Re-Arch: The Initiative for Renewable Energy in Architecture

Best Practices in Daylighting & Passive Systems for Smaller Commercial Buildings

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Midwest Renewable Energy Society (MRES)
Center for Sustainable Building Research (CSBR)
Midwest Renewable Energy Association (MREA)
American Institute of Architects Minnesota (AIA MN)
Green Institute

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Part 5 –
Daylighting Strategies
Shading
Case Studies

Funded in part by the Minnesota Pollution Control Agency (MPCA)
• **Daylighting**
  – Shading

• **Source:**
• Daylighting – Shading

<table>
<thead>
<tr>
<th>Window Orientation</th>
<th>Shading strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Usually not needed</td>
</tr>
<tr>
<td>South</td>
<td>Overhang, horizontal louvers, trellis over window</td>
</tr>
<tr>
<td>East/West</td>
<td>Vertical louvers, horizontal slats, deciduous trees</td>
</tr>
</tbody>
</table>

Deciduous trees allow sun to warm building in winter
Deciduous trees provide shade in the summer

Effective use of Vegetation for Shading

• Source: Canada-Daylighting-Guide-shading-text-1.jpg
• Daylighting
  – Strategies
    • No Shading
    • Shading
    • Overhangs
    • Fins
    • Setbacks
    • Shades

• Source: Window-System-High-Performance-Bldgs-Carmody-Selkowitz-Shading-1.jpg
• Daylighting
  – Shading

Examples of Various Exterior Shading Devices

- Standard Horizontal Overhang (HO)
- HO, dropped edges for less projection
- Louvers, instead of a solid dropped edge, to allow more light entry
- HO, broken up for less projection
- HO, sloped down for less projection
- HO, louvers in place of solid overhang for more diffuse light
- Vertical Louvers or fins
- HO broken up for less projection

• Source: Canada-Daylighting-Guide-shading-1.jpg
Daylighting
- Shading

- Source: LBL-Daylighting-Guide-shading-1.jpg
• Daylighting
  – Shading

Vertical and Horizontal Louvers to Re-direct Sunlight

Overhang to Increase Light Diffusion

Use of Screens to Diffuse Lights

• Source: Canada-Daylighting-Guide-shading-5.jpg
• **Daylighting**
  – **Shading**

**Fin Size**

Fins should project out from the building the same distance as they are spaced between windows. Shortening the spacing between fins can reduce the fin projection.

*Credit: CKCO Building, Waterloo, Ontario*

An exterior shade screen fits neatly within window framing, a bit away from the glass. Design for easy removal for cleaning.

• **Source:** Canada-Daylighting-Guide-shading-7.jpg
Daylighting
  - Shading

Shades, blinds, and draperies are the categories of interior shading products.

Visible Transmittance and SHGC for Interior Shades

<table>
<thead>
<tr>
<th>Shading Type</th>
<th>% Visible Transmittance</th>
<th>% Reduction in SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venetian Blinds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Colour</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>Dark Colour</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Vertical blinds (closed)</td>
<td></td>
<td></td>
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<tr>
<td>Light Colour</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Dark Colour</td>
<td>0</td>
<td>18</td>
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<tr>
<td>Roller Shade</td>
<td></td>
<td></td>
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<tr>
<td>Light translucent</td>
<td>25</td>
<td>54</td>
</tr>
<tr>
<td>Opaque, white</td>
<td>0</td>
<td>60</td>
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<tr>
<td>Opaque, dark</td>
<td>0</td>
<td>18</td>
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<tr>
<td>Draperies</td>
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<td></td>
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<tr>
<td>Shears</td>
<td>55</td>
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<tr>
<td>Closed weave, light</td>
<td>20</td>
<td>48</td>
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<tr>
<td>Closed weave, medium</td>
<td>12</td>
<td>39</td>
</tr>
<tr>
<td>Closed weave, dark</td>
<td>5</td>
<td>28</td>
</tr>
</tbody>
</table>

• Daylighting
  – Shading

1. Characterize your shading needs. Long axis running east-west: shading is relatively simple (overhang or deep reveal on south may be all that’s needed). Large area of glazing on west: shading becomes more critical and more difficult if daylight is to be maintained. Budget design time accordingly. You must know your true north orientation.

2. Review options for shading and select a basic approach (exterior vs. interior, an architectural projection, an off-the-shelf attachment, blinds, drapes, shades). A different strategy may be appropriate for each facade.

3. For exterior schemes, calculate preliminary size of projections. Use rules of thumb given here or use LOF Sun Angle Calculator method.

4. Refine with LOF Sun Angle Calculator (if still working on paper) or through quick physical model studies (for easier 3-D analysis).

5. Select an interior shading product and get solar heat gain coefficient data from manufacturer literature or product reps (see Sweets for starters). See ASHRAE Fundamentals for tables of generic products.

6. Get solar heat gain coefficient data for preliminary glazing selection from manufacturer literature, product reps, or generic table in Section 4, CLAZING SELECTION, or in ASHRAE Fundamentals.

