playbook

Lighting the Way

Upgrading lighting systems for commercial offices

Advanced lighting system retrofits can reduce lighting energy use by as much as 75%, pay back in less than three years, and improve occupant satisfaction and well-being.

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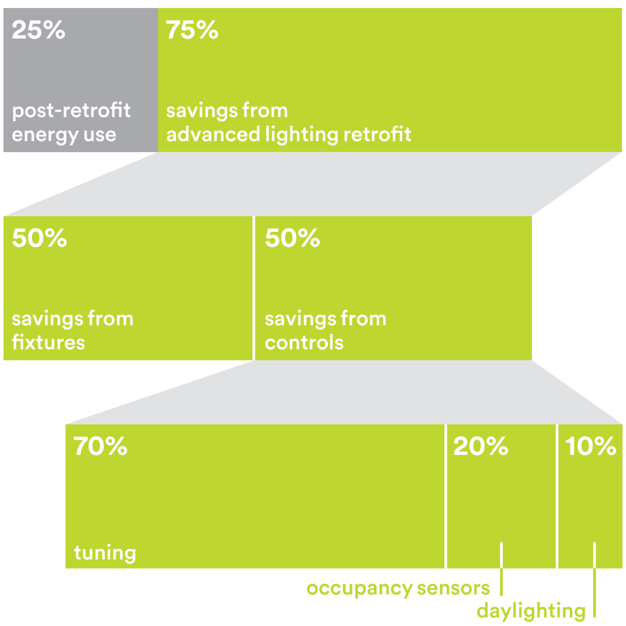
advanced lighting upgrades save money & energy

Lighting accounts for one-third of electricity use in New York City commercial buildings.[1] By upgrading to higher efficiency fixtures and installing advanced lighting controls, commercial building owners can reduce their lighting energy use by as much as 75%.[2]

Advanced Lighting Upgrades: A Bright Idea

Due to significant strides in lighting technology, advanced lighting system upgrades are among the most cost-effective means for commercial building owners to lower their energy use, cut operating costs, and reduce their carbon footprints. Lighting upgrades also enhance lighting quality and aesthetics, which can improve occupant well-being and increase property values and rents.

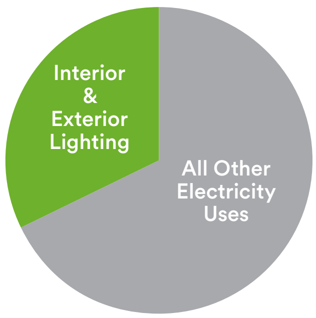
Lighting system upgrades can be completed at varying levels of complexity and cost, from replacing individual components (such as lamps, ballasts, or sensors), to relighting or redesigning entire spaces. Lighting projects that successfully improve the office environment and save energy will select upgrade measures to meet the specific needs of the space and organization. Typically, the more comprehensive the retrofit, the greater the improvements to comfort, aesthetics, lighting functionality, and project payback.



Upgrading to more efficient fixtures and installing advanced controls can reduce lighting electricity use as much as 75%. Individual project savings will vary depending on the scope of work and baseline conditions. (Source: BE-Ex analysis, 2017.)

New York City Context: Codes and Regulations

Advanced lighting upgrades can help building owners comply with New York City codes and regulations. Analysis of energy audits performed to satisfy NYC Local Law 87 found that lighting retrofits are the most commonly recommended energy conservation measure, cited in nearly one out of every five audits.[3] Recognizing the importance of lighting upgrades, local regulations of lighting systems have become progressively stricter, a trend that is expected to continue.



Lighting accounts for one-third of electricity use in NYC commercial buildings. (Source: Con Edison, 2010.)

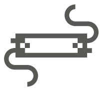
For instance, large and mid-sized commercial buildings must comply with NYC Local Law 88, which requires lighting systems to be upgraded to meet current code by 2025.[4] With codes getting stricter every cycle, building owners are encouraged to perform these upgrades as soon as possible to begin saving energy and money.

Even with increasing code stringency, upgrades that go significantly beyond code requirements often have quick paybacks. In NYC, comprehensive lighting upgrades typically pay back in just 3 to 5 years, with even shorter paybacks available for simple component upgrades.[5] Buildings that install advanced lighting controls may be able to improve project payback by enrolling in demand response programs through their local utilities, receiving compensation for reducing their electric load when the grid is working to meet high demand.

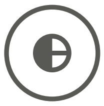
advanced lighting system components

The icons below depict some of the most common components of advanced lighting systems.

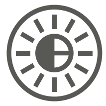
data collection



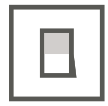
ballast/driver
Fluorescent ballasts and LED drivers regulate power to fixtures based on signals from sensors and system software.



occupancy sensor
Occupancy and vacancy sensors are used to determine whether a space is occupied, to reduce the wasteful lighting of empty spaces.

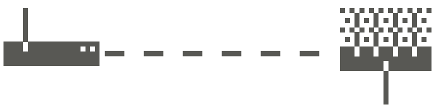


daylight sensor
Daylight sensors, or photosensors, measure the amount of daylight in a space, enabling the system to dim electric lighting when it is not needed.



wall switch
Wall mounted light switches provide individual control of lights, and often include dimming and pre-set lighting scenes.

