International Institute
for Sustainable Laboratories®

Best Practices Guide
Daylighting in Laboratories

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Executive Summary

This guide to daylighting is one in a series on best practices for laboratories produced by the International Institute for Sustainable Laboratories (I²SL). A prior version was published by Laboratories for the 21st Century ("Labs 21"), a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy (Carlisle, 2003). Geared toward architects, engineers, designers, owners, and facility managers, these guides provide information about technologies and practices to use in designing, constructing, and operating safe, sustainable, high-performance laboratories.

This publication updates the prior daylighting guide with new information that includes the role of daylighting in the integrated design process, daylighting performance metrics and daylighting-related provisions of model energy codes, and recommendations specific to new and existing buildings.

Life science contains a growing number of branches, such as ecology, biology, medicine, and artificial intelligence. These endeavors have the potential to improve our lives and change the world. It is vital that enough well-designed lab buildings exist to advance the study of life and meet ongoing challenges, such as the recent coronavirus pandemic. Moreover, it is important that these buildings provide scientists and other researchers with environments that support research, foster innovation, and enhance performance.

One way to do this is by designing and building laboratories that make good use of available natural light, or daylighting. Daylighting not only saves energy; it is also intrinsic to an interior work environment that promotes occupant well-being and stimulates creativity and discovery.

Multiple studies conducted in schools and office settings have demonstrated that access to good daylighting and exterior "natural" views helps to improve overall well-being and increase productivity (Jamrozki, 2019; Shishegar, 2016). An increase in productivity of even 1%—because of providing natural light and views to the outdoors—has been known to nearly offset an organization's annual energy costs. In addition, providing access to natural light and exterior views in offices and labs is a good way to recruit and retain top scientists, technicians, and other key research personnel.

Daylighting Design

What Is Daylight?

The three sources of daylight are:

- Exterior reflected daylight (sunlight and sky light reflected from the ground, adjacent buildings, and other objects in the surround).
- Direct light from the sun and sky.
- Room inter-reflected daylight (natural light from the prior two sources that is reflected off walls, ceilings, and other interior surfaces).

Sky light, defined as diffuse light from the sky dome, as opposed to direct sunlight, is typically the preferred source of daylight.

What Is Daylighting?

Daylighting is the controlled admission of natural light into a building interior for the specific purpose of illumination, in balance with parallel considerations of sun control, view access, privacy, and energy savings.

Figure 1. Lucile Packard Children's Hospital, Palo Alto, CA, features a design that places a unique emphasis on mind, body, and spirit. The overall design is structured around connecting children to nature. To support the experience, daylight is incorporated as an integral design element. Photo: Emily Hagopian.

Energy savings from daylighting result from reductions in lighting and cooling load. Lighting load can be reduced with occupancy sensing and daylight harvesting. Daylight harvesting is the dimming, or turning off, of a building's electrical lighting to save energy when daylight is available. However, with the advent of LED technology, electrical lighting loads have decreased significantly, thus limiting potential energy savings.

The control of electrical lighting in response to daylight may be by the occupant (manual control) or by a computerized building control system (automated control) and may involve an array of system component equipment that includes switches, dimmers, sensors, timeclocks, power supplies, and drivers. Reducing electrical lighting load can, in turn, impact cooling requirements and increase energy efficiency.

Additionally, envelope decisions for improving daylighting access also impact cooling loads. Façade design decisions that balance access to daylight to maximize visual comfort while minimizing cooling loads are critical to a good daylighting strategy. Early energy modeling can be useful for assessing façade variations and their impact on daylight availability, artificial lighting needs, and cooling and heating loads.

Integrated Design

Successfully daylit buildings begin with the integration of daylighting into the building's overall design concept, interior spaces, electric lighting system, and mechanical systems. It involves a higher reliance on energy modeling to inform design decisions and results in smarter use of heating and cooling systems. Ideally, this effort starts early in the design process, involves the entire design team, and continues through to commissioning and ongoing tuning and maintenance.

When done properly, the benefits of daylighting may vary by project type (for instance, increased retail sales in a store, increased learning in a classroom, or accelerated healing in a hospital). However, a common thread is that, in all applications, benefits extend to the occupants of the space. In a laboratory setting, these typically include increased productivity, reduced absenteeism, and promotion of the well-being of all occupants, which may extend to a variety of living things.

Envelope Decisions

Site, Climate, Massing and Fenestration

A critical measure of daylighting performance is the percentage of building floor area that falls within “daylight zones” where daylight provides usable illumination. High levels of daylighted floor area are achieved by designing a building for a specific location and climate so that these contextual parameters drive “first order” design decisions of siting, orientation, massing, fenestration, and shading.