• Source: LBL-Daylighting-Guide-shading-checklist-2.jpg
• Daylighting
  – Shading

If you have...

no time
1. Minimize window area on east and west.
2. Use sizing rule of thumb for a horizontal projection or reveal on south windows.
3. Use sizing rule of thumb for a vertical projection or reveal on west windows.
4. If no exterior shading is possible, a lower solar heat gain coefficient for the glazing will be mandatory (see Section 4, GLAZING SELECTION), and interior shading will be required as well.
5. For best occupant comfort, provide either a light-colored venetian blind or light-colored translucent shade on all windows in occupied areas. For energy savings, these are desirable to include even with exterior shading; they are mandatory if there is no exterior shading.

a little time
In addition to above:
1. Use the LOF Sun Angle Calculator method for preliminary sizing of exterior projections instead of rule of thumb, or to refine schematic design after using rule of thumb.
2. Browse through Sweets catalog for ideas on shading strategies and products.
3. If undecided on best shading approach to take, a mechanical engineer’s simple calculations can help compare cooling reductions with different options.

more time
In addition to above:
1. Build a physical model and test under sun for best final design of exterior shading.
2. Mechanical engineer takes special care to properly model shading elements and solar heat gain coefficients in computer calculations.
3. If large area of east or west glazing, mechanical engineer performs more complex calculations to determine cost-effectiveness of an automated exterior system.
4. Mechanical engineer helps explore opportunities for cooling equipment downsizing through optimum shading. Refine shading design to yield smallest possible cooling equipment.
Daylighting
  – Shading

ARCHITECTURE
Projections work well with an articulated or layered facade and can integrate well with structural members.
Exterior screens can make windows look dark.
If interior devices are the only shading, many occupants will always keep them closed. This can mean the window is permanently no longer transparent.
Use exterior shading to avoid the facade clutter of variously adjusted interior coverings.

INTERIOR
Choose light-colored window coverings for best energy savings and comfort.
Choose interior window treatments that allow occupants to make adjustments for individual comfort needs.

HVAC
Good shading provides cooling load reductions. The mechanical engineer should perform calculations that include shaded windows, but acknowledge that not all shading systems will be deployed when needed.

LIGHTING
Shading devices modify the intensity and distribution of daylight entering the space. Lighting design scheme and placement of control zones may be affected.

• Source: LBL-Daylighting-Guide-shading-integration-1.jpg
• Daylighting
  - Shading

**COST-EFFECTIVENESS**

Proper shading devices can be partially or fully paid for by reduced cooling equipment and cooling energy costs. However, the likelihood of proper use by occupants must be accounted for. Mechanical engineers should calculate these savings. Compare to any additional construction costs for the shades and calculate simple payback for the shading.

Automated movable systems can have an added maintenance cost and a higher first cost relative to other shading schemes. However, the operation should be more reliable than with manually operated systems. Careful calculation of expected energy savings are needed to determine cost-effectiveness for this approach.

**OCCUPANT COMFORT**

Direct sun in the workplace is almost always a comfort problem. Uncomfortable occupants will be less productive, close their window coverings, bring in energy-using portable fans, and reduce thermostat setting if possible. Good shading means occupants will have minimal complaints.

Shading reduces glare. Exterior elements partially shield occupants’ view of the bright sky. Screens, glazing treatments, and shades reduce the brightness of the window. Exterior elements and venetian blinds reduce contrast by sending some light deeper into the space (improving distribution).

• Source: LBL-Daylighting-Guide-shading-integration-3.jpg
Daylighting
  - Shading

![PROVISOS]

A controlled and limited use of sunlight may be appropriate in some cases.

Direct sunlight:
  • aids the growth of plants.
  • provides strong illumination that enhances details, texture, shape, and color.
  • gives a dynamic vitality to a space through its daily variation—especially beneficial in relieving institutional monotony in schools, hospitals, and public buildings.
  • provides a visual and emotional link to the outdoor world.
  • provides a real and suggested warmth in winter.

Direct sunlight may be more appropriate in circulation areas, transition areas and other spaces that do not contain critical visual tasks. Be sure to account for the peak cooling and annual cooling cost of such designs.

Be sure to balance the needs for sun control against the usefulness of daylight admittance. Some sun control strategies may severely reduce daylighting opportunities.

Source: LBL-Daylighting-Guide-shading-integration-5.jpg
• **Daylighting**
  – **Shading**

  **Exterior Devices**
  - Use exterior shading, either a device attached to the building skin or an extension of the skin itself, to keep out unwanted solar heat. Exterior systems are typically more effective than interior systems in blocking solar heat gain.
  - Design the building to shade itself. If shading attachments are not aesthetically acceptable, use the building form itself for exterior shading. Set the window back in a deeper wall section or extend elements of the skin to visually blend with envelope structural features.
  - Use a horizontal form for south windows. For example, awnings, overhangs, recessed windows. Also somewhat useful on the east and west. Serves no function on the north.

  • The shade’s color modifies light and heat. Exterior shading systems should be light colored if diffuse daylight transmittance is desired, and dark colored if maximum reduction in light and heat gain is desired.
  • Fixed versus movable shading. Use fixed devices if your budget is tight. Use movable devices for more efficient use of daylight and to allow occupant adjustment; first cost and maintenance costs are higher than with fixed devices. Use movable devices that are automatically controlled via a sun sensor for the best energy savings. Reliable systems have been in use around the world for years and have only recently become available as cost-effective options in the United States.

  • Use a vertical form on east and west windows. For example, vertical fins or recessed windows. Also useful on north to block early morning and late afternoon low sun.
  • Give west and south windows shading priority. Morning sun is usually not a serious heat gain problem. If your budget is tight, invest in west and south shading only.
  • Design shading for glare relief as well. Use exterior shading to reduce glare by partially blocking occupants’ view of the too-bright sky. Exterior surfaces also help smooth out interior daylight distribution.

• **Source:** LBL-Daylighting-Guide-shading-text-1.jpg
• Daylighting
  – Shading

**Interior Devices**

- **Interior shading alone has limited ability to control solar gain.** All interior systems are less effective than a good exterior system because they allow the sun’s heat to enter the building. They also depend on user behavior, which can’t be relied upon.

- **If interior devices are the only shading, specify light colors in order to reflect the sun’s heat back out.** Light-colored blinds or louvers are best. Light-colored woven or translucent shades are acceptable, but may not control glare under bright summer conditions.