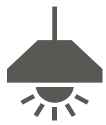
data management



energy manager
Energy managers, also called gateways or “Energy Control Units,” collect and send information between both wired and wireless components and pass it on to the system server.

server
The server receives and stores data from the energy manager and connects with the graphic user interface.

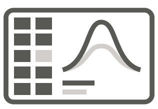
data response



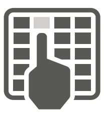
fixture
The light fixture includes the housing, sockets, optics, and lamps. High efficiency fixtures are dimmable and may have ballasts, drivers, or sensors built in or attached remotely.

automated shading
Automated shades adjust their position using software and sensors, and are designed to allow maximum comfortable daylight into a space while minimizing glare.

interactive controls



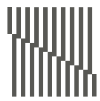
graphic user interface
A graphic user interface (GUI) visualizes lighting system data via an app or desktop software, typically indicating in real-time which lights are in use, how much energy is being drawn from the electrical grid, and alerting managers to maintenance issues.



The GUI can be used to schedule when lights turn on and off, to tune light levels in individual spaces for specific needs, and to participate in demand response programs.

control signals

DALI and 0 -10
Lighting systems utilize either digital or analog control signals. The most common digital control protocol is DALI (Digital Addressable Lighting Interface), an open standard used by the major lighting manufacturers.



Analog systems have long utilized a DC-based 0–10 V signal, in which the dimming output is scaled to be 100% at 10V, and 0% at 0V (although the actual dimming ranges of certain components, like ballasts, are often limited).

anatomy of an advanced lighting retrofit

Careful retrofits can improve the function of lighting systems, reduce energy use, enhance occupant comfort, and save money. Understanding the process, players, and goals at the beginning of a retrofit can make the project easier and more successful.

To ensure that a lighting retrofit is successful, project teams should identify and select the right technologies and functions for their specific needs, make use of available financing and incentives, assign a project manager to oversee the retrofit process, and educate building stakeholders.

The following steps can help guide your team through a successful lighting retrofit:

1 Identify Goals and Requirements

When exploring retrofit options, it is important to assess the needs of both your space and organization. These may include energy saving goals, budget limits, current and anticipated use of the space, and occupant concerns. Assessing these needs with your project team can help you determine the appropriate functions for your lighting system.

At the outset of the project, be sure to identify:

- Area of the retrofit
- Budget and schedule
- Lighting system needs & functions
- Energy savings goals
- Project manager

2 Select Technology

Using the goals and requirements identified by your team, work with a lighting designer, distributor, contractor, or some combination of these, to ensure appropriate technology selection. Advanced lighting retrofits may include technologies from some or all of the following categories:

Lamps & Fixtures – Incorporating higher efficiency lamps and/or fixtures can result in significant savings, especially if upgrading to LEDs. There are several ways to incorporate LEDs into an existing space (see *Fixtures Selection,* pp. 6–7).

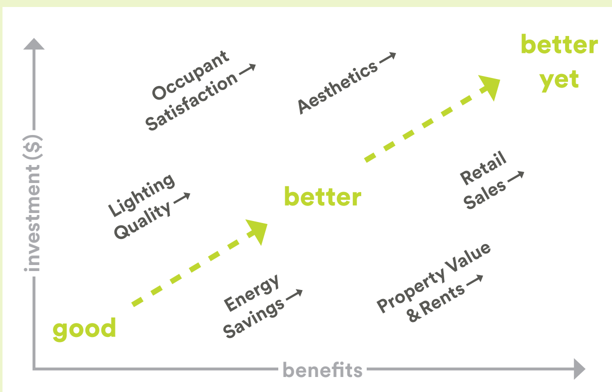
Advanced Controls – A control system is the crux of the retrofit, ensuring functionality and integration. Controls can be adapted to suit your existing construction and end-use needs (see *Controls Selection,* pp. 8–9).

Daylighting – Daylighting controls use photosensors to monitor interior lighting levels and reduce electric lighting in proportion to available daylight. Automated shades can be integrated with the system, allowing maximum comfortable daylight into a space while minimizing glare and decreasing cooling loads (see *Daylighting,* p. 10).

Good, Better, Better Yet

Lighting upgrades can vary considerably in complexity and cost. Before you choose the right technology, choose the right project – one with expectations aligned with both your budget and your capacity to manage the project.

The figure on the right depicts three tiers of lighting upgrades, from simple to complex: “Good,” “Better,” and “Better Yet.” As the level of retrofit investment increases, so do the associated benefits. This tiered framework can help guide your selection of appropriate lighting fixtures and controls.



3 Invest & Finance

Lighting retrofit costs vary greatly depending on project scope, degree of disruption, and market forces. In New York City, labor costs are high but return on investment is improved by the relatively high cost of electricity, especially during peak demand periods. In NYC, a comprehensive lighting upgrade will typically pay back in just 3 to 5 years.[6] Payback can be improved by accessing incentives from the New York State Energy Research and Development Authority (NYSERDA), Con Edison, and others. Financing is available through many lenders and non-profits, like the NYC Energy Efficiency Corporation (NYCEEC).