Climate is another consideration. Successful daylighting strategies need to respond to a building site’s predominant sky condition and the specific range of solar angles incident on the building envelope, the latter which is determined largely by latitude and façade orientation.

The form of the building impacts many critical internal and external daylighting considerations, such as the amount of façade area that faces a particular direction, the building’s self-shading and self-reflecting properties, and so on. Next is the fenestration design, involving the amount of window-to-wall area and the pattern of window and skylight openings.

Fenestration for daylighting design entails more than the maximization of envelope window area. Fenestration needs to be properly sized and located to maximize available daylight and avoid direct sunlight in critical task areas. In existing buildings, it often impossible to modify the perimeter envelope, but toplighting may offer a solution for increasing core daylit area. An overarching goal is to maximize the distribution of usable daylight illuminance over the “regularly occupied” interior building space while avoiding glare and excess heat gain.

Shading

Shading strategies need to be discussed, and budgeted for, in the Concept or Schematic Design phase and not discarded in the value engineering process. These strategies should describe the specific types of shading devices and shading control systems required, and a Shading Control Intent Narrative should be provided.

Shading devices have a variety of forms. They may be exterior elements, such as overhangs and fins attached to the building exterior, or interior elements, such as light shelves hung along a curtain wall. They may be dynamic, such as motorized louvers in a skylight system or electrochromic glazing units that provide variable light transmittance based on tint state.

Shading control systems may be manually operated, for instance through the use of pull cords or chains, or may be automated by computer-controlled systems that employ motorized control, timeclocks, customized algorithms, and real-time sensing of sky conditions by window sensors or rooftop radiometers. Although manual controls are easily understood by the building occupant, cheaper to install, and less prone to failure, they do not provide the wide range of benefits that come with automation. For example, automated shade controls reduce the numerous “touch points” associated with manual shade pull chains, which will require periodic cleaning and sanitizing to reduce the spread and transmission of viruses, bacteria, and germs. Control parameters can be set to operate shades based on limits to sun penetration depth, sky brightness, and heat gain.

Glazing

Glazing selection has high impact on the visual and thermal performance aspects of a daylighting design and for this reason is an important parameter in building energy simulation. With the goal of net zero-carbon buildings in sight, each successive cycle of energy codes has become increasingly stringent in regard to envelope glazing area and overall thermal performance requirements of the exterior envelope assembly. The prescriptive compliance approach of energy codes uses window-to-wall ratio (WWR) to limit the amount of envelope window area and skylight-to-floor ratio (SFR) to limit the amount of envelope skylight area.

Other prescriptive energy code provisions specify several minimal glazing performance parameters based on climate zone. These include visible transmittance (VT), solar heat gain coefficient (SHGC), and assembly U-value. Visible transmittance is a measure of the percentage of visible light transmitted into the interior through the fenestration unit. The total VT of the window unit sums the effect of many possible combinations of glazing properties, such as substrate tint, low-E coating, and ceramic frit, as well as the effect of other elements, such as materials or structures located within the cavities of the glazing unit.

In regard to thermal performance, the primary glazing properties are solar heat gain coefficient (SHGC) and U-value. A low U-value indicates a higher level of insulation, which is typically better for energy efficiency. SHGC specifications can help reduce or increase solar heat gains through glazing. Specifying SHGC based on façade orientation and a space’s requirement for solar heat gain can optimize energy efficiency. A high ratio of VT to SHGC, also referred to as the light to solar gain (LSG) ratio, is an indicator of spectrally selective high-performance glazing.

In the past decade, many glazing innovations have helped improve availability of high-performance options without a significant cost premium for projects. This allows designers to maintain energy performance and access to good daylight without compromising aesthetics.

Technologies like triple glazing, quad-layer silver coatings, vacuum-insulated glazing, and electrochromic glazing have vastly increased options for high visual and thermal performance. It is also worth mentioning developments in non-glass fenestration. One example is ethylene tetraflouroethylene (ETFE). This lightweight foil material (approximately 1% the weight of glass) can be printed or fritted upon for varying levels of transparency or translucency and can be used as a single-ply membrane or as a series of pneumatic cushions of two to five layers. Such innovations can help projects meet the more stringent code requirements of envelope performance while maintaining access to good daylight.

Figure 2 (on page 5) shows how designers of a research lab in the University of Washington School of Medicine took advantage of glazing technology and incorporated in the window design a central strip of brightness-reducing frit to reduce the potential of glare from sun, sky, and ground.