**In the Window Plane**

- **Use exterior shades for a smooth facade.** Exterior shade screens are highly effective on all facades and permit filtered view.

- **Use roller shades for a movable alternative.** Open weave exterior shades are not as effective, but acceptable.

- **Don’t rely on dark glazing.** Glazing treatments (reflective coatings, heavy tints, and reflective retrofit film) can be effective at reducing heat transfer. They allow direct sun penetration but with reduced intensity. This may not be an effective shading strategy from an occupant’s perspective unless the transmittance is very low to control glare, e.g., 5-10%. Fritted glass, with a durable diffusing or patterned layer fused to the glass surface, can also provide some degree of sun control, depending upon the coating and glass substrate properties, but may also increase glare.

- **Between glass systems.** Several manufacturers offer shading systems (e.g., blinds) located between glazing layers. Some are fixed and others are adjustable. See related comments on interior devices below.

• Source: LBL-Daylighting-Guide-shading-text-4.jpg
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades

• Source: Sun-Protection-Danz-Gansberg-school-WG-1.jpg
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades
• **Daylighting Examples**
  – Sidelighting
    • Exterior Sunshades
    • Fins

[Image: Sun-Protection-Danz-Heuss-school-WG-1.jpg]

• Source: Sun-Protection-Danz-Heuss-school-WG-1.jpg
• **Daylighting Examples**
  - Sidelighting
    - Exterior Sunshades
    - Fins
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades

• Source: Hoffman-Corp-Appleton-WI-1.JPG
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades

• Source: Owens-Corning-Offices-Toledo-OH-1.jpg
• Source: Seattle-Public-Library-1.jpg
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades

• Source: Tubelite-Sunshades-1.jpg
• Source: EPA-Offices-KC-exterior-lightshelves-1.jpg
• **Daylighting Examples**
  – Sidelighting
    • Exterior Sunshades

• Source: CS-Sun-Controls-shading-4.jpg
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades

• Source: Indianapolis-Art-Museum-Entry-4.JPG
• Daylighting Examples
  – Sidelighting
    • Exterior Sunshades
    • Spring Equinox
    • Noon

• Source: Indianapolis-Art-Museum-Lobby-4.JPG
• Daylighting Examples
  – Sidelighting & Toplighting
    • Exterior Shading
    • Fritted Glazing

• Source: Columbus-IN-Irwin-Union-Bank-2.JPG
• **Daylighting Examples**
  – Sidelighting & Toplighting
    • Interior Sunshade

• Source: Window-System-High-Performance-Bldgs-Carmody-Selkowitz-Blue-Cross-IL-2.jpg

• Source: Columbus-IN-Commons-Mall-1.JPG
• **Daylighting Examples**
  – Sidelighting
    • Transom Louver
    • Specular
    • Shaped

• Source: Light-Louver-product-2.jpg
• **Daylighting Examples**
  – **Sidelighting**
    - Exterior Sunshades
    - Exterior Lightshelves
    - Interior Lightshelves

• **Source:** Sunlighting-Lam-Johnson-Controls-UT-1a.jpg
- Daylighting
  - Integrated Lighting Controls
Daylighting
– Integrated Controls

Lighting Control

Define an appropriate lighting control strategy for each lighting zone. Decide whether the zone lights should be controlled by occupancy sensors, daylight sensors, time scheduler or a combination of the above.

Use dimming control for daylighting, lumen maintenance or tuning control strategies. Although dimming control strategies are expensive (at least twice as costly as switching controls) it is the best method to implement. Also, space occupants generally prefer them, as changes in electric light level are less dramatic. Dimming will not be cost-effective in non-daylight areas unless it is coupled with scheduling controls.

Use on/off switching controls where changes in light levels are acceptable. Switching controls will result in abrupt (on/off) light level changes so are most applicable in areas that will receive sufficient daylight all day long and for non-critical tasks (e.g. corridors, atria). On/off switching should not be used in offices. This is disruptive to the occupant and will likely result in the occupant disabling the control system. Sufficient light is usually available in zones that are less than 4.5 metres deep from large windows (if the weather is not predominantly cloudy).

Use staged or dual-level switching as a compromise between dimming and on/off switching. Dual-level or multi-level switching can be activated by daylight and occupancy sensors at less cost than dimming, but will provide better occupant acceptance than the simpler on/off controls.
Daylighting
– Integrated Controls

Daylight Control Algorithm

Decide between open or closed loop control algorithms. Closed-loop systems are those in which information is fed back to the system to achieve control objectives. This information feedback does not occur in open-loop systems. For this reason, open-loop systems cannot compensate for electric light losses (i.e., the lumen maintenance strategy). However, they can be more easily calibrated than most closed-loop systems and are more forgiving to errors in sensor placement. Closed-loop systems that work with daylight may cause electric light levels to drop below desired light levels if they receive interference (e.g., placed too close to a window) or patches of bright light from indirect lighting.

For on/off switching systems, the time delay and setpoint deadband should be independently adjustable. Variable cloud conditions will cause system oscillations between on and off if the time delay or setpoint deadband are improperly set. The light level at which the devices switches off should be at least twice the level at which it switches on to ensure that the design illuminance is met at all times.

The response time to sudden daylight changes should be slow. To avoid unnecessary dimming response to temporary daylight conditions (such as moving clouds), the dimming response time should be set to about 30 seconds.

Use programmable time controls over simple timeclocks. If the building has multiple daily schedules, programmable controls (with manual override) can yield increased energy savings. For example, sweep-off control, in which all lights are automatically turned off after building closing time, will turn off any forgotten lights and will result in approximately 15% energy savings.

Use occupancy sensors. These sensors are easily installed, yield approximately 15 to 30% energy savings and are very cost-effective. Ensure they are installed in a location that will provide an unobstructed view of the space. It is possible to purchase integrated daylight and occupancy sensors. Sensors are routinely shipped to contractors at minimum setting that, if retained, will cause light to cycle rapidly and sensitivity to be almost non-existent.