4 Install & Commission

It is crucial for a project manager to oversee the installation process and ensure that systems are properly commissioned prior to full operation. Installation oversight is critical to avoiding complications during the retrofit process, and commissioning by a trained professional will ensure that the system is performing effectively and occupants are comfortable. Systems should be periodically monitored, tuned, and maintained to ensure that they continue to function correctly.

5 Educate Stakeholders

Close cooperation with building occupants is key to project success. Maintenance personnel, facility managers, and the office occupants themselves must be involved in the installation process and educated on system operation. Engaging end-users throughout the entire process reduces mis-understandings that can derail projects, ensures a smooth transition, and creates project advocates.

Case Study: The Time Warner Center

Related Companies, developer of the Time Warner Center completed in 2003, retrofitted their two floors in the building with advanced lighting controls in 2012. The control system includes occupancy sensors throughout the space, daylight sensors in perimeter offices, and wirelessly controlled, continuously dimmable digital ballasts in overhead fluorescent fixtures. This retrofit reduced Related's energy consumption by 56% and had a three-year return on investment.

Read the full case study here:
be-exchange.org/resources/case-study/1

The Time Warner Center

Good: Component Replacement
Perhaps the most common, this approach involves simple component replacement, such as relamping or reballasting existing luminaires, or replacing stand-alone controls to meet current energy code requirements.

While this approach does not typically provide improvements in lighting quality, it can yield energy savings at very low costs.

Better: Retrofit
Somewhat more involved, this approach involves replacing whole luminaires and installing a centralized control system, coupled with additional energy reduction control strategies.

The advantages of this approach are improved lighting quality and an updated aesthetic, which can improve occupant satisfaction and enhance the marketability of a space.

Better Yet: Redesign
The most comprehensive, this approach involves total redesign and relighting using new products and current best practices, as well as installation of an integrated control system with multiple energy reduction control strategies.

This approach allows a space to max-imize its marketability and command higher rents or sale prices. Tenant fit-outs are ideal times for "better yet" upgrades.

fixture selection

Upgrading to higher efficiency lamps and fixtures can result in significant energy savings, while also improving lighting quality and comfort. Selecting the right fixture for each job maximizes lighting quality, flexibility, visual interest, and energy savings.

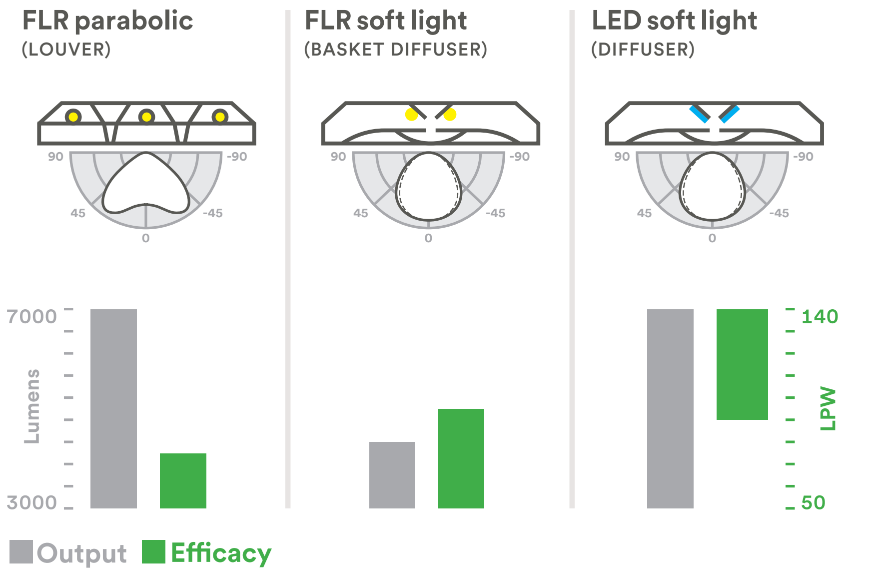
Evaluating Fixtures

Lighting fixtures, or “luminaires,” are durable devices that will remain in your space for years to come. It is worth spending the time and money to ensure that you select the right fixtures for your space. In addition to cost, be sure to consider a fixture’s output, efficacy, and lifespan when making your selection.

Output
Output is the amount of light emitted by a source and is measured in lumens. The more lumens, the brighter the light. Be sure to consider the output of the entire luminaire (including optics), not just the output of the LED or fluorescent lamp.

Efficacy
Measured in lumens per watt (LPW), lighting efficacy tells you how efficiently a light source converts power into light. Be sure to evaluate the efficacy of the entire luminaire, including efficacy of the lamp (LED or fluorescent), losses from the ballast/driver, and losses within the fixture.

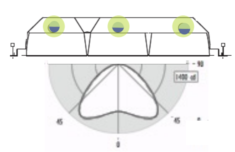
Lifespan
While fluorescent lamps essentially fail at their end of life, LEDs dim slowly as they age. Use the L70 rating to compare anticipated LED lifespans.



LED fixtures typically have greater output and efficacy and far longer lifespans than fluorescent fixