DAYLIGHTING GUIDE

For the Commercial Office

INTRODUCTION

ADVANCED ENERGY OFFICE
EFFICIENCY·PRODUCTIVITY·CONTROL

AEO design strategies were developed by a national team of leaders in building energy and the indoor work environment.

The strategies reduce the energy used by lighting, plug loads and HVAC systems by 25% and more over current codes, while improving lighting quality and air conditioning/heating performance.

The measures include:

- Best Practice
- Efficient Plug Loads
- HVAC Performance
- Advanced Metering
- Demand Response Thermostat

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An office space taking advantage of daylighting

INTRODUCTION

"Daylighting" refers to the use of sunlight, skylight, and overcast sky illumination to provide functional interior lighting that is appropriate to specific programmatic areas and comfortable to the occupant. The design of an office tenant improvement (TI) nearly always provides substantial opportunity to use daylight to meet these objectives.

The benefits of buildings illuminated with daylight include:

- Healthier and higher quality interior environments for occupants
- Increased individual productivity
- Increased human comfort
- Mental and visual stimulation necessary for the proper regulation of human brain chemistry

When daylight is used as part of an integrated design strategy it can provide substantial energy savings.

The contents of this guide are proposed as a process to successfully design with daylight in a commercial office space. In most areas, this means complete control of direct sunlight during all occupied times and assurance of adequate-diffuse daylight to meet ambient and/or task illumination criteria during daylight hours.

In office environments, daylighting traditionally encompasses three primary avenues of design inquiry:

- Interior surface design and selection for effective daylight harvesting
- Shading for glare control
- Shading for thermal comfort (and heat gain control)

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Programming Criteria

For Each Program Element

Is daylight important for this space?

Are views to the exterior important?

How frequently is this space used?

What time of day and time of year will the space be occupied?

Facts

An overcast sky in the summer equates to a range of 2200 to 4000 footcandles.

An overcast sky in the winter equates to a range of 650 to 1600 footcandles.

Glossary

FOOTCANDLE (fc)
A unit of measurement for calculating adequate lighting levels.

It is the amount of light that actually falls on a given surface.

The footcandle is equal to one lumen (a measure of the power of light perceived by the human eye) per square foot.

Resources

SOLAR CLIMATE ANALYSIS SOFTWARE DATABASE
http://www.eere.energy.gov/
Search for:
"Solar Climate Analysis"

PROGRAMMING
For Daylight Criteria

In an office TI, we assume that window size, orientation, exterior solar control devices and overall floor plate depth are predetermined. Yet, the interior designer still has a critical role to play in creating a design that meets daylighting criteria appropriate to visual comfort. Placement of the program elements takes into consideration the patterns of occupancy, the times of use and orientation of the building to determine the availability and best use of daylight in relation to the program daylight requirements.

Programming for daylight may include LEED™ criteria, however, successful daylighting is far more specific to the visual experience than a single metric.

In order to determine the availability and best use of daylight in relation to the program, the designer must ask themselves a series of qualitative and quantitative questions. The column at left titled Programming Criteria For Each Program Element lists four key queries. While the first two speak of quality of light and view, the second two open up opportunities to hard wire a link specific programmatic elements and thoughtful daylighting strategies.

An example of a program for daylight criteria might include the following:

