lighting are obviously important, but whatever the commission's findings it is safe to say that more is not always better. The key to outdoor lighting is minimizing glare and increasing uniformity. This means that lighting levels can be relatively low and still offer both safety and security perception.

Selecting well-shielded area lighting equipment is the first step in minimizing glare. This applies to parking lots and building-mounted and canopy lighting equipment, and is especially important for luminaries with lamps over 55 watts. Equipment bearing IESNA's "full cut-off" designation provide no direct exposure of the light source and work well in accomplishing this goal. Pedestrian lighting can also be "full cut-off" or low wattage "cut-off." Compact fluorescent, induction or metal halide lamps of 55 watts or less are excellent choices. For parking areas, lighting level ratios of 10:1 or less reduce the perception of spotty lighting.

Finally, everything does not need to be lighted all the time. Light only essential areas and combine the right types of lighting with motion sensors.

Conclusion

Imagine urban areas where lighting does not create sky glow. This can be accomplished by eliminating direct upward light transmittance, minimizing lighting levels by not over-lighting, eliminating glare and increasing uniformity of lighting in critical areas. Once communities start turning down the lights, the Milky Way will reappear. ◆

References

The Heshong Mahone Group—*www.M-H-G.com.* (Studies on the effects of daylighting.)

The Illuminating Engineering Society of North America—*www.iesna.org.*

The International Association of Lighting Designers—*www.iald.org.*

The New Buildings Institute—*www.newbuildings.org.* (Downloadable *Advanced Lighting Guidelines* and updates on the California Energy Commission assessment on exterior lighting.)

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