Interior Decisions

After envelope and fenestration, the next critical building decisions occur at the inside plane of the fenestration and extend into the interior. Interior shading devices, such as operable fabric shades, often provide the first line of sun control. Due to the geometry of the annual solar path, shades within 45° of east and west facades typically need to deploy and retract at least once per day for half a day for the entire year, while those facing south may be deployed for the entire day during winter.

Changing sky conditions, exterior reflections, task requirements, and user preferences further modify the pattern and frequency of shade operation. Studies have shown that in commercial buildings where users are left to manually control shade operation, shades tend to be left in their lowest position for extended periods, nullifying the benefits of daylighting and view access. Therefore, the selection of automated over manual shade operation, along with the associated cost increase, should be considered—and budgeted for—early in the project design.

Shade Fabric

After the selection of glazing, if interior fabric roller shades are utilized for sun control, the selection of shade fabric is the next material decision that affects daylighting performance. Like glazing, fabrics have multiple properties that determine thermal and visual performance. The most important visual properties to consider are color, openness factor (OF), and VT. When in full sunlight, a lighter color fabric can become a source of diffuse daylight, but this same quality affords it poor "view-through" and increases its potential to become a source of glare. Darker fabrics have better "view-through" that increases with OF and weave type, but usually don't contribute significantly to interior daylight levels or the perception of brightness at the window wall.

Figure 2. A research lab in the School of Medicine, University of Washington, shows different glazing properties within the same fenestration elements to optimize performance. Photo: Benjamin Benschneider.

Shade fabric needs to be considered together with glazing to assess combined visual effects. In-situ mock-ups are highly recommended.

Room Elements

The heights and arrangement of walls, partitions, and furniture, and their openness and transparency, will modify the flow of daylight into the core of the building. Walls and partitions placed parallel to the window wall will impede daylight flow, while those placed perpendicular, or simply omitted, will promote it. Room shape also enables the optimization of daylight flow and can involve many details such as sloped ceilings, window and skylight splays, and room depth and proportion. (Splayed windows or skylights have frames set at an angle with respect to the face of the wall or ceiling.)

Paramount to interior room considerations is the selection of interior materials and finishes. High-reflective finishes not only increase the inter-reflected component of daylight; they also increase the occupant's perception of brightness to affirm they are in a daylighted space.

Figure 3 shows key room elements that enhance the perception of daylight. These include the shade configuration, high-reflective finishes, and openness of partitions placed perpendicular to let daylight deeper into the space.

Daylighting Techniques

Sidelighting

Sidelighting is the most common daylighting technique. Sidelighting describes the admission of daylight into interior space "from the side," through windows in either individual (e.g., punched) or grouped (e.g., strip or ribbon) configurations. For many buildings in dense, urban environments, exterior reflected daylight is the primary source of sidelighting. For multistory buildings in urban environments that tower above surrounding buildings or obstructions (greater than 25° above the horizon), the primary source of sidelight is from sun and sky. This simple concept is, in turn, affected by façade orientation and sky type.

Figure 4 (on page 7) shows how HGA, the firm that designed of the University of Rhode Island's Beaupre Center for Chemical and Forensic Sciences, creatively applied a combination of sidelighting techniques that aligned with the project's aesthetic and functional goals.

Sidelighting Rules of Thumb

The location of the window on the window wall may be closer to the ceiling or floor or may extend floor-to-ceiling to form a fully glazed "curtainwall." In general, the higher the location of the window on the wall, the deeper the depth of daylight penetration. It is important to note that extending window glazing to the floor plane does not necessarily deepen daylight penetration and, in some cases, may increase the potential for glare and thermal loads. Also, the wider the window, the more uniform the distribution. These concepts are captured by two simple sidelighting rules. (These

Figure 3. A split window design with distributed internal shading devices, high-reflective interior finishes, and open partitions used at the UC Davis Veterinary Medicine 3B building to enhance access to daylight. Photo: David Wakely Photography.

formulas, or some variation of them, are used by model energy codes to establish daylight zones that contain specific electrical lighting controls requirements.)

The first rule states that daylight zone depth is twice the window head height as measured from the ground, and broken into two zones identified, respectively, as "primary" and "secondary." The second rule is that these daylight zones extend beyond the edge of the window about a quarter of the window head height, usually estimated at 2 feet, 6 inches.

Many sidelighting techniques have been developed around these simple rules. For example, sloping a ceiling down from the window wall into the room can effectively heighten the location of a window on a wall, or locating a tall window near the corner of a room can allow daylight to reflect off a sidewall. Refer to Figure 5 (page 8).