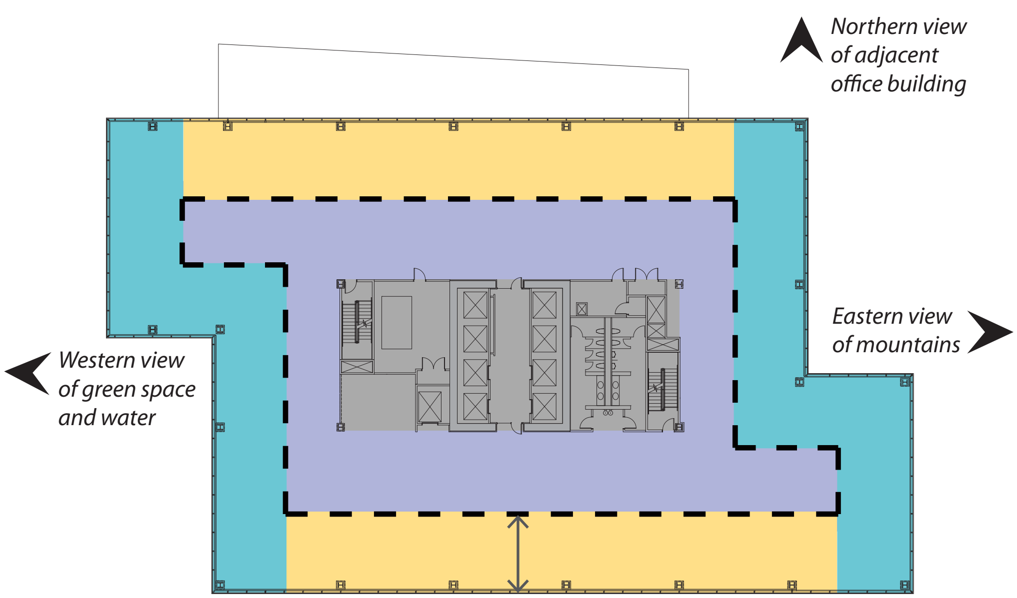
Open Office - Daylight and view desired, occupants have glare control

Private Offices - Daylight and view desired, individual occupant glare control

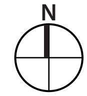
Support Spaces - Minimal daylight or view opportunities required

Building Core - No daylight or view opportunites are necessary

Example of a daylighting opportunity analysis



18' deep into floor plate, window head height is 9' in this space



Legend

- *Daylight available, requires occupant control of glare*
- *Direct sunlight, requires occupant control of glare*
- *Minimal daylight penetration or view opportunities*
- *No daylight penetration or view opportunities*
- *Approximate daylight penetration (2x window head height)*

Programming Criteria

For Each Daylit Space

What are the minimum daylighting requirements?

How crucial is direct sun and glare control?

What is the minimum footcandle level?

Are there maximum light levels required?

What might be the ideal solar orientation?

What might be the best strategy for providing daylight ?
Side lighting?
Toplighting?

Best Practice Footcandle Levels

5 fc: Reception area – simple orientation for short visits.

10 fc: Working spaces for simple visual tasks.

30 fc: Performance of visual tasks of high contrast and large size.

50 fc: Performance of visual tasks of high contrast and small size, or visual tasks of low contrast and large size.

100 fc: Performance of visual tasks of low contrast and small size.

The next critical step during programming is to understand the patterns of light specific to the TI space over the course of a day. Daylighting simulation software can be used to understand the distribution of diffuse daylight, while direct sunlight patterns can be understood quickly with any design software that allows for simple shadow casting. Remember that sun control performance is only critical during occupied times.

Understanding patterns of light specific to the TI space is a critical step in the programming process.

- Identify distribution of diffuse illumination and direct sunlight
- Recognize locations of direct sunlight patterns and the time of day they occur

Once the charactaristics of each daylit TI space are better understood and documented, specific programming criteria can then be applied. The column at left titled Programming Criteria For Each Daylit Space lists six key queries to help define the lighting control strategy of each space.

Tip

Daylight and views are typically preferred in areas that are most heavily occupied for extended periods of time, such as open office areas. Corridors, circulation paths, break areas, copy/print zones or other short-term gathering spaces may be tolerant of direct sunlight whereas fixed workstations or reception desks will almost never remain comfortable with the presence of direct sun.

Fact

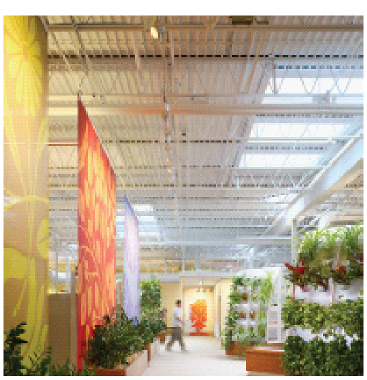
PRACTICAL DEPTH
The practical depth of the daylight zone is limited to1.5 to 2 times the window height.

Glossary

TOPLIGHTING
Daylight that enters the space through skylights or clerestories.

DIFFUSE
Refers to the natural light entering the space through indirect sources, be it obscured by trees, reflecting off adjacent buildings or transmitted through translucent materials.

CLERESTORY
Windows set above eye-level on a wall allowing daylight to enter higher within the space.


Skylights provide toplighting in open office circulation area.

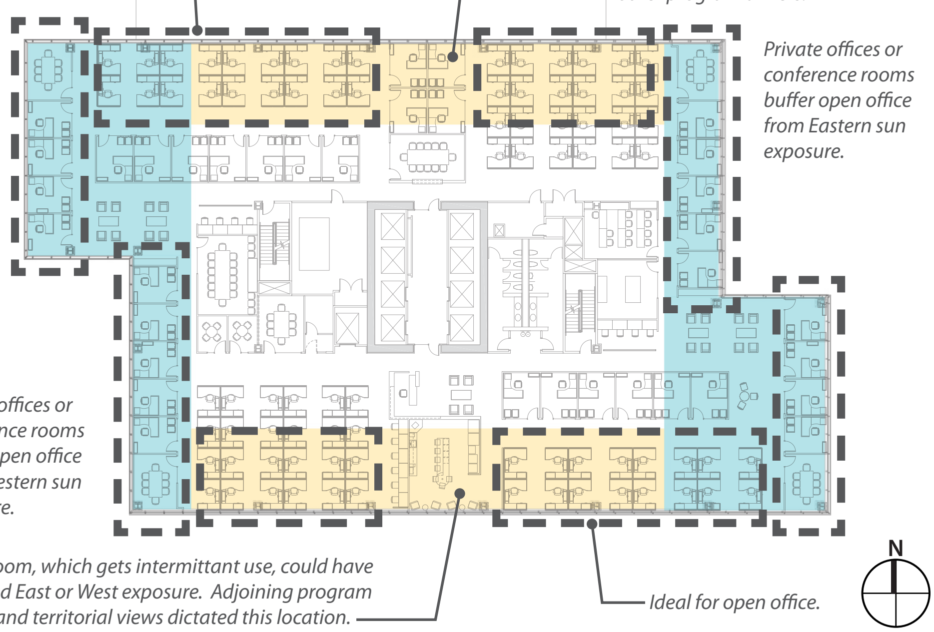
SPACE PLANNING

Relative to patterns of daylight and times of occupancy

When space planning for daylight, the designer can synthesize what they know about the patterns of diffuse and direct sun in the space with each program element's needs, priorities and occupancy patterns.

For example, it is well known that open office environments tend to be occupied by someone nearly continuously during the work day, yet private offices are often unoccupied as much as two-thirds of the time. Occupants in private offices are likely to adjust their blinds frequently, since the "ownership" of their space is clear. In order to ensure an equitable distribution of light and views, the following is recommended:

- Locate open office areas within 18'-20' of the perimeter zone and at areas where direct sun penetration is limited (North) or less variable (South)
- Position individual offices where low angle direct sun may otherwise be problematic (East and West)



The exact alignment of all program element daylighting criteria and the type of space available to the occupants is not always achievable. However, the visual comfort of building occupants must remain paramount in any performance equation. Thus reiterating the importance of an integrated design approach where all strategies in this guide work together to create the most appropriate solution.

Toplighting Strategies

Toplighting via diffuse skylights, or clerestories should be included where possible. Studies show that toplighting tends to provide the most effective daylight performance, since it typically avoids the direct sunlight and glare challenges associated with perimeter windows.

Once a clear description of the daylight performance is in hand, the designer must synthesis the spatial needs of the program elements with the specific patterns of sunlight and diffuse daylight relative to the daylighting design criteria set forth.

Shades / Blinds

Fabric Window Shades:

- Easy to use.
- Requires frequent user attention to block direct sun and re-open for view and diffuse daylight.
- Generally reduces diffuse daylight levels by 90% or greater.
- Cost is approximately $5.70/sf. (2009 installed)

Horizontal Blinds:

- Blocks direct sunlight.
- Requires users to continuously adjust blind slat angles.
- Redirect to create diffuse light.
- Cost is approximately $2.25/sf. (2009 installed)

Window Covering Operation

Manual Operation:

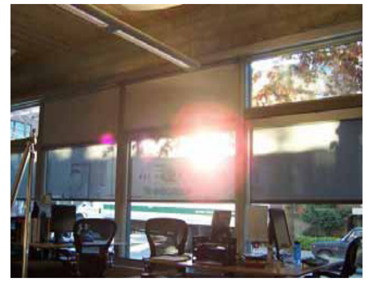
- Proper use can achieve maximum daylight performance.
- Requires frequent user attention to maintain daylight performance.

Automated Operation:

- Deployed and retracted only when needed.
- No user interface required therefore maximizing daylight effectiveness.
- Up to four times as expensive as manual.

WINDOW COVERING DESIGN
For Glare & Thermal Control

The selection of blinds , window coverings, or the lack thereof is likely the most crucial choice a designer will make when seeking to ensure visual comfort while maintaining daylight performance over time.



We have all seen buildings where blinds are down continuously. Typically, this is associated with visual discomfort (glare). The most common source of glare issues in daylighting is a line of sight to the disk of the sun. Selecting a window covering that is opaque enough to block the sun, such as fabric window shades with 3% or less openness or horizontal blinds, can control this phenomena.

Manually operated blind systems can be very effective if properly used, however, they rely on and require constant user attention to maintain complete glare control while achieving maximum daylight performance. For this reason, blinds or shades are often permanently deployed at the "worst case scenario" position to maintain visual comfort throughout the day and year. This typically results in poor daylight performance and the elimination of views to the exterior.

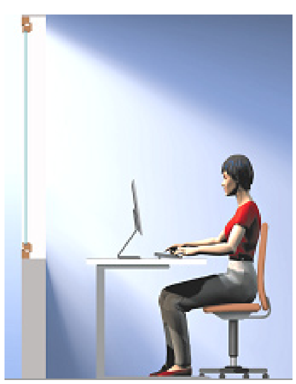
Automated glare control has the distinct advantage of being deployed only when needed and retracting without user intervention when direct sunlight is no longer present to allow for unimpeded diffuse daylight. In most cases, this will deliver longer periods of effective daylight contribution, increased electric lighting power savings, and longer durations of unobstructed views to the exterior. Automation of glare control may provide the most persistent daylight performance where low angle direct sun is present during large portions of the occupied times.

Shading and Exposure Tips

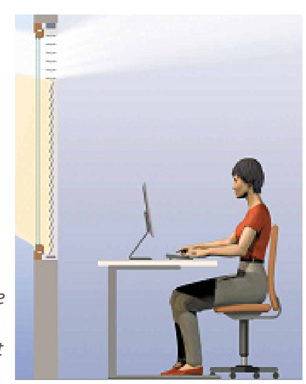
North:
Shading may only be needed in early morning or late afternoon.

South:
Good access to strong illumination but varies through the year. Shading is easier than East/West.

East/ West:
Shading is difficult but critical for comfort.



Direct sunlight can cause visual discomfort. Shutting the blinds here would eliminate the benefit of the daylight.



Example of split window covering strategy to preserve views or block sun where needed, allowing for indirect light into space.

Images couretsy of WAREMA Renkhoff GmbH

WORKSTATION PANEL DESIGN
And Orientation

Influence of Furniture

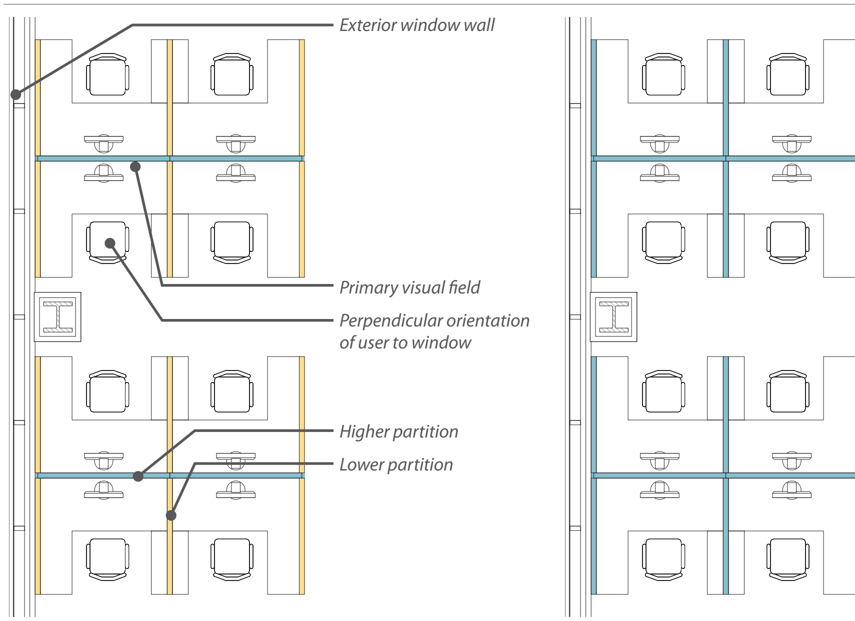
Low panels perpendicular to daylight distribution via exterior window

High panels parallel to daylight distribution

The selection and design of open office furniture, especially workstation panels, requires a continued commitment to the preservation of daylight and views. Workstation panels must be kept low (42" or less) and parallel to the direction of the daylight distribution to ensure the maintenance of views. Where higher panels (48" or greater) are required for privacy or to create a sense of enclosure, they should be oriented perpendicular to the perimeter glazing. 65" high panels that are perpendicular to the direction of daylight distribution can enable privacy and allow for ample storage without compromising views or creating dark shadows.

Workstations should be designed so that the direction that most occupants face while performing visual tasks (most often, looking at their computer) is parallel to daylight openings wherever possible. This helps avoid visual discomfort from building users looking into their own shadow, or worse, from the excessive contrast that might occur when a visual task area is immediately surrounded by the brightness of a view to the exterior.

Workstation Panels



Facts

Facing bright windows can create harsh contrast to tasks at the desk, which can create eye fatigue.

Typically, a better quality of light is that which reaches a task indirectly, such as bouncing from a white wall or ceiling, instead of that which arrives directly from a natural or artificial source.

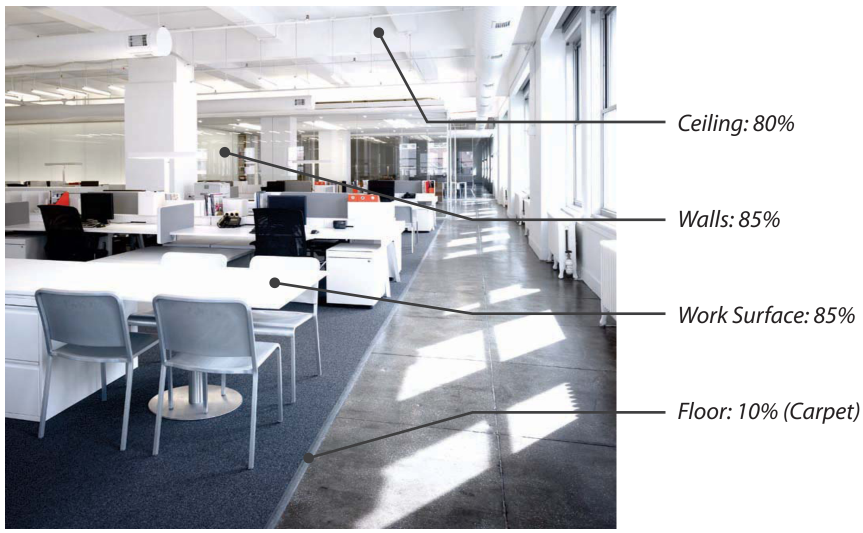
University of Washington/University of Idaho: Daylighting Pattern Guide (New Buildings Institute)

Glossary

VISUAL DISCOMFORT
Can be caused by glare on a computer screen, direct line of sight to the disk of the sun, or excessive contrast of two items within a person's visual field. Often occupants will resort to shutting the blinds or shades if the daylight is causing the visual discomfort. If a space then becomes too dark, users will turn on the electric lighting; thus negating the anticipated energy savings of using daylight.

INTERIOR SURFACE FINISHES

When done in conjunction with the daylighting goals, effective selection of finishes can substantially improve daylighting performance. The position and visual character of the "back" wall, the wall opposite a perimeter window, can serve a crucial role in receiving and reflecting daylighting that travels horizontally into the space. If this wall receives sufficient daylight, and is of a relatively high reflectance value, it will serve to balance the brightness of the view through the perimeter windows.



A high performance interior is designed for direct sun at transition/ circulation space. Note the LRVs of the ceiling, walls & work surfaces.

Interior surface finishes can be a powerful tool in shaping the perception of brightness within interior spaces. Physiologically, our eyes tend to adjust to the brightest location within an interior space. This means that if the perimeter zone is substantially brighter than interior zone, the space will tend to be perceived as dark. This is often referred to as the "cave effect."

It is very difficult to achieve balanced illumination from one side to the other with core depths in excess of 25'-0", with typical office ceiling heights. The balance of daylight distribution within a given volume is crucial to visual comfort and the perception of brightness. Furthermore, structure, beams, ductwork, and other equipment should be positioned so that they do not cast shadows on surfaces that are crucial for daylight inter-reflection. This is especially true with the ceiling plane.

The placement of bright surfaces opposite or around daylight apertures can help reduce contrast and help balance the luminosity in the space. The strategic placement of darker surfaces adjacent to planes that are designed to be perceived as bright can, by contrast, enhance the perception of brightness and uniformity where desired.

Evaluation of Light Reflectance Values ▼

The light reflectance is based on a scale of 0 (total light absorption) to 100 (total light reflection), where 0 is black and 100 is white.

Light reflectance values (LRV) traditionally have been calculated by lighting designers as follows:

80 for ceiling
50 for walls
20 for floors

When estimated LRVs do not match the actual design, the lighting solution may not be appropriate to the space.

It is difficult to achieve maximum energy efficiency when interior finishes are as dark as estimated above.

Glossary ▼

LUMINOSITY
The state of being luminous, emitting light, or glowing brightly.

LUMINOUS INTER-REFLECTION
The reflection of daylight off adjacent surfaces within the tenant space. This can either help balance the brightness of the space or create areas of contrast depending on the reflectance level of the material from which the light is bouncing.

DAYLIGHT APERTURES
An opening such as a window, skylight, or clerestory that allows daylight to enter a space.

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Guidelines

Open office areas: Where daylight is present, utilize daylighting controls.

Workstations: Use occupancy sensor controlled plug strips to control plug loads (computer monitors, task lights and personal items).

Restroom/copy/storage: Install occupancy sensor controlled lighting.

Private offices/conference rooms/break rooms: Install vacancy sensor controlled lighting.

Glossary

PHOTOCELL CONTROLS
Photosensors automatically adjust the light output of a lighting system based on detected illuminance. While some photosensors just turn lights off and on, others can also dim lights.

OCCUPANCY SENSORS
Turn lights on and off by detecting motion within a space. Some sensors can be used in conjunction with dimming controls to keep the lights from turning off completely when a space is unoccupied.

VACANCY SENSORS
Require user to manually turn lights on but will automatically turn lights off after preset duration.

ELECTRIC LIGHTING AND CONTROLS INTEGRATION

Implicit in the discussion of daylighting in the context of an office tenant improvement is that the electric lighting in areas with daylight will be under photocell control. When applied effectively photocell lighting controls can save substantial lighting power. A crucial step in integrating the lighting design and controls with the daylighting strategy includes the identification of user expectations of their role in operating the lighting system and their tolerance for automated transitions in electric light output when daylight conditions change.

We know that the human eye adapts to a wide range of light levels if the transition occurs slowly, however, jarring and unexpected transitions in light distribution and intensity have caused numerous photocell lighting controls systems to be disabled via occupant intervention. An empowered, educated, and motivated building user who takes responsibility for her interior environment is the state-of-the-art in building controls technology.

Organizing Lighting Control Zones

A daylighting "control zone" is a group of fixtures in locations of similar daylight availability that are controlled together via a photocell to reduce light output when daylight is present in an effort to save energy. Automated lighting controls should be prioritized to areas where daylight performance is expected to be high over time, and where individual occupant control of lighting is not realistic.

Responsibility for photo-controls design and integration occurs at the nexus of the interior designer, the lighting designer, and the electrical engineer. Critical considerations are as follows:

- What is the reference location for calibration and commissioning of each zone?
- Who is responsible for doing this work?
- What are the maintained illumination levels?
- Is the photocell placed in a location where what it "sees" is representative of the luminous experience of the space or zone during typical daylight conditions?
- Will other light sources interfere with the ability of the photocell to control a particular zone or layer of light?
- What will the transition transitions between electric light levels feel like?

Tip

Generally, shared open offices areas, rather than private offices, provide the best opportunity for automated photocell control of electric lighting in an office TI.

DAYLIGHTING GUIDE

For the Commercial Office

Facts

Electric lighting comprises between 35% and 50% of the nation's electricity consumption.

Not only is electric lighting used to light an office's perimeter zone where daylighting already exists, it requires additional cooling due to the heat it creates.

By incorporating optimal daylighting strategies, a commercial office's total energy cost can be reduced by as much as one third.

Rebates

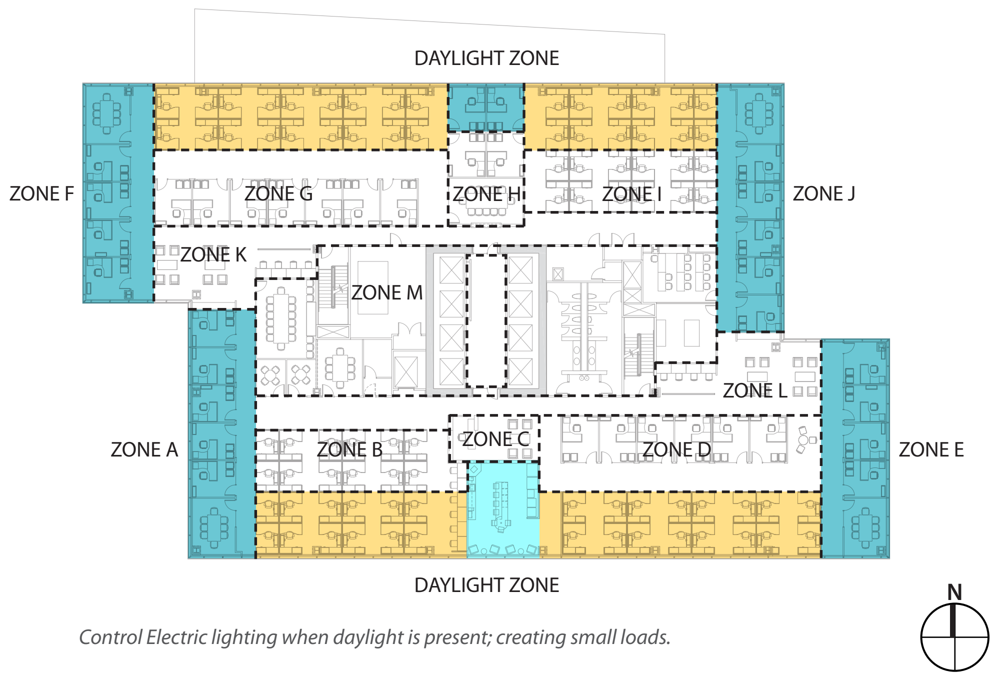
Occupancy sensors provide energy savings simply by turning off lights when the rooms are not being used.