Choose manual-on/automatic-off occupancy sensors. Occupants often forget to turn lights off when leaving a room. Occupancy sensors will ensure that the lights are off when the space is empty after a set time interval. The occupant can over-ride the control to turn the lights off but cannot over-ride the control to keep the lights on when they are not in the room.

Source: Canada-Daylighting-Guide-techniques-9.jpg
Daylighting

- Integrated Controls

Sensor Location

Place the daylight sensor in a location appropriate to the task. In a room with only one task area, a ceiling-mounted sensor placed above the task will likely be most effective. In a room with multiple task areas, the most representative location should be chosen. However, if the controller will accept multiple inputs, then sample the daylight from multiple locations.

Place the sensor in a position appropriate for the chosen control algorithm. For closed-loop systems, place the sensor approximately two-thirds into the depth of the daylight control zone. For open-loop systems the photosensor location is less critical and can be optimized during commissioning. However, if a light shelf is being used with an open-loop control system, the sensor should be placed above the shelf, not on or below it.

Set the sensor placement according to the type of lighting system. With indirect and indirect/direct lightings systems the photosensor should be placed in the plane of the fixtures. Care must be taken to ensure they do not have a view of the electric lights they control. For direct lighting systems, the photosensor should be recessed into the ceiling.

Optimize the sensor field of view. Ceiling-mounted closed loop sensors should have a large field of view and should be shielded from direct light from the windows. Sun shields are an option if the sensor cannot be placed far enough from the window. For switching systems, locate a photosensor such that it views external daylight but not the electric light that it controls.

Source: Canada-Daylighting-Guide-techniques-10.jpg
• Daylighting
  – Integrated Controls

• Choose dimming hardware if daylighting, lumen maintenance, or tuning are the selected control strategies.
  With the cost of dimming ballasts still high but falling, dimming control is at least twice as expensive as switching control but it is the best for implementing these strategies.
  It is also generally the most acceptable to occupants, because changes in the electric light levels are least disturbing.
  Daylighting and lumen maintenance strategies integrate well, since they use the same hardware.
  Dimming is generally not cost-effective in non-daylit areas unless coupled with scheduling controls.
  Dimming can capture all possible daylight savings.
  For spaces with adequate daylight all day long and for non-critical visual tasks, switching may be acceptable, since the lights may adjust only once or twice during stable daylight hours.

• Do not count on manual controls. Manual switching capability is already required by Title 24, but it is generally not well used by the typical office occupant. Use automatic controls to ensure that projected savings are actually achieved over time.

• Use dual-level switching. This wall-mounted switch reduces light levels by turning off individual lamps in 2-, 3-, or 4-lamp fixtures. This is the minimum switching requirement specified by California code. Dual-level or multi-level switching can also be activated by daylight sensors at less cost than dimming, but with better acceptance than simple on-off controls.

• For all OTHER strategies, choose switching hardware. Scheduling (either with automatic time controls or occupant sensors) can be implemented effectively with switching controls. Switching technologies are inexpensive, have a short payback period, and typically do not require special expertise to install. They are compatible with other lighting systems and are easily adjusted.

• Select switching for daylight control with caution. This hardware is less expensive than dimming, but has the disadvantage of abrupt light level changes.
  Switching is acceptable in intermittently occupied spaces or in spaces with fair constant and adequate daylight all day (e.g., clear weather, large windows). In zones less than five feet deep from windows, simple on/off switching is the most cost-effective, especially if daylight is abundant. Do not use switching when it is anticipated that lights will turn on and off during occupied hours; case studies show occupants find this disruptive and will disable the system.

• Source: LBL-Daylighting-Guide-controls-text-3.jpg
• Daylighting
  – Integrated Controls

**Zoning**

- Control zones should match areas of similar daylight availability and space function (e.g., conference, computer, etc.). In open plan areas with a uniform window facade, group fixtures in runs parallel to the window with separate control for each row in from the window (for strip windows), or in groups associated with each window (punched windows).
- Design control zones to correspond to window shading device zones. For example, if an individual office contains manually operable drapes or blinds, the entire office would generally form (at least) one control zone.

**Limit the number of zones where possible.** Costs go up with the number of control zones, so make zones as large as practical. However, too large a zone can lead to some areas being underlit.

**Any circulation space running along a window-wall should be a separate control zone.** If this area is well-daylit, its lighting can often be switched off.

**Occupant Satisfaction**

- In general, dimming hardware is preferred by occupants because the changes are less noticeable. If lighting changes are too abrupt, case study experience shows occupants tend to be disturbed or otherwise unsatisfied with the system. If the lighting controls are not expected to operate more than once or twice during occupancy (for example, if daylight levels are adequate all day such that the system perhaps operates only morning and evening), then switching hardware may be equally acceptable.

- Switching hardware will be more acceptable if coupled with split-wired lighting. Split-wiring, also known as stepped switching, allows lights to be switched in discrete steps (OFF, 1/2, FULL or OFF, 1/3, 2/3, FULL), so the changes are not so abrupt.

• Source: LBL-Daylighting-Guide-controls-text-7.jpg
• **Daylighting**
  
  – **Integrated Controls**

  • **Avoid daylight controls on downlights.** Switching hardware with daylighting control is generally not acceptable for downlight fixtures, especially if fixtures are turned on and off (rather than split-wired), because occupants find automatic switching of electric lighting to be disruptively noticeable.

  • **Occupants will disable a system they find unsatisfactory.** There may be any number of causes for negative user reaction to automatic controls. Choose an approach to controls that will most likely meet user needs, and ensure that the system will be installed and calibrated so that it operates properly. An unpredictable or poorly functioning system is a major cause of occupant dissatisfaction. Another problem may be the occupants’ sense that the system is beyond their control. In these cases, visible manual controls are important, and manual overrides, while they may result in lower savings, will increase user satisfaction. Another problem witnessed in case studies is that an office with lights on signals that its occupant is in the building. Dimming strategies may be useful here. These issues should be discussed with the building owner during design and followed up with occupant education during the commissioning and occupancy phases.

  • **Use programmable time controls** for a more sophisticated form of scheduling control than simple timeclocks. This is good for facilities with many different daily schedules. Sweep-off control (after an initial warning, automatically sweeps off lights after the building closing hour) is effectively implemented with programmable controls and a manual override via wall switch or phone. This control strategy typically yields at least 15% savings in lighting energy and is helpful for picking up lights left on by after-hour workers or cleaning crews. If sweep-off control is used, wire lighting circuits back to the electric panel for operation by building controls.

  • **Source:** LBL-Daylighting-Guide-controls-text-17.jpg
Daylighting
  - Integrated Controls

If you have...

**no time**
1. Disperse with daylighting controls at this stage if you have not previously used them in a project. Perhaps they can be installed in the future.
2. Design the lighting system to accommodate the addition of daylighting controls in the future.
3. Follow Title 24 control requirements.

- Source: LBL-Daylighting-Guide-controls-1.jpg
• **Daylighting**
  – **Integrated Controls**

<table>
<thead>
<tr>
<th>a little time</th>
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<tbody>
<tr>
<td>1. Include a lighting designer on the project team.</td>
</tr>
<tr>
<td>2. Use dimming daylight controls as much as possible in perimeter zones.</td>
</tr>
<tr>
<td>3. If budget is restricted and daylight is abundant, use stepped switching instead of dimming hardware in perimeter zones.</td>
</tr>
<tr>
<td>4. Use simple on-off switching elsewhere.</td>
</tr>
<tr>
<td>5. Use occupancy sensors wherever appropriate.</td>
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<tr>
<td>6. Use time clock controls for after-hours savings.</td>
</tr>
<tr>
<td>7. Follow or exceed Title 24 control requirements.</td>
</tr>
<tr>
<td>8. Take care to anticipate occupant dissatisfaction with controls.</td>
</tr>
<tr>
<td>9. Make the control documents, including calibration and maintenance plans, part of the construction documents.</td>
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<table>
<thead>
<tr>
<th>more time</th>
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<tbody>
<tr>
<td>1. Include a lighting designer on the project team.</td>
</tr>
<tr>
<td>2. Perform computer analysis to accurately estimate control savings and use results in a cost/benefit analysis to help determine best combination and types of control strategies.</td>
</tr>
<tr>
<td>3. Use dimming daylight controls as much as possible in perimeter zones.</td>
</tr>
<tr>
<td>4. Use daylighting controls in a lumen maintenance strategy as well.</td>
</tr>
<tr>
<td>5. Use occupancy sensors wherever appropriate. Combine with the photocell in perimeter zones.</td>
</tr>
<tr>
<td>6. Use programmable time clocks and sweep-off control for after-hours savings.</td>
</tr>
<tr>
<td>7. Follow or exceed Title 24 control requirements.</td>
</tr>
<tr>
<td>8. Work with building owner to resolve any anticipated trouble with occupant acceptance of the control system.</td>
</tr>
<tr>
<td>9. Explore opportunities to integrate with mechanical controls and tie into energy management control system, if any.</td>
</tr>
<tr>
<td>10. Make the control documents, including calibration and maintenance plans, part of the construction documents.</td>
</tr>
<tr>
<td>11. Verify that occupants are satisfied with the controls after calibration and occupancy. Educate occupants and building manager about the function and purpose of the sensors and the control system.</td>
</tr>
</tbody>
</table>

• **Source:** LBL-Daylighting-Guide-controls-checklist-4.jpg
Daylighting
  – Integrated Controls

ARCHITECTURE
Window location, task location, and shading strategy affect control zoning.

INTERIOR
Space planning, finishes, and furnishings are strongly tied to control zoning.

HVAC
Perform load calculations accurately, with lights dimmed at peak cooling conditions. The lighting designer should supply expected lighting power reductions to the HVAC designer, or use advanced energy analysis software that can model daylight controls.

LIGHTING
Control system and hardware must be compatible with other lighting equipment.

COST-EFFECTIVENESS
Most building controls designed for energy efficiency are highly cost-effective, especially when supported by utility incentives. Simple lighting controls such as occupancy sensors are especially cost-effective.

OCCUPANT COMFORT
Tolerance for fluctuation in electric lighting levels varies. We experience lighting fluctuation all the time in the natural environment but tend to find changes in the artificial environment disturbing.

Some people are uncomfortable with a highly automated environment. Others may want lights on for non-task reasons (e.g., employee is “in” the office). These and other reasons can cause occupants to disable the system. Discuss these issues with building owner, building manager, and occupants.

Source: LBL-Daylighting-Guide-controls-integration-1.jpg
• **Daylighting**
  – **Integrated Lighting Controls**

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**PROVISOS**

- Never turn off lights automatically at night in an occupied space without a prior warning, such as flashing the lights ten minutes before shut off. This gives occupants a chance to manually override the shut off.

- Calibration of automatic daylighting systems and occupant sensors should always be performed after furniture installation is complete (see CALIBRATION & COMMISSIONING).

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• **Source**: LBL-Daylighting-Guide-controls-integration-3.jpg
• Daylighting
  – Guidelines

Environmental Building News
Daylighting with Windows and Skylights: A Checklist for Action

General Daylighting
• Provide a daylighting scheme that works under the range of sky conditions expected at that location.
• Orient building on an east-west axis.
• Brighten interior surfaces.
• Organize electric lighting to complement daylight.
• Provide daylight controls on electric lighting.
• Commission the daylighting controls.

• Source: Environmental Building News 9-99 – www.buildinggreen.com
Daylighting
   – Guidelines

Environmental Building News
Daylighting with Windows and Skylights: A Checklist for Action

Perimeter Wall Daylighting
   • Provide perimeter daylight zones.
   • Extend windows high on perimeter walls.
   • Provide light shelves on south-facing windows.
   • Minimize direct-beam sunlight penetration into workspaces.
   • Choose the right glazing.
   • Arrange interior spaces to optimize use of daylighting.

• **Daylighting**
  – Guidelines

  **Environmental Building News**
  Daylighting with Windows and Skylights: A Checklist for Action

  **Roof Daylighting**
  • Provide roof apertures for daylighting.
  • Optimize skylight spacing.
  • Consider extending skylight performance with trackers.
  • Use reflective roofing on sawtooth clerestories.
  • Diffuse sunlight entering building through roof apertures.

  **Core Daylighting**
  • Provide a central atrium or light well for daylighting.

• Source: Environmental Building News 9-99 – www.buildinggreen.com
• Daylighting
  – Guidelines
    • RPI Lighting Research Center
      www.lrc.rpi.edu
    • Innovative Design
      www.innovative design.net

• Source: www.innovative design.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

Innovative Design - School Daylighting Guide

Consider Human Factors
• Improve student performance
• Create a healthier indoor environment
• Increase attendance

• Source: www.innovativedesign.net – www.lrc.rpi.edu
Daylighting

- Guidelines

Innovative Design - School Daylighting Guide

Daylighting must be superior
- Eliminate direct beam radiation
- Consider the need to darken individual spaces
- Only use shades if entire space needs to be darkened
- Don't count on view glass, due to potential blockage
- Concentrate on the most utilized spaces
- Utilize low view glass to provide visual connection to outdoors

Source: www.innovative design.net – www.lrc.rpi.edu
Daylighting

- Guidelines

Innovative Design - School Daylighting Guide

Consider the Energy Ramifications

- electricity for lighting and peak electrical demand;
- cooling energy and peak cooling loads;
- maintenance costs associated with lamp replacement;
- electrical service to building; and, in some cases,
- the number of installed lighting fixtures in the school.

Source: www.innovativedesign.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

  Innovative Design - School Daylighting Guide

  Orient building to maximize daylighting
  • Maximize south glazing, minimize east and west facing glass
  • Avoid uncontrolled skylights
  • Optimally size overhangs on south-facing glazing
  • Reduce installed lighting
  • Reduce installed lighting

• Source: www.innovativedesign.net – www.lrc.rpi.edu
Daylighting
- Guidelines

Innovative Design - School Daylighting Guide

Reduce cooling loads
- no more radiation is allowed to enter the building than is required to meet your footcandle objectives;
- properly sized overhangs limit the radiation to optimal amounts; and
- the lights, with the use of photosensors, are automatically dimmed or switched off.

Source: www.innovativedesign.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

Innovative Design - School Daylighting Guide

Take advantage of passive solar
  • Select the right glazing

Consider reduced maintenance

Account for Site Constraints and Benefits
  • Account for shading from adjacent buildings and trees
  • Consider the reflectance from adjacent surfaces
  • Utilize landscaping to benefit overall design

• Source: www.innovativedesign.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

Innovative Design - School Daylighting Guide

Select Well-Integrated Daylighting Strategies

• Do not bid daylighting as an alternate
• Consider roof monitors first and lightshelves second
• South-facing Roof Monitors
• South-facing Lightshelves
• North-facing Roof Monitors
• North-facing Transom Glazing

• Source: www.innovativedesign.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

Innovative Design - School Daylighting Guide

Provide proper glass-to-floor area ratios

- South-facing roof monitor 8% to 11%
- South lightshelf 8% to 11%
- South lightshelf w/blinds between glazing 15% to 20%
- North-facing roof monitor 12% to 15%
- High, north transom glazing 15% to 20%

Optimize the Most Appropriate Daylighting Strategies

• Source: www.innovativedesign.net – www.lrc.rpi.edu
## Daylighting

### Guidelines

<table>
<thead>
<tr>
<th>South-Facing Roof Monitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize size by maximizing transmission</td>
</tr>
<tr>
<td>Consider the passive solar benefits</td>
</tr>
<tr>
<td>Use light colored roofing in front of monitors</td>
</tr>
<tr>
<td>Use baffles to block direct beam radiation, diffuse light, and reduce glare</td>
</tr>
<tr>
<td>Specify fire-retardant, UV resistant baffles</td>
</tr>
<tr>
<td>Use translucent baffles to help reduce contrast</td>
</tr>
<tr>
<td>Minimize contrast at well-to-ceiling intersection</td>
</tr>
<tr>
<td>Address the monitor design</td>
</tr>
<tr>
<td>Let the heat stratify</td>
</tr>
<tr>
<td>Minimize the depth of the ceiling cavity</td>
</tr>
</tbody>
</table>

Source: [www.innovativedesign.net](http://www.innovativedesign.net) – [www.lrc.rpi.edu](http://www.lrc.rpi.edu)
## Daylighting

### Guidelines

<table>
<thead>
<tr>
<th>Innovative Design - School Daylighting Guide</th>
</tr>
</thead>
</table>

### Lightshelves on South Walls

- Recognize the limitations of side daylighting
- Bounce light deeper into space
- Select durable but reflective lightshelf material
- Select durable materials for both interior and
- Shade lower view glass
- Stop direct beam with directional blinds
- Use horizontal blinds between glazing
- Elongate room to maximize glazing opportunity
- Slope ceiling from top of lightshelf down to back of room
- Implement lightshelves to complement roof monitors

