Integrated Design Team Guide to Realizing Over 75% Lighting Energy Savings in High-Performance Office Buildings

Overview

This checklist packet is a team-focused guide to realizing energy savings in high-performance office buildings through carefully considered lighting and control design. The checklists should be distributed among the integrated project team members, including the owner, lighting designer and engineer, commissioning agent, and facility manager, at the beginning of a project and referred to regularly during design meetings and drawing reviews. The checklists are arranged by key design considerations (daylighting, occupancy, task) and key integration points (energy goal, sequence of operations), which relate to the cumulative energy savings shown in Table 1. Each action or question is related to a design stage during which failure to act could jeopardize energy savings.

Pre-Contract and Schematic Design (SD)

- Define an energy goal: A whole-building energy goal is a good way to allow freedom in design while ensuring all disciplines work together toward energy efficiency. This is the starting point for team integration.
- Account for occupant habits: Monitor or predict occupant behavior in terms of interaction with control devices and daily movement between spaces and tasks.
- Start with nothing: Use space planning and daylighting as means to passively light the building for daytime occupants before considering electric lighting or controls.

Design Development and Construction Documents (DD and CD)

- Layer for occupant needs: Zone and stage lamps for daylight, unique occupancy types and task tuning so that electric lighting is used only when and where it is necessary.
- Address smaller loads: Consider controlling emergency lamps in tandem with other lamps in a space.
- Define a sequence of operations: Use written and diagrammatic explanations are to be used for team reviews, manufacturer system performance assurance, as a basis for functional testing, and as an operations guiding document. This is the closing point for team integration.

Construction Administration (CA) and Postoccupancy

- Commission to the energy goal: Check control device for behavior from perspective of each use case and confirm control interfaces are intuitive.
- Monitor the results: Use metered data to verify energy goal and consider how all postoccupancy changes will affect energy savings.

Purpose ▼

The checklist will help prevent omissions in the design, installation, and commissioning of the lighting and control system.

Possible lighting control savings and additional benefits in high-performance office buildings follow:

- **Energy savings that exceed 75% over ASHRAE 90.1 2007 are possible**. Additional control requirements in ASHRAE 90.1 2010 will reduce baseline energy savings to approximately 60%, including lighting power density (LPD) reduction and lighting controls.
  - A cost saving of **$0.47/ft²/yr** for LPD and control (assume energy cost to be $0.10/kWh/yr).
  - An estimated, average 6-year payback* for lighting and control equipment and installation over baseline cases.
  - Use metered data to verify the energy goal, making system adjustments as needed and noting potential future upgrades. Also, consider how all postoccupancy changes will affect energy savings if retrofits are made in the future.

* This payback uses Research Support Facility (RSF) and RSMeans data, which can show a range of 2- to 13-year payback depending on the baseline used. Daylighting components of the envelope can be designed to be equivalent in cost to baseline cases, or can reveal a payback of up to 10 years, depending on the baseline considered.

- Table 1 shows potential energy savings for LPD and lighting control measures. Even one team member failing to follow through with checklist items could have a negative impact on energy savings. An integrated team effort with a strong sequence of operations is needed to realize aggressive lighting savings.

Table 1. Possible Lighting System Savings Reported by Design Consideration

Design Consideration	Cumulative Percent Savings*	kWh/ft²/yr Savings	Annual Dollar Savings Potential***
Energy goal	(76% cumulative savings with 40% savings due to a direct LPD reduction from 1.0 W/ft² to 0.6 W/ft²)	4.7 kWh/ft²/yr total savings potential 2.5 kWh/ft²/yr for LPD reduction	Example: $94,000 for a 200,000-ft² building
Daylighting control	(50% cumulative savings)	0.7 kWh/ft²/yr **	Example: $64,000 for a 200,000-ft² building
Occupancy control	(68% cumulative savings)	1.1 kWh/ft²/yr	
Task control	(76% cumulative savings)	0.4 kWh/ft²/yr	
Sequence of operations	(30% potential reduction in predicted energy savings due to improper implementation)	(1.3 kWh/ft²/yr)	

* The savings are based on the National Renewable Energy Laboratory Research Support Facility modeled and measured data. Groupings are not clear cut, as daylight can increase the use of certain task lighting scenarios. The breakout is intended to show that the complete savings require detailed consideration of all lighting control opportunities.

** This row relates to direct savings from daylighting controls only, but daylighting affects the potential savings for task and ambient layering.

*** Assume $0.10/kWh electricity cost and basic savings from lighting and not secondary heating and cooling impacts. Multiply $0.10 by the savings and building square footage.

Lighting Control Checklists for High-Performance Office Building Integrated Design

Take checklist actions and evaluate questions to realize more than 75% lighting energy savings. The actions are listed with respect to design considerations and, within each consideration, listed in order of design phase. ▼

Owner

▸ Energy Goal

Require the design team's compliance with a whole-building energy density goal.

☐ Pre-contract Perform a preliminary climate-based optimization to determine a goal or target a 50% reduction over ASHRAE 90.1 2004.

yes	no	
☐	☐	Is a 50% saving possible? Yes, a 50% energy saving over the ASHRAE baseline is possible (see the appended case study and Advanced Energy Design Guides at *http://www.ashrae.org/technology/page/938*).

☐ SD Require that the goal be substantiated with energy simulation or detailed case study comparisons.

yes	no	
☐	☐	Has additional time and budget for modeling been accounted for in the contract (if this is the preferred substantiation method)?
☐	☐	Do proposals show preliminary calculations indicating that the goal is achievable by the design?

▸ Daylighting Control

Require daylighting in office and transition spaces.

☐ Pre-contract Require 25 footcandles (fc) for 75% of the work areas, from 10:00 a.m. to 2:00 p.m. year round.

☐ Pre-contract Stipulate that the daylighting must be low glare (free from direct sun using shading studies as proof) and modeling must take into account expected occupant interactions (adjusting manual blinds, for example) with the daylighting components.

☐ SD Require the designers to look for daylighting solutions to provide saturation as indicated with a 25% or less window-to-wall ratio.

☐ DD Require the contractors to account for the cost of advanced daylighting options compared to typical glare controls such as blinds.

☐ DD-CD Require the team to substantiate the impact of all relevant design decisions on the expected daylighting saturation and quality.

▸ Occupancy Control

Require lighting layers for all occupancy types.

☐ SD Review an occupancy type list with designers (e.g., computer work, reading and writing, meetings, display, presentations, preference variations). Consider logging occupancy patterns of future occupants using light sensors, feeder current metering, or surveys to accurately reflect time spent in the different space types. If this is not completed, predicted savings can be inaccurate by 30%–70%.

Owner, Occupancy Control (continued)

☐ DD Request and review the zoning diagrams and controls narrative, focusing on large and small savings.

yes	no	
☐	☐	Will each occupant type have only the quantity and duration of electric lighting needed?
☐	☐	Can all lights in the building, including egress, shut off at night? Verify with the local code.
☐	☐	Are vacancy sensors provided in all locations where electric lighting may not be needed, such as in partially daylighted spaces or spaces with borrowed electric light?
☐	☐	Do zones make sense for occupants entering in the morning and exiting at night?
☐	☐	Will elevator lights use occupancy sensors?

☐ CD Request and review the zoning diagrams and controls narrative, focusing on interface details.

yes	no	
☐	☐	Are interfaces addressed in the sequence of operations?
☐	☐	Will interfaces be obvious to new occupants and encourage energy savings?
☐	☐	Do the switches prevent unintended recommissioning when used improperly?
☐	☐	Is zoning fine-grained enough (e.g., personal lighting control versus two large office zones) to prevent overlighting of an area considering most occupancy scenarios?

☐ CD Request samples of possible occupant interfaces.

yes	no	
☐	☐	Are the interfaces intuitive?
☐	☐	Has signage been included to make desired occupant actions clear?

▸ Task Control

Require lighting layers for all task types.

☐ SD Review a task type list with designers (e.g., computer work, reading and writing, meetings, display, presentations, preference variations).

☐ SD Review the zoning diagrams and controls narrative, focusing on large and small savings.

yes	no	
☐	☐	Can multitask zones turn On to a reduced load such as 50% versus all On?
☐	☐	Do spaces with partial daylight or borrowed electric light have bilevel control for brief tasks?

☐ CD Review the zoning diagrams and controls narrative, focusing on interface details.

yes	no	
☐	☐	Will occupants be directed to energy-saving options such as bilevel switching or egress fixture switching for noncritical tasks?
☐	☐	Are there controls or reminders to turn off workstation task lights?

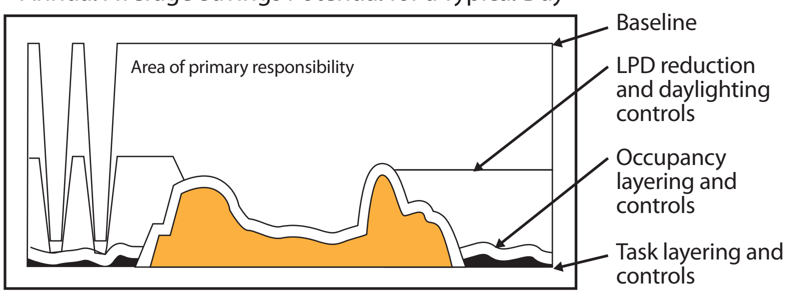
Owner (continued)

Sequence of Operations

Require written and graphical sequence of operations documents.

- [ ] SD Request an evaluation of the benefits of lighting and HVAC system communication, demand control, security overrides, and other features an integrated system can provide.
- [ ] SD Review the zoning diagrams and written sequence of operations for clear language.
- [ ] DD Request continued discussion and cost estimates of extended building system integration.
- [ ] DD Review the zoning diagrams and written sequence of operations for thoroughness, clarity, and commissioning set points.
- [ ] DD Define the integration responsibilities if building system integration will be extended.
- [ ] DD Ask for statements from submitting manufacturers verifying that the systems will meet intent; review exceptions for matched intent.
- [ ] DD Review the commissioning plan to ensure all sequences of operations are included.

Annual Average Savings Potential for a Typical Day



Designer/Engineer

Energy Goal

Design the lighting with respect to energy goals.

- [ ] Pre-contract If the owner has not set energy goals, present the energy cost savings opportunity, ability to engage occupants through control interfaces, and the payback calculations such as a simple payback estimate of 6 years compared to a typical baseline. Follow the owner's checklist for setting goals.
- [ ] Pre-contract Use early design modeling tools to drive form factors and preliminary window-to-wall-ratios for design proposals.
- [ ] SD-DD Select modeling tools based on considerations of necessary time and level of detail.

yes	no	
☐	☐	Can case studies be used to substantiate design ideas?
☐	☐	Can annual lighting simulation results be passed to the energy model? Do tools such as OpenStudio, SPOT, and DAYSIM enable this type of information sharing?

Designer/Engineer, Energy Goal (continued)

- [ ] DD Achieve a 40% LPD reduction over 90.1 2007 through the use of task/ambient lighting schemes and high-efficiency lamps/ballast combinations. Show the LPD on each space plan for quick review by the owner.
- [ ] DD-CD Model annual schedules for control options, if possible.

Daylighting Control

Design daylighting in office and transition spaces.

- [ ] SD Design to 25 fc for 75% of the work areas, for a sunny equinox at noon. Provide accurate or conservative annual daylight accounting in the energy model.
- [ ] SD Investigate daylight redirection devices such as louvers to achieve the required daylight saturation with a 25% or less window-to-wall ratio.
- [ ] SD Locate all enclosed spaces such as data centers and copy rooms in areas that cannot be daylit (e.g., those shaded by other buildings).
- [ ] DD Use worst- and best-case bound estimates to account for complex daylighting devices if annual daylight simulation is not possible.
- [ ] DD-CD Account for all design decisions such as interior color changes or structure orientation in the daylighting model. Reflect electric lighting savings changes in the annual energy model.
- [ ] CD Determine the exact sensor position, orientation, and set points and include in the sequence of operations.

yes	no	
☐	☐	Has a redundant open-and closed-loop system been investigated to provide superior performance to take dimming ballast to Off, prevent cycling, or drift?
☐	☐	Will the daylighting zone be commissioned to the average illuminance in the space, allowing some areas of lower illuminance to address occupant preferences? This should be weighed against the expected population. If variation in illuminance preferences is not anticipated, commission to the darkest point in the room to prevent complaints and system overrides.

Occupancy Control

Design lighting layers for all occupancy types.

- [ ] SD Review an occupancy type list with the owner (e.g., typical occupant, special hours, security, cleaning, transition options).

yes	no	
☐	☐	Are occupancy data available or collectible to determine optimal control types and settings such as occupancy sensors versus timed sweeps?
☐	☐	Can security personnel or other transient occupants use egress lighting or timer switches for walk-throughs?

- [ ] DD Refine electric lighting zoning for each occupant type.
- [ ] DD Provide control for small loads such as elevator lights and task lighting.
- [ ] CD Specify performance parameters for occupant control interface.

yes	no	
☐	☐	Are switches available that behave like traditional mechanical switches to prevent incorrect use?
☐	☐	Are signs or engraved labels provided to guide occupants to desired lighting controls action?

Designer/Engineer (continued)

Task Control

Design lighting layers for all task types.

- [ ] SD Review the task type list with the owner (e.g., computer work, reading and writing, meetings, display, presentations, preference variations).

yes	no	
☐	☐	Can the lowest illuminance needed for a given task in a space be used as the base ambient layer?
☐	☐	Have combinations of bilevel switching, task lighting, and ambient fixture zoning been evaluated to see which most effectively addresses the variety of task types in each space?
☐	☐	Can separate transition zones and equipment zones be provided for large mechanical rooms and data centers?

- [ ] DD Add task zoning to occupancy zoning of electric lighting. Provide diagrams to the team for review.
- [ ] CD Specify performance parameters for task control interface.

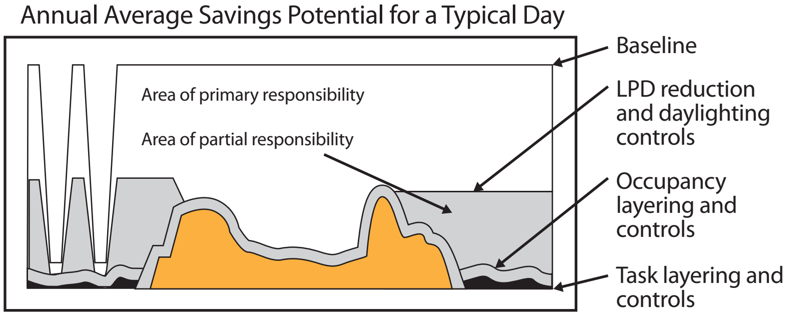
yes	no	
☐	☐	Are automatic controls or visual reminders, a better option to turn off task lights for the typical occupant and task patterns in each space?

Sequence of Operations

Provide written and graphical sequence of operations documents.

- [ ] SD Evaluate the benefits of lighting and HVAC system communication, demand control, security overrides, and other features an integrated system can provide.
- [ ] SD Use the terms sheet included in the packet to provide general control intent language for each space, occupant, and task type, including daylighting integration.
- [ ] DD Facilitate a discussion and cost estimates for extended building system integration.
- [ ] DD Be specific in the control narrative about control interfaces, commissioning expectations, and sensor settings. Use plain language.
- [ ] DD-CD Account for parasitic control load in energy calculations.
- [ ] CD Specify points that need integration and set points each system will hold, and define integration responsibilities.
- [ ] CD Elevate the document to specification language.

Annual Average Savings Potential for a Typical Day



Contractor/Installer

Energy Goal

Understand the energy goal and modeling assumptions.

- [ ] DD-CD Point out inconsistencies with modeling assumptions and actual implementation to the team as soon as possible.
- [ ] CD When evaluating product alternatives and installation options, ensure functions and settings that are required to meet the energy goal are maintained.

Daylighting Control

Understand the daylight modeling assumptions.

- [ ] DD-CD Point out inconsistencies with modeling assumptions and actual implementation to the team as soon as possible.

yes	no	
☐	☐	Are material assumptions realistic?
☐	☐	Are all large obstructions that can cause shadowing considered in the daylighting substantiation?
☐	☐	Are highly reflective interior or exterior surfaces or objects causing glare?

- [ ] DD-CD Include the cost of blinds and vision glazing when comparing baseline scenarios to daylighting solutions.

Occupancy Control

Understand the design intent for switching as it relates to occupant flow.

- [ ] SD-CD Do electric lighting zoning diagrams match the occupancy-focused control intent?
- [ ] CD Can occupants easily operate the selected control package?

Task Control

Understand the design intent for switching as it relates to task options.

- [ ] DD-CD Point out inconsistencies with modeling assumptions and actual implementation to the team as soon as possible.
- [ ] CD Can the occupants easily operate the selected task lighting?

Sequence of Operations

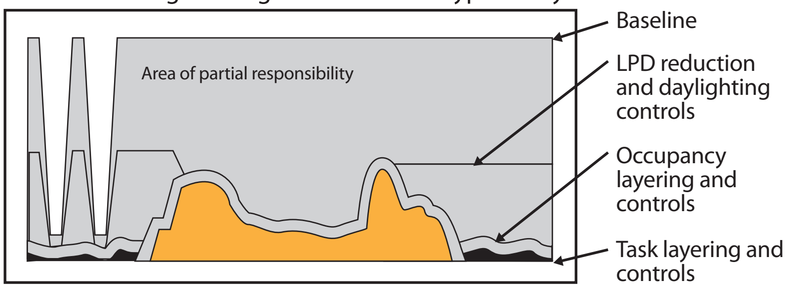
Use written and graphical sequence of operations documents.

- [ ] SD-CD Provide cost and other installation considerations for a discussion of an integrated control system that might include lighting and HVAC system communication, demand control, or security overrides.
- [ ] DD-CD Include installation times when comparing traditional systems to networked systems, as well as wired to wireless.

Contractor/Installer, Sequence of Operations (continued)

- [ ] DD-CD Use a control narrative as part of the specification package for lighting control system submittals.
- [ ] DD-CD Request parasitic load estimates from manufacturers.
- [ ] CD Know and monitor integration responsibilities.

Annual Average Savings Potential for a Typical Day



Commissioning Agent

Energy Goal

Understand the energy goal and modeling assumptions.

- [ ] SD-CD Point out inconsistencies with daylight and energy modeling assumptions and actual implementation to the team as soon as possible.
- [ ] CD When evaluating product installation and setting options, ensure functions and settings that are required to meet the energy goal are available.

Daylighting Control

Understand daylight modeling assumptions.

- [ ] Pre-contract Include multiple site visits in the scope of work so the daylighting system can be tested and tuned under cloudy and sunny conditions.
- [ ] DD-CD Request daylight position and set point assumptions from the team early in the design to provide feedback about whether the photosensor equipment can meet daylight reduction expectations.

yes	no	
☐	☐	Does the photosensor have a consistent view of the sky or material that will change predictably with respect to the work surface illuminance?
☐	☐	Is the photosensor free of any unintended light source at night or glare from specular building materials?
☐	☐	If a dark area in the daylighting zone will drive a higher set point, can it remain darker for occupants who prefer lower illuminance?

- [ ] CD Confirm the plausibility of predicted savings based on equipment type.
- [ ] CA Commission the daylighting controls after interior finishes and furniture installations are complete.

Commissioning Agent (continued)

Occupancy Control

Confirm that zoning and switch placement provide a means to realize predicted energy savings.

☐ CA Move through the space as each occupant type. Does each occupant receive only the light needed as given in the sequence of operations?

yes	no	
☐	☐	Typical occupant
☐	☐	Special hours
☐	☐	Telecommuters
☐	☐	Security
☐	☐	Cleaning staff
☐	☐	Elevators, stairs, and other path options

☐ CA Install temporary occupancy and light sensors where needed, such as in elevators and workrooms, to confirm they are shutting off.

Task Control

Confirm the design intent for switching as it relates to task options.

☐ DD-CD Is task lighting automatically controlled to prevent plug-load lighting from being left On?

☐ CD Are task lighting control interfaces obvious and accessible for all occupants?

Sequence of Operations

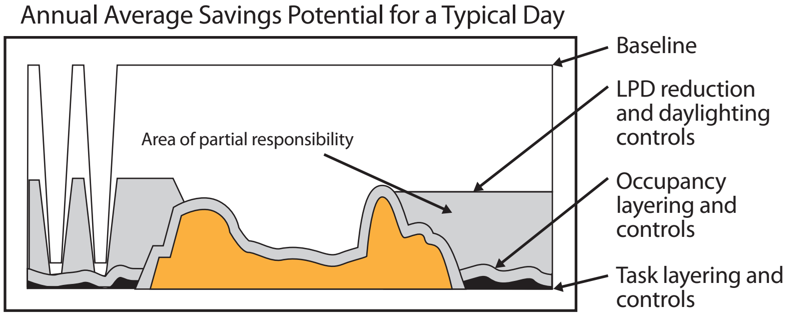
Use written and graphical sequence of operations documents.

☐ SD-CD Evaluate the sequence of operations for building system integration, commenting on the clarity of set points, controllability, and other possible omissions.

☐ DD-CD Use a control narrative as part of the functional checklist.

☐ DD-CD Confirm that integration has occurred and that all points intended to be shared by systems can be viewed and controlled.

Annual Average Savings Potential for a Typical Day



Facility Manager

▸ Energy Goal

Maintain the energy goal set for the building.

- [ ] Postoccupancy Document changes to the commissioned lighting control system settings and monitor their impacts on energy savings.
- [ ] Postoccupancy Provide individual solutions for discomfort (e.g., glare) versus blanket solutions to the building. One example is to provide additional task lighting if an occupant is not receiving enough light instead of lowering the daylighting set point.

▸ Daylighting Control

Maintain daylight performance.

- [ ] SD-CD Plan a maintenance schedule for daylighting components.
  - [ ] What type of maintenance will be necessary to ensure long-term performance: cleaning, motor replacement, system resets to account for interior surface reflectance changes or photocell drift?
- [ ] Postoccupancy Evaluate how changes to the building will affect daylight savings.

yes	no	
☐	☐	Are there policies against postoccupancy changes such as decorations or furniture alterations that will reduce daylight saturation?
☐	☐	Are there policies against new interior materials that might cause additional glare in the space?

- [ ] Postoccupancy Implement a cleaning schedule for daylighting devices such as light shelves and louvers.

▸ Occupancy Control

Maintain occupancy zoning functionality.

- [ ] Postoccupancy Does metering or building automation system information match expected occupancy patterns? If not, investigate possible faults in the system.

▸ Task Control

Maintain task zoning functionality.

- [ ] Postoccupancy Does metering or building automation system information match expected task types? If not, investigate potential faults in the system.

Facility Manager (continued)

▶ Sequence of Operations

Maintain task zoning functionality.

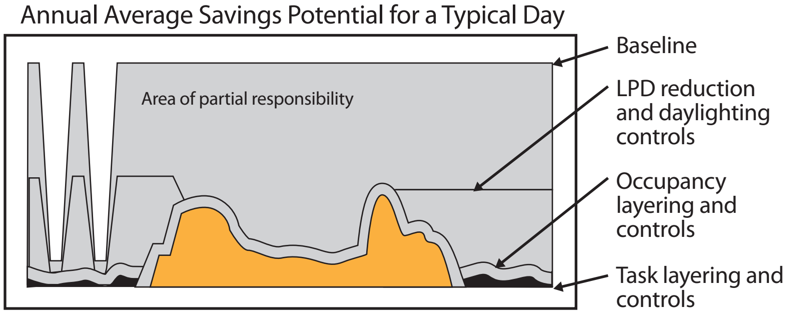
☐ SD-CD Request the consideration of maintenance costs in system comparisons.

yes	no	
☐	☐	Have wireless and wired systems been compared for ease of installation, maintenance, and life cycle cost?
☐	☐	Has a networked system been considered for its greater long-term energy maintenance potential than local, non-networked systems?

☐ SD-CD Evaluate the sequence of operations for building system integration, commenting on the clarity of set points, controllability, and other possible omissions.

☐ CA Confirm that integration has occurred and that all points intended to be shared by systems can be viewed and controlled.

☐ Postoccupancy Use the sequence of operations when evaluating lighting changes, keeping changes in line with the intent as much as possible.



Lighting Control Terms ▼

Auto On to 50%: Occupancy sensor control providing automatic On to 50% power with the remaining 50% load requiring manual On.

Bilevel switch: A control scheme providing two levels of light at the work plane. Typically, lamps are switched in two stages within each fixture or spatially across a zone.

Daylighting control: Electric lighting load responding inversely to ambient daylighting change. Savings associated with the term *daylighting* in this packet are due to automatic photosensor control only, although daylighting control can refer to manual control savings.

Daylight dimming: Continuously varying electric lighting level in response to daylight to maintain a commissioned set point.

Daylight switching: Discretely varying electric lighting level when daylight reaches a commissioned set point.

Emergency light control: Using control units to allow emergency lighting fixtures to be controlled in tandem with other lighting fixtures in the space in all scenarios except for emergency situations.

Layering or staging: A lighting design approach that creates different levels of light on a surface using dimming, bilevel switching of lamps in one fixture, or bilevel switching of fixtures in a zone.

Occupancy control: In this checklist, the term refers to design measures such as light layering or lamp zoning for unique occupancy patterns. Available daylight can enhance savings from these design measures.

Occupancy sensor: Provides automatic On, automatic Off electric lighting control based on detected occupant presence.

Sequence of operations: The intent document for the lighting control system and its connection to other building systems. The written aspect can be included in the design specifications, but a package that includes the written document, zoning diagrams, and one-line diagrams should be provided to all team members and manufacturers for review as early in the design as possible.

Task/ambient lighting: A lighting design strategy using overhead lighting to produce approximately 25 fc at the work plane and supplementing with fixtures such as desk lamps to provide 50 fc at the task.

Task control: In this packet, the term refers to design measures such as light layering and lamp zoning for unique task types. Available daylight can enhance savings from these design measures.

Timed sweep: A lighting control event turning Off all associated lamps. It is preceded by a blink or dim warning, giving occupants time to override the sweep.

Vacancy sensor: Provides manual On, automatic Off electric lighting control based on detected occupant presence.

Zoning: A lighting design approach that separates fixtures within a space by circuiting to prevent all fixtures from having to be On at the same time.

Control Type Savings Potential.

Table 2 shows a sample of lighting control types and the spaces to which they best apply. These values can be used early in design to think through proper applications of different strategies.

Table 2. Sample of Lighting Control Types

Control Type	Savings Potential*	Application Notes
Auto On to 50%	10%–50%	Consider in private offices and break rooms. Lowest savings for private offices and greatest savings for break rooms. Best in non-daylit spaces with varying tasks.
Bilevel switching	25%–40%	Consider in open offices and break rooms. Lowest savings for break rooms and greatest savings in open offices. Best in daylit spaces with varying tasks and occupancies.
Daylight dimming and switching	10%–50%	Consider in any space except electrical/mechanical rooms or data centers. Lowest savings for break rooms and greatest savings for offices.
Emergency light controls	20%–30%	Consider in all open offices and transition spaces.
Occupancy sensor	10%–70%	Consider in transition spaces, break rooms, mechanical/electrical rooms, and restrooms. Lowest savings for break rooms and highest savings in mechanical rooms.**
Timed sweep	15%–35%	Consider in open offices and transition spaces. Transition spaces are likely to show greater savings than open offices.
Vacancy sensor	20%–50%	Consider in private offices, break rooms, and any other auxiliary space. When paired with measures such as daylighting or task/ambient lighting, this measure is likely to show greater savings than occupancy sensors.

* Resources include the NREL Research Support Facility modeling and measured data, California Lighting Technology Center publications, Lawrence Berkeley National Laboratory publications, New Buildings Institute publications, the *Lighting Controls Handbook* by Craig DiLouie, and WattStopper energy savings online calculator.
** Use bilevel occupancy sensing or two circuits, one in pathway and one in work zone, to address safety concerns.

Case Study: RSF I ▼

Installed LPD: 0.6 W/ft²

First-year peak operating LPD: 0.4 W/ft²

Annual lighting energy use estimate: 4 kBtu/ft²/yr

Lamp types: T8 fluorescent (primary), metal halide (lobby accent), light-emitting diode (LED) (restrooms, exterior, task)

Daylighting

South-facing optical louvers and north-facing clerestories, as shown in Figure 1, provide 25 fc for 75% of the open office wing during a sunny equinox at noon. Perimeter bilevel switching and core dimming provide fine-tuned ambient lighting control in response to annual daylighting saturation.

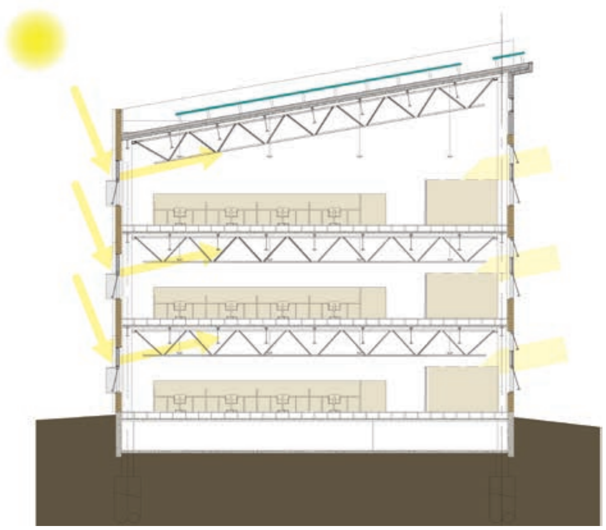


Figure 1: RSF sections showing optical louvers redirecting sun to the south (left) and north clerestories (right) providing diffuse daylight.
Credit: RNL Design.

Occupancy

Vacancy sensors require occupants to turn lights On in private offices and storage spaces, and occupancy sensors to automatically turn lights On in restrooms and elevators. All lights in the building, including emergency lighting, are controlled by occupancy sensors or time sweeps. Only vestibule lights and lights near corridor switching remain On when the building is unoccupied.

Conduct open office and corridor lighting sweeps every 2 hours starting at 6:00 p.m. Egress and nonegress lighting in any office zone can be overridden separately for 2 hours depending on task needs. Security switches allow for egress lights to be turned on for a 10-minute override to Off.

Task

A maintained ambient illuminance of 25–30 fc is provided using 25-Watt, T8 fluorescent lamps with 96% efficient luminaires. Supplemental task lighting is provided at each occupant's workstation with a 6-Watt LED task lamp.

Dual switching is provided in kitchens and copy rooms for area versus counter lighting, and in maintenance rooms for pathway versus equipment lighting.

Control system

The final design resulted in a mixed system: low-voltage relays reside in central panels to control open offices, corridors, and private offices with line voltage control using local occupancy and daylight sensors for unique spaces such as large conference rooms.

Sequence of operations

The sequence of operations is a critical document to ensure predicted savings are realized. Common problems it can prevent include incorrect wiring of fixtures, too few sensors to adequately control zones, and inadequate sensor settings. Owners need to request this type of document from the designers; installers, commissioning agents and facility managers should use this document in tandem with electrical and lighting plans to check work and assess how changes will affect intent.

For the sequence to be useful for all, it should be developed in early design and evolve to contract document status at the end of design.

The package should:

- Include clear, simple language describing the sequence of lighting events for each space, occupant type, and task type throughout the day.

- A preamble that describes goals, relevant codes, and primary methods used for:
  - Each room type, provide the sequence over the course of the day
  - Each occupant and task type.
- Describe failures that the sequence is designed to prevent.
- Discuss integration with other building components such as shade and HVAC control.
- Provide zoning graphics for daylight, occupancy, and task layers.

Abbreviated example

This text is compiled from RNL's full sequence of operations document. This is only a brief example. There is a better chance for successful integration when specific information, such as equipment locations and device settings, is given.

Preamble

Energy goal: 35 kBtu/ft^2/yr

Daylighting goal: 25 fc for 75% of the work areas during a sunny equinox at noon.

Primary methods: The lighting system is designed to be dynamic; the light levels will respond to the available daylight and to occupant needs. Open and private office areas have daylight-controlled overhead task lights, ambient illumination, and personal task lights. Conference and training areas have multiple layers of light that can be independently controlled from local wall switches, except for the overhead task lighting, which is controlled by the daylight harvesting system and local wall dimmer switches. Occupants can turn the light up to the level allowed by the daylight harvesting system and lower it at will.

Open office

Initial Illuminance = 30 fc, work plane average

Maintained Illuminance = 25 fc, work plane average

The open office space has one primary layer of ambient illumination in the form of dimmable suspended direct/indirect luminaires with two, 25-Watt T8 lamps in cross section. Each workstation is equipped with one, 6.2-Watt LED luminaire desktop task light with an integral switch, cord, and plug.

This task light can be repositioned and provides an additional 20–30 fc of illumination to the surrounding work surface.

Typical Occupant

The first occupant to enter the open office shall use the manual switch located at the entry, labeled per zone (i.e., "east," "west") to turn On the ambient lights if there is not enough daylight in the space. The appropriate office zone switch may be used or the egress fixture light switch labeled "egress" may be used if only a small amount of ambient light is needed. For lights turned On, the closed-loop sensor at the perimeter will use the bilevel ballast capability for daylight switching of perimeter-zone ambient lights in response to daylight. The closed-loop daylight sensor in the center of the space will use 0- to 10-V daylight dimming for all center-zone ambient lights. The intent of the separate daylighting zones is to allow the perimeter lamps to remain Off for most of the day while the center lamps can be On to a low dim level when needed during certain times of the year. Closed-loop daylight sensors shall be commissioned to provide the average space criteria. An average is used to allow for variety in workspace lighting conditions and prevent overuse of ambient lighting. Time delays should be set to prevent rapid cycling of lamps.

The occupant can usehis or her personal task light throughout the day as necessary for specific tasks. When the last occupant leaves, the manual switches are available for manual override to Off. If the occupant forgets to turn Off the lights, the timed sweep will turn Off all office lights at 6:00 p.m. All sweeps Off are preceded by a blink warning 10 minutes prior. If occupants return or remain, the office lights can be overridden On for 2 hours.

Perimeter daylight switching, center daylight dimming, east and west occupant-based switching, and task/occupant-based egress switching are outlined in Figure 2.

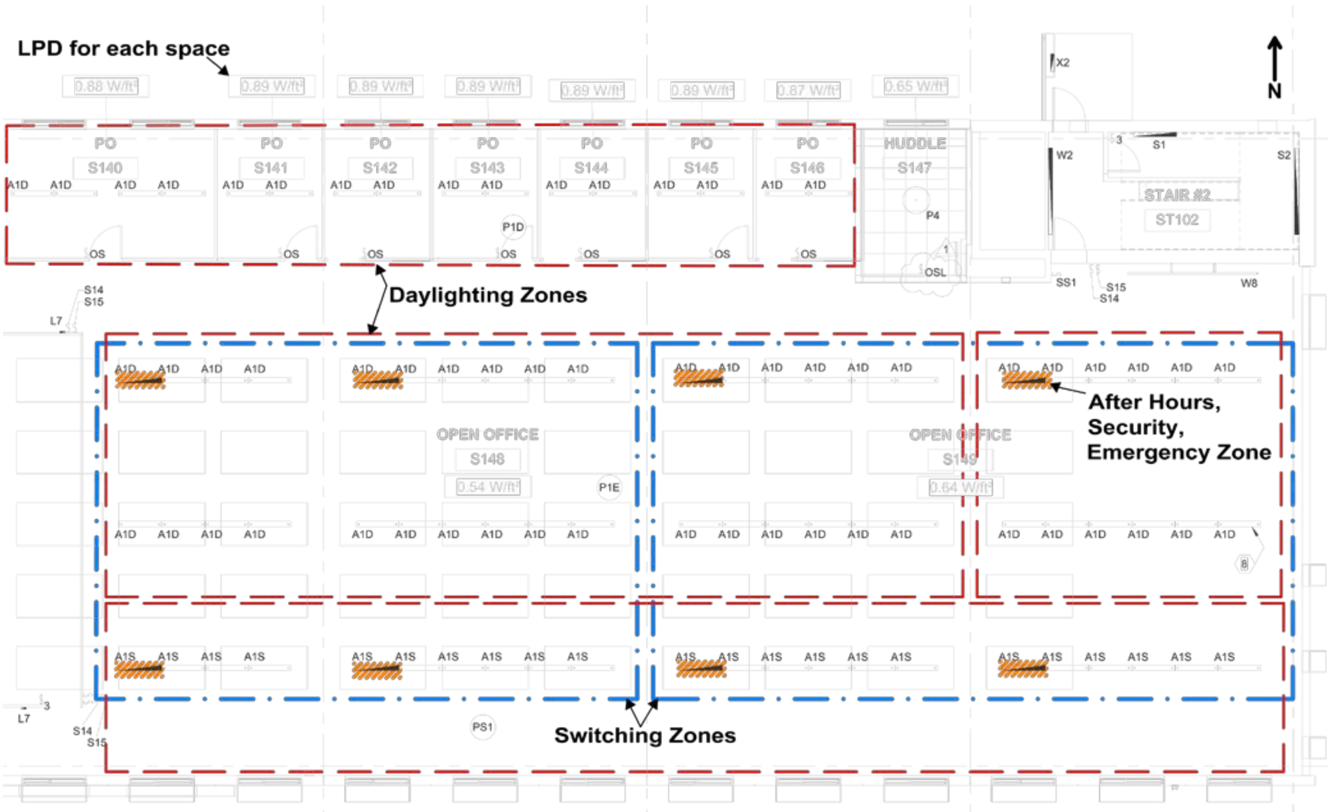


Figure 2: Zoning diagram example. Credit: RNL Design

Security Personnel

When security personnel enter the building at night, they shall use the switches labeled "security," which will turn on the emergency fixtures for 10 minutes. The "security" switches prevent lights other than vestibule and stair entry lights from remaining On during most of the night.

Integration

No building automation system connection will be directly made. Lighting relay status must be viewable and editable from the facility manager's workstation.Provide written and graphical intent for all space types, refining through each design phase and using manufacturer to aid in development as well as to give the final assurance that the proposed equipment can meet the plan.

Useful Links ▼

California Lighting Technology Center's home to research and demonstrations covering a variety of lighting control technologies: *http://cltc.ucdavis.edu/*

Basic lighting and control definitions: *http://www.energysavers.gov/your_home/lighting_daylighting/index.cfm/mytopic=12180*

Resources for the understanding of energy saving, flexibility, and environmental quality aspects of lighting controls: *http://lightingcontrolsassociation.org/*

Manufacturer-provided white papers and online energy saving calculation tools: *http://www.wattstopper.com/*

Whole Building Design Guide, which contains a controls selection matrix and additional resources for more in-depth learning of key lighting control terms used in this guide: *http://www.wbdg.org/resources/electriclighting.php*

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-5500-51665 • November 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.