Check with your local utility for rebates associated with occupancy sensors.

Resources

WATTSTOPPER
www.wattstopper.com Search for Lighting Control Best Practice Guide & Daylighting Control Design and Application Guide

LIGHTING DESIGN LAB
www.integrateddesignlab.com/Seattle/Resources/Daylighting.html



Control Electric lighting when daylight is present; creating small loads.

The various control options include:

Continuous dimming is achieved by using a single ballast/single circuit that continuously lowers the light output of its lamps from a maximum 100% output to a low end of 50%, 20%, 10%, 5% or 1% depending on the ballast type. Ballast cost typically goes up as the low end dimming range goes down.

Step-dimming is achieved by using a single circuit that "dims" its lamps to a predetermined lower level through the use of a second circuit to the lamp. One example is 100%/50%/off, which offers a second light level to ALL lamps within the luminaire, which maintains the luminaire's photometric distribution. There are some step-dimming ballasts that offer multiple sub-steps between 100% output and off.

Step-switching is achieved by using multiple ballasts/multiple circuits, each attached to 1 or more lamps, where the de-energizing of a ballast leads to the turning off of its lamps. This requires multiple circuits to each luminaire and produces a shift in photometric distribution when lamps are turned off.

For most traditional shared open office environments continuous dimming is the appropriate choice. This is because the transition in light level is gradual enough that it is not noticeable to most occupants. The unexpected and sudden change in light levels associated with step-switching in office environments has often resulted in irritated occupants disabling their controls systems. Another common source of dissatisfaction is that occupants see fixtures that are obviously de-energized (off) and perceive that something is "wrong." This is an opportunity for lighting designers to choose fixtures that will minimize this perception and to include accent or task lighting that serve to increase occupant acceptance of automated controls.

CONCLUSION

Daylighting design goals and aspirations vary widely among program elements and the visual tasks they support. However, there is a common linkage between design relationships that connect the sky and its patterns of illumination at the macro scale with an individual workstation and the specific needs of a person that will use that space to accomplish necessary tasks. This set of relationships includes:

- The site and sky as a light source
- The massing and orientation of the building (or space within the building)
- The depth of the floor plate
- Building aperture sizes and locations
- Architectural elements and window coverings for glare and thermal control
- The interior surfaces and their luminous properties
- Interior furnishings including workstation panel layout
- And ultimately the orientation of the occupant within their workstation or office; the direction one faces when performing visual tasks

The interior designer, in partnership with others on an integrated design team, has significant influence in realizing the daylighting potential in any tenant improvement project.

Checklist Items

- ☐ Determine daylighting and view criteria for each program element.
- ☐ Do a site visit to understand the existing conditions during the hours of occupancy: where & when the daylighting enters the space, potential reflection off of or shading created by adjacent buildings.
- ☐ Diagram out the daylighting and view opportunities on the floor plan.
- ☐ Align the program criteria for each space with the most desirable location on the floor plan.
- ☐ Select the appropriate windowcovering for the space to diffuse light or glare when and where required. Privacy needs are also a consideration with windowcovering selection.
- ☐ Choose interior finishes that will support the maximum efficiency of electric lighting & daylighting but also support balanced luminosity in the space.
- ☐ Plan for open office workstation panels to be 42" or lower where they are parallel to the perimeter window.
- ☐ Integrate a lighting control system into the space. Zone areas with similar daylight performance together to help reduce electrical light output.

Resources

US DEPARTMENT OF ENERGY, ENERGY EFFICIENCY & RENEWABLE ENERGY
www.eere.energy.gov/buildings
Search for "Lighting and Daylighting" in Commercial Buildings

WHOLE BUILDING DESIGN GUIDE
www.wbdg.org/resources
Search for "daylighting"

DAYLIGHTING COLLABORATIVE
www.daylighting.org

LIGHTING DESIGN LAB, REFINING THE WINDOW
www.lightingdesignlab.com/ldlnewsRefining_the_window.pdf

BETTER BRICKS
www.betterbricks.com