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*Source: www.innovativedesign.net – www.lrc.rpi.edu*
• **Daylighting**
  – Guidelines

Innovative Design - School Daylighting Guide

**North-Facing Roof Monitors**
• Serve as a mounting surface for a solar system
• Consider the elimination of baffles

**High Transom Glazing on North Walls**
• Don't use lightshelves on north wall

• **Source:** www.innovativedesign.net – www.lrc.rpi.edu
• Daylighting
  – Guidelines

Innovative Design - School Daylighting Guide

Employ many of the same optimization strategies as with south-facing lightshelves

• Place the glazing high in the room with the head of the glazing at the ceiling.
• Utilize sloped ceilings to enhance performance.
• Elongate the rooms in an east-west direction so that there is more exposed wall area in which to place the glazing.
• Window treatments should only be used to provide a strategy to temporarily darken a space.
• Do not use low-E glass in the high, designated daylighting apertures. It will reduce visible light transmission, in turn requiring more glazing.

• Source: www.innovativedesign.net – www.lrc.rpi.edu
Daylighting

Guidelines

General Recommendations for All Daylighting Options

- Use lower glass areas as a last resort
- Minimize contrast
- Select light colors for interior finishes
- Select highly reflective ceiling tile
- Use continuous dimming controls
- Locate your photosensors correctly
- Select compatible light fixtures
- Consider the furniture and space layout
- Intentionally darken select spaces within classrooms

Source: www.innovatedesign.net – www.lrc.rpi.edu
Daylighting
  - Guidelines

Building Shape establishes the potential daylight area
  • 1 story 300’ x 300’ daylight zone equals 25%
  • 3 story 100’ x 300’ daylight zone equals 50%

Avoid direct sunlight on task areas
  • North facing windows work best
  • South facing windows work second best due to higher sun angles
  • East and West windows are least favorable

Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• **Daylighting**
  – Guidelines

  *Weidt Group - Iowa DNR Sustainable Design Initiative*

  Make rooms no deeper than 2 to 2.5 times the head height of the window.

  Raise ceiling height at window to increase daylight depth.

  Use the right amount of window area:
  • 15 to 20% of the daylight zone floor area.
  • Or between 25 to 40% of the perimeter wall area.

• Daylighting
  – Guidelines

**Weidt Group - Iowa DNR Sustainable Design Initiative**

Reduce the sharp contrast between the bright sky and darker interior walls
• Use continuous windows
• Raise window head flush with the ceiling plane

Use Spectrally Selective Glazings
• Higher light transmittance
• Low solar heat gain

Lower partitions means higher daylight potential

• Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Guidelines

Weidt Group - Iowa DNR Sustainable Design Initiative

Daylighting Control Systems
• Continuous Dimming
• Photosensor Control of electronic dimming ballasts
• Stepped Dimming
• Photosensor Control of selected lamps within fixtures
• Astronomical Time Clock Control of Selected lamps within fixtures
• Manual Control
• Strategic location of wall switches to encourage manual reduction in electric
• lighting use based on daylight

• Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Calculations
Daylighting
– Calculations

**Daylight Factor**

- The daylight factor gives an indication of the amount of light that contributes to lighting an interior.
- The daylight factor (DF) is defined as the ratio of the illuminance at a particular point due to daylight within an enclosure to the simultaneous unobstructed outdoor illuminance under the same sky conditions.
- \[ DF = 100 \times \frac{\text{Illumination at a point in interior}}{\text{Illumination outside building}} \]
- Multiply by 100 to get the daylight factor as a percentage. The illuminations are assumed to be onto a horizontal surface and the exterior illuminance is assumed to result from the entire hemisphere of the sky.
- Note: The illumination outside the building does not include direct sunlight.

Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Calculations

\[
\text{Daylight Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \frac{\text{Window Geometry}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}
\]

• LEED requires a minimum Daylight Factor of 2% to qualify for LEED-NC IEQ credit 8 for daylighting in occupied spaces.

• Source: LEED-20-Daylight-Factor-Equation-1.jpg
### Daylighting Calculations

<table>
<thead>
<tr>
<th>Window Type</th>
<th>Geometry Factor</th>
<th>Minimum $T_{vis}$</th>
<th>Height Factor</th>
<th>Best Practice Glare Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidelight daylight glazing</td>
<td>0.1</td>
<td>0.7</td>
<td>1.4</td>
<td>Adjustable blinds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Interior light shelves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fixed translucent exterior shading devices</td>
</tr>
<tr>
<td>Sidelight vision glazing</td>
<td>0.1</td>
<td>0.4</td>
<td>0.8</td>
<td>Adjustable blinds</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Exterior shading devices</td>
</tr>
<tr>
<td>Toplighting vertical monitor</td>
<td>0.2</td>
<td>0.4</td>
<td>1.0</td>
<td>Fixed interior</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjustable exterior blinds</td>
</tr>
<tr>
<td>Toplighting sawtooth monitor</td>
<td>0.33</td>
<td>0.4</td>
<td>1.0</td>
<td>Fixed interior</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Exterior louvers</td>
</tr>
<tr>
<td>Toplighting horizontal skylights</td>
<td>0.5</td>
<td>0.4</td>
<td>1.0</td>
<td>Interior fins</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Exterior fins Louvers</td>
</tr>
</tbody>
</table>

**Source:** LEED-20-Daylight-Factor-values-1.jpg
Daylighting
  - Calculations
  - oikos.com

<table>
<thead>
<tr>
<th>Task</th>
<th>Ample winter daylight (nearer equator)</th>
<th>Scarce winter daylight (nearer pole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary seeing tasks, such as reading, filing, and easy office work</td>
<td>1.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Moderately difficult tasks, such as prolonged reading, stenographic work, normal machine tool work</td>
<td>2.5%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Difficult, prolonged tasks, such as drafting, proofreading poor copy, fine machine work, and fine inspection</td>
<td>4.0%</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

Source: Millet and Bedrick (1980)
• Daylighting
  – Calculations
  – Archipysics.com

• Source: ArchiPhysics-Website-1.jpg
• **Daylighting**
  - Calculations
  - Archipysics.com

• Source: ArchiPhysics-website-Daylight-1.jpg
• **Case Studies**
  – Integrated Design
  – Passive solar
  – Daylighting
• Daylighting
  – Case Study
  – Iowa Municipal Utilities Association

• Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Case Study

Weidt Group - Iowa DNR Sustainable Design Initiative

Iowa Association of Municipal Utilities

North Daylight zone
• one photosensor per three north facing offices
• No blinds on north windows
• Wall box occupancy sensor per each office
• Transom/vision glass

• Source:  www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Case Study

Weidt Group - Iowa DNR Sustainable Design Initiative

Iowa Association of Municipal Utilities

Center Daylight zone
• One photosensor controlling all lights in center zone
• Seasonal banner to control low angle direct sun during winter months only
• Supply duct doubles as light shelf to control direct sun on south open office areas

• Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Case Study

Weidt Group  - Iowa DNR Sustainable Design Initiative

Iowa Association of Municipal Utilities

South Daylight zone
• One photosensor controlling all lights in south zone
• Daylight transom window - 15’ head height w/ no blinds
• 5’ roof overhang and lower sunscreen effectively blocks direct sun during cooling season
• Horizontal blinds on south view window - light color - vertical blinds on east windows

• Source:  www.iowadnr.com/energy/sustainable/files/model.pdf
• Daylighting
  – Case Study

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Iowa Association of Municipal Utilities

• Electric Lighting System
• 8’ Indirect Industrial fixture mounted up
• T8 lamps w/ electronic dimming ballast
• Illumination level @ 30 to 35 fc - connected power density at 1.15 w/sf
• White painted metal deck ceiling 85% reflectance

• Source: www.iowadnr.com/energy/sustainable/files/model.pdf
• Integrated Design
  – A Wisconsin case Study
• Integrated Design
  – A Wisconsin case Study

• At the core of LEED and Green Globes is plain old “good design”....

• Many of the basic LEED criteria and their associated credits can be achieved by informed design choices that have little or no cost implications and are easily incorporated into a building design.

• Other criteria and credits require a higher level of decision making and increasingly selective materials choices, leading to higher levels of LEED certification.
• Integrated Design
  – A Wisconsin case Study

• The design process should involve an analysis of how to prioritize choices leading to higher levels of sustainability, breaking down
  • “design” choices vs.
  • “materials” choices vs.
  • “methods” choices.
• Integrated Design
  – A Wisconsin case Study

• Adapting the LEED criteria:
  – Site issues
  – Building Design issues
  – Building Systems issues
  – Building Materials issues
  – Construction Method issues
  – Wildcard issues
• Integrated Design
  – A Wisconsin Case Study
• Integrated Design
  – A Wisconsin Case Study
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  – A Wisconsin Case Study
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  – A Wisconsin Case Study
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  – A Wisconsin Case Study
• Integrated Design
  – A Wisconsin Case Study

Sustainable Building Strategies & Materials for LEED certification:
• Reduced site disturbance at building, site access roads, parking & utilities to reduce erosion.
• Reduced impervious surfaces, parking areas, etc. and retention ponds to reduce runoff.
• Cut-off exterior lighting fixtures to eliminate glare and light pollution.
• Non-irrigated drought-resistant plantings and restored prairie plantings to reduce water needs.
• Reduced energy load and renewable energy sources for heating & cooling.
• On-site construction waste management.
• Panelized construction to reduce construction waste.
Integrated Design

- A Wisconsin Case Study

*Sustainable Building Strategies & Materials for LEED certification:*

- Construction practices to minimize contamination and degradation of materials and systems.
- Use of low or non-VOC finishes, sealants, adhesives, etc.
- Use of non-urea formaldehyde containing products and components.
- Operable windows for light, views and ventilation
- Water-efficient plumbing fixtures for water conservation.
- Recycled-content building materials and finishes, such as ceiling panels, wallboard, etc.
- Fundamental Building Commissioning for optimal system performance.
• Integrated Design
  – A Wisconsin Case Study

**Energy Projections:**

- Energy usage modeled according to ASHRAE 90.1 projected that the building would use 73% less energy than a base case building of similar size and type built to model energy codes.
- Estimated energy requirement, modeled according to the actual final building design, was 71,000 KWH/yr.
- Estimated Renewable Energy output is 12,100 - 14,900 KWH/yr.
- Projected Renewable Energy contribution, based on full-time occupancy, was 17 - 21%.
- Energy usage tracked for the first 6 months of occupancy shows the building using less electricity than anticipated and a contribution of 25% generated on site.
• Integrated Design
  – A Wisconsin Case Study
• Integrated Design
  – A Wisconsin Case Study
• Integrated Design
  – A Wisconsin Case Study
• Summary & Conclusions
  – Questions
• Thank You
  – Thomas Brown, Architect
    LEED-AP
  – www.tombrownarchitect.com
  – tbjs@coredcs.com
Re-Arch: The Initiative for Renewable Energy in Architecture

Best Practices in Daylighting & Passive Systems for Smaller Commercial Buildings

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Center for Sustainable Building Research (CSBR)
Midwest Renewable Energy Association (MREA)
American Institute of Architects Minnesota (AIA MN)
Green Institute

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Funded in part by the Minnesota Pollution Control Agency (MPCA)