Split-Window Design Approach

In a typical window, the primary function of the upper part (above 7 feet, 6 inches above finish floor, or AFF) is to illuminate the secondary daylight zone and drive daylight deeper into the room, while the lower part (below 7 ft, 6 in. AFF) of the window has a dual function to deliver daylight to the primary daylight zone plus provide occupants located in both the primary and secondary zones with a visually comfortable view to the exterior.

A "split-window" design approach can balance the functional requirements of daylight and view. It brings high brightness exterior elements to within a visually comfortable indoor luminance range and can use a higher VT at the upper part of the window to admit the greater amount of daylight needed to extend to the secondary daylight zone and beyond. (Note that brightness reduction of the solar orb is not mitigated through the use of glazing VT alone.) These basic principles can be used with more advanced glazing technologies such as sunlight redirecting glass, electrochromic glazing, and selective angle view glazing. Figure 4 illustrates a split-window design approach.

Figure 4. Different sidelighting techniques (curtain wall, punched windows, ribbon windows, exterior shade) in a single façade design by HGA at the University of Rhode Island's Beaupre Center for Chemical and Forensic Sciences. Photo by Anton Grassl; image ©HGA.

Toplighting

Toplighting describes the admission of daylight into interior space from above. It includes a broad range of fenestration typologies, such as includes skylights, roof monitors, sawtooth roofs, and atria.

"Core lighting" describes a toplighting technique in which daylight is brought down into a building core, possibly over multiple stories. It can be accomplished with traditional architectural features such as atria and light wells, or with a variety of technological devices that allow deeper core lighting, such as tubular daylighting devices (TDDs), fiber optic-based hybrid solar systems, and sunlight-redirecting mirrors called heliostats.

Toplighting is an effective solution for tenant improvement or repositioning projects involving existing buildings where envelope modifications to wall surfaces are not possible, such as through the addition, replacement, or deletion of existing

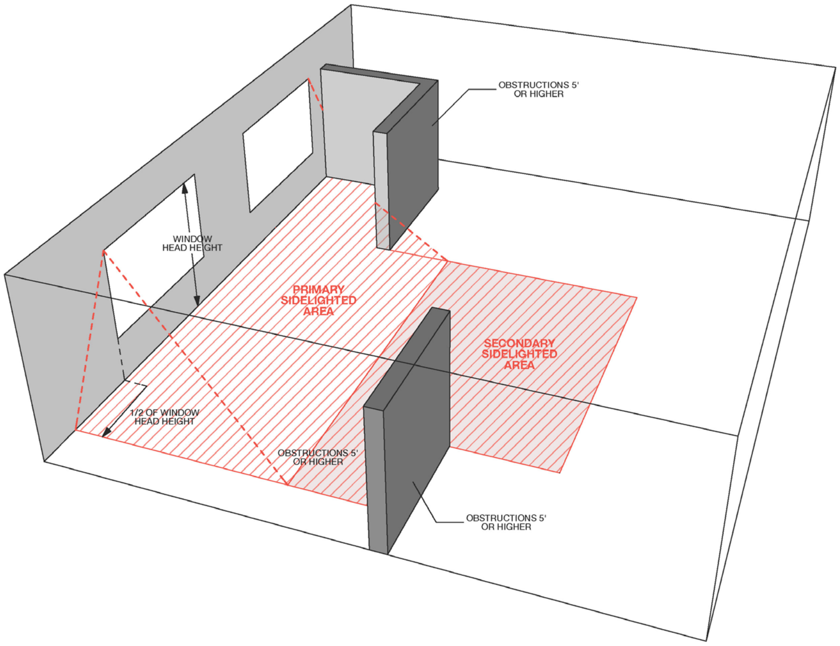

Figure 5. Sidelighting rule of thumb. A sidelighted room with sufficient daylight, as per ASHRAE Standard 90.1, illustrates the rule of thumb in designing for daylight. Source: ©Tanteri + Associates 2014.

windows, but changes to roof and core areas of the building are possible.

Toplighting Rule of Thumb

Toplighting results in a single, primary daylight zone. The rule is that the toplight zone extends 1.5 times beyond the height of the fenestration boundary in plan, typically measured at ceiling height.

Combinative Approaches

Although toplighting has a relatively simple rule set compared with sidelighting, the typologies are highly varied, from simple skylights to more complex designs, monitors, clerestories, and atria.

Daylighting from two directions is much more effective than from one. Sidelighting can be from one side (unilateral sidelighting) or two (bi-lateral sidelighting). In staggered sections, a roof may slope down and up and incorporate various daylighting techniques. A room can be sidelighted on one side and toplighted on the other, or sidelighted on both sides and toplighted in the middle.

Figure 6 (on page 9) shows how the design team for the Bill and Melinda Gates Center at the University of Washington incorporated a large skylight within the lighting scheme. The skylight covers half of the ceiling and brings a flood of daylight into the main atrium. Tunable white uplights integrated into the design extend this experience to the remaining expanse of the atrium ceiling, subtly changing color throughout the day to replicate the cyclical daylight conditions.

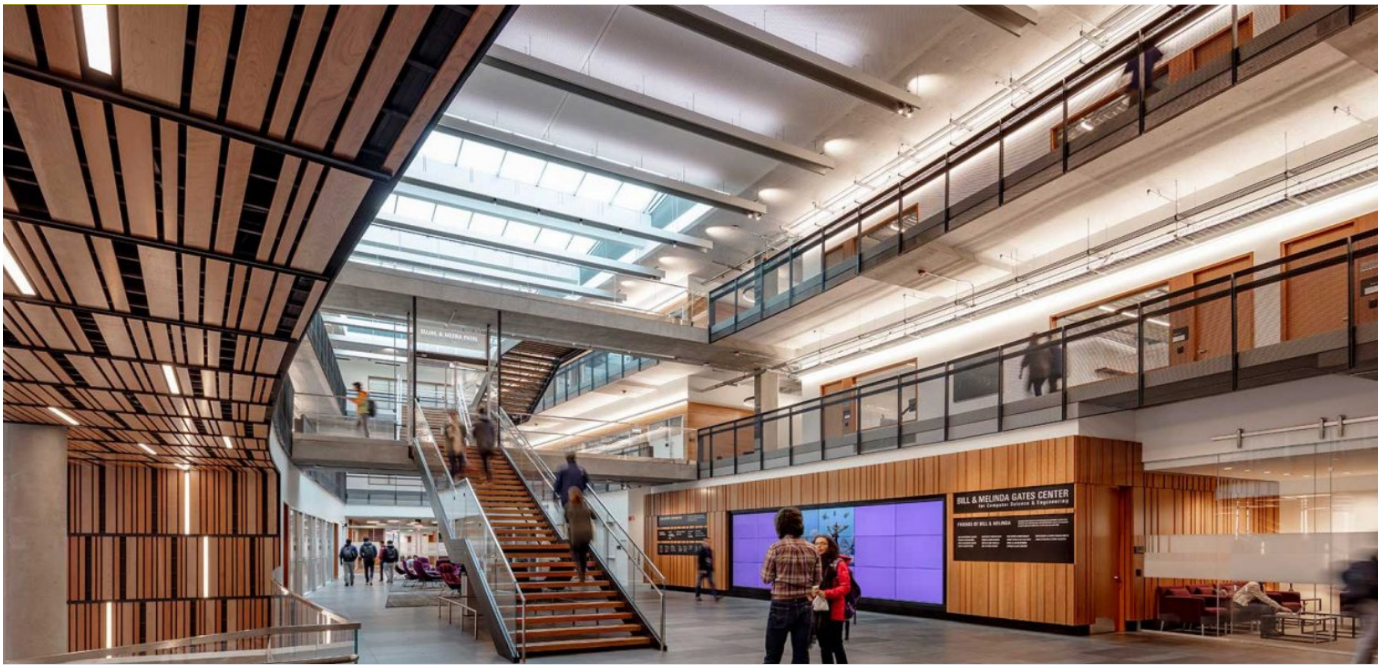

Figure 6. Atrium at the Bill and Melinda Gates Center at the University of Washington, with a large skylight that covers half of the ceiling, bringing a flood of daylight down into the main atrium. Photo: Tim Griffith.

Daylighting Laboratories: Specific Conditions and Strategies

Daylighting laboratory buildings is moving from “best practice” to “standard practice” as building designers gain expertise in addressing the unique challenges of this application.

The daylighting requirements of labs vary widely, as each individual project seeks to balance daylighting requirement with a unique set of parallel, and sometimes conflicting, design factors. These may include view access, privacy concerns, solar control for visual and thermal comfort, UV exposure, overall energy use, and overall lighting approach. For example, in some labs, access to views may be more desirable, and daylighting is of lesser concern. In other labs, scientists may prefer an ambient lighting approach over task lighting and daylight to provide the ideal quality and quantity of light. Where daylighting is not desirable in the lab portion of a life science building, it might still be used in offices and public areas.

In most labs, less energy is needed for lighting than for ventilation. However, according to CBECS 2012 data, in commercial buildings (which includes offices and public spaces), lighting still accounts for the second largest energy end-use (11%) after building space heating (EIA, 2016). Daylighting helps to reduce both the lighting load and the cooling load in these spaces within a lab building.

Daylighting design strategies for life science buildings must often address distinct issues such as the large interstitial spaces between floors, higher lighting requirements, and higher relative complexity of electrical and mechanical equipment and systems.

Laboratory designs often dedicate large amounts of interstitial space above ceilings for MEP (mechanical, electrical, and plumbing) equipment.

An effective daylighting technique is to increase floor-to-floor height by locating utilities, such as ductwork, away from the perimeter. The ceiling can then step or slope up toward the perimeter to meet the top of the window to increase daylight penetration and daylighted floor area. (Rule of thumb: The higher the daylight can enter a space, the farther back it can reach.) Figure 7 shows a ceiling sloping away from the perimeter to bring in more daylight.

Labs typically have higher, and more complex, task illumination requirements than other space types. The selection of appropriate strategies is critical. For example, a daylighting design may target fulfilling most general illumination requirements that occupy greater floor areas with daylight, and the higher task illumination requirements with supplementary electric lighting.

Figure 8 (page 11) illustrates office cubicles placed next to the vertical fenestration while lab benches, where direct daylight is less desirable, are placed further away from the fenestration in this thoughtful interior layout at the Life Science Laboratories at UMass Amherst by Wilson Architects.

Given the complex MEP systems in labs, integrating daylighting is more challenging than it is for other building types. For example, MEP systems may represent up to 50% of a lab's construction budget, whereas these systems typically represent 20% to 25% in an office building.

Daylighting Performance Metrics

Metrics used to predict daylighting performance have been under continuous development. One traditional daylight performance metric that has been losing favor in North America is daylight factor (DF). DF is the percentage of daylight at an interior point compared with the amount of daylight available on the exterior under an unobstructed overcast sky condition. Aside from the "point-in-time" limitation of this metric, it is inherently unable to accurately assess a non-overcast sky condition.

In response, "annualized" climate-based metrics have evolved that use local, hourly-based weather data to predict some aspect of daylighting autonomy. The spatial daylight autonomy (sDA 300/50) metric, introduced by IES LM-83 and adopted by LEED and WELL, is one such metric; it estimates the percentage of interior area that may achieve a threshold daylight illuminance, in this case 300 lux, over an annual period (Illuminating Engineering Society, 2012). Its co-metric, annual sunlight exposure (ASE 1000/250) uses the same climate data and analysis points to assess the likelihood of glare based on the percentage of analysis points receiving 1000 lux for more than 250 hours annually.

Daylight-specific glare metrics, most notably daylight glare probability (DGP), have also been developed to assess the probability of glare in an occupant's field-of-view based on several factors,

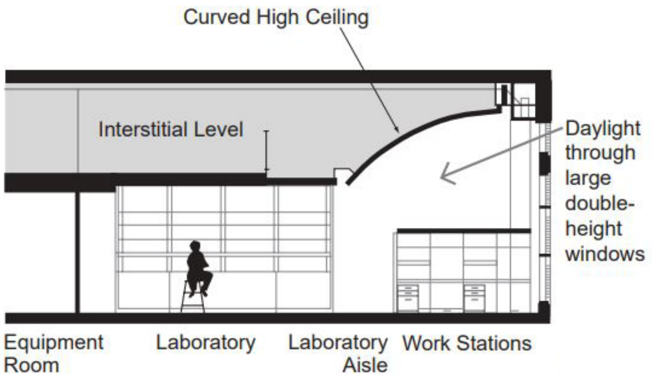

Figure 7. Cross section of laboratories and work stations in Building 50 at the National Institutes of Health, Bethesda, Maryland, showing daylighting through double-height windows. The curving ceiling enhances access to daylight. Source: HLM Design, Inc.

including light source size, location, intensity, and contrast ratio with surrounding luminance.

Use of Simulation Tools in Predicting Daylighting Performance

The prediction of daylighting performance using the newer metrics (sDA, ASE, DGP) is commonly done through computer simulation models as part of an integrated design process assessing both the visual and thermal impacts of daylighting in the design. During the early design phases of a project (e.g., concept and schematic), iterative analysis using "shoebox" models can help quickly evaluate the impact of siting, massing, and fenestration alternatives on daylight availability, thermal loads, and energy performance.

As the design progresses, simulations incorporating more detailed and full building models can be used to analyze daylight performance, integrate lighting control schedules with HVAC loads, help identify primary and secondary control zones, and so on.

Codes and Standards

The Illuminating Engineering Society of North America (IESNA) defines criteria for appropriate lighting, which depend on the nature of the tasks. IESNA recommends footcandle levels as well as visual quality guidelines to consider

Figure 8. The designers of the Life Science Laboratories at UMass Amherst placed office cubicles next to the vertical fenestration to take advantage of direct daylight from perimeter glazing. HLB Lighting's design seamlessly merges daylight and artificial lighting in the writeup and lab spaces. The work desk placed parallel to the double-height windows, followed by lab stations, promotes daylight integration in the space. Source: HLB.

SUCCESSFUL DAYLIGHTING DESIGN: AN INTEGRATIVE PROCESS

The key to a well-designed daylighted project is an the execution of an integrative process. Daylight-responsive design should be envisioned as an integral design need, rather than a stand-alone requirement to meet codes or demonstrate compliance with LEED, WELL, or some other standard or guideline. Principles include the following:

- Identify daylighting performance goals early in the feasibility/concept design phase. The goals should be quantitative and qualitative to address issues of illuminance levels, heat admission, restoring circadian rhythm, sun control, access to quality views, and so on.
- Learn from success of others. Review case studies and/or visit sites to understand a well-daylit space and metrics that were used to attain success.
- Engage a daylighting consultant/designer in the early phases—preferably the conceptual or schematic design phase. A daylighting consultant brings expertise and tools to the team to help identify strategies to meet the project goals.
- Include the identified goals in the Owner's Project Requirements (OPR) and Basis of Design document (BOD) to track them during the design phases and for verification during commissioning.
- Use daylighting and thermal simulation tools during all design phases to optimize strategies (siting, massing, fenestration, glazing, zoning, etc.) and support informed decision-making.
- Investigate design alternatives' impact on capital cost, energy use, solar glare potential, thermal performance, control strategies, and so on.
- Investigate the latest technologies like dynamic glazing, light louvers, and automated networked lighting controls to optimize the daylighting design.
- Ensure that commissioning requirements for daylighting controls are included in the construction documents.
- Ensure that daylighting and lighting systems, and their controls, are commissioned and maintained post-construction.

in lighting design. There are no universally applicable standards for illuminance in laboratory spaces. While there are tasks that require higher illuminance (80 to 100 fc), it is rarely necessary for the whole space to achieve these levels. The 10th edition IESNA Handbook recommends illuminance levels for laboratories to be 50 fc on the horizontal work plane (Illuminating Engineering Society, 2011).

Model building energy codes like ANSI/ASHRAE/IES Standard 90.1 and the International Energy Conservation Code (IECC) code standards set requirements for lighting power densities, controls and daylighting, WWR and SFR thresholds, and glazing performance (ASHRAE, 2019; International Code Council, 2021).

Envelope Requirements

The amount and location of fenestration in a building directly impacts daylighting and view access. However, large amounts of fenestration do not guarantee better daylighting and may increase energy use. Energy codes address this issue by limiting the amount of fenestration and setting requirements for improved thermal performance.

The prescriptive compliance path for energy codes sets limits on WWR and SFR. In fact, the performance compliance path of ASHRAE 90.1-2016 Appendix G limits WWR thresholds based on the building type and penalizes projects with a higher WWR (ASHRAE, 2016). For example, the baseline threshold WWR for schools is only 22%, compared with 40% for large offices.

In recent code cycles, some of the more stringent local energy codes, such as in New York City and Massachusetts, have further increased envelope thermal performance requirements regardless of compliance path approach. These requirements restrict trading poor envelope performance for increased efficiency from other building elements like efficient HVAC systems. For example, Massachusetts amendments to the current building energy code require the use of "envelope backstop" to establish minimum requirements for performance that the envelope should meet, irrespective of the compliance path and other energy efficiency measures incorporated in the design. These more energy restrictive codes are driving buildings to incorporate more opacity in their envelopes, lowering WWRs and bringing back new and old materials and craftmanship to façade design.

Lighting Requirements

ASHRAE 90.1 – 2019, Table 9.6.1, "Lighting Power Density Allowance Using the Space-by-Space Method and Minimum Control Requirements," lists 1.11 watts (W) per square foot as an allowance for lighting power density (LPD) for laboratories in an academic setting and 1.33 W/sf for laboratories in other settings (ANSI/ASHRAE/IES, 2019). In model energy codes, the minimum LPD requirements have seen a drop across all space types in recent years. In some space types (e.g., offices, retail) the reduction is higher than for other types. In ASHRAE 90.1, LPD requirements for laboratory spaces (in non-academic settings) were reduced by more than 25% between the 2010 and 2019 editions.

One significant shift in the code requirements in recent years has involved daylight harvesting controls. The current versions of both the ASHRAE 90.1 and IECC standards require daylight harvesting and automatic daylight-responsive lighting controls for sidelighting and toplighting. It's a code requirement to provide daylight zones on the plans.

Laboratory buildings have high LPD allowances per code compared to other space types. Hence, a daylight-responsive building design with integrated controls provides greater opportunities for energy use reductions, among other benefits, compared with other space types. Admittedly, the potential for significant energy use reduction through a daylight-responsive design has fallen in the past decade since lighting technology innovations have improved electrical lighting performance. For instance, lighting energy end-use in commercial buildings decreased by 50% between 2003 and 2012 (Schwartz, 2017). At the same time, improving occupant well-being and enhancing productivity has taken a central role in good daylighting design strategies.

Voluntary Standards

Voluntary standards like Leadership in Energy and Environmental Design (LEED), the WELL Building Standard (WELL), Collaborative High Performance Schools (CHPS), and so on provide an opportunity for projects to establish aspirational goals beyond the model building energy code requirements to enhance daylight availability, reinforce circadian rhythms in occupants, and provide access to quality outdoor views.

- LEED’s Daylighting and Views credits address design requirements to meet minimum thresholds for daylight availability (Spatial Daylight Autonomy or Illuminance levels) to reduce electrical lighting energy use, design glare control strategies, and ensure access to quality views and connection with the outdoors.
- The WELL standard addresses the importance of providing access to daylight and views through several “features.” To demonstrate compliance, a project design must meet requirements addressing issues of circadian rhythm, solar glare control, daylight design planning, and access to natural light and connection with the outdoors.

The requirements in the voluntary standards in general are established around illuminance levels achieved for ambient lighting needs in a generic office setting. They may not meet requirements for specific tasks in lab spaces. Illuminance and visual acuity requirements for labs are different (and usually higher) compared with ambient lighting requirements. Integrating daylighting in labs is a complex process that should start early (Kozminski, et al., 2006). Voluntary standards do provide a baseline for performance metrics to be included in projects seeking to exceed code requirements.

A newer trend in lighting design, “circadian-effective lighting,“ is designed to entrain the body’s circadian rhythm. Recent research suggests that lack of appropriate light levels and spectra early in the day for sufficient period of time can hinder the body’s circadian response and negatively impact health. Access to good daylight provides the best opportunity to maintain this rhythm. An integrated electric lighting and daylight system that affects the circadian response (measured in Equivalent Melanopic Lux or Circadian Stimulus) can help improve occupant health and well being.

TIPS ON CONTROL STRATEGIES FOR DAYLIGHT HARVESTING

Daylight-responsive controls may be optimized by using the following strategies:

- Minimize number of zones to simplify control logic and system complexity. Avoid over-zoning.
- Differentiate dimming control strategies based on primary daylight zone vs. secondary daylight zones, and so on. For example, primary zones may have continuous dimming with on/off, while secondary zones may have three-stepped dimming. This strategy maximizes lighting energy use reduction while maintaining appropriate illuminance levels across zones.
- Use advanced lighting control systems like networked lighting. LED lighting technology combined with advanced controls provides significant opportunities to optimize dimming strategies.
- Group fixtures in control zones parallel to the perimeter glazing. For example, place the first two rows in the primary control zone and the next two rows in the secondary control zone.
- Separate laboratory tasks and general tasks to allow for greater user flexibility and provide access to daylight for less critical tasks. This can lead to a more optimized dimming strategy that results in greater energy efficiency (Kozminski, et al., 2006).
- Include commissioning of the lighting controls system to make sure it works as designed. Commissioning should include verification of appropriate levels of daylight zoning and zoning control response and corrective action plans for task tuning if necessary.

Integration With Electrical Lighting

An optimized lighting design system incorporates electrical lighting and daylight controls to provide uniform lighting in a space. A good lighting design strategy improves energy efficiency by integrating photosensor and occupancy-based dimming controls to reduce the need for electrical lighting in response to available daylighting and occupant use.

A strategy that uses lighting controls to save energy, simplifies controls as opposed to using overly complex/sophisticated systems, and balances features vs. usability will result in more effective design. This includes defining electric lighting zones, selecting proper task and ambient luminaires, and determining the best lighting control strategy based on occupancy type. It is estimated that if the daylighting and electric lighting systems are well-integrated, the ambient lighting load can be reduced significantly between 10 a.m. and 2 p.m. on most workdays.

Conclusion

Daylighting saves energy, enhances productivity, and reduces costs associated with electric lighting. Daylighting should be considered during the design phase of every new and retrofit laboratory building project. The best time to address it is during the goal-setting process, when defined and measurable goals are established. A successful daylighting strategy must be well-integrated with the building's external appearance, site, and form as well as its mechanical and electrical systems. Therefore, it is important to set a goal for daylighting early in an integrated design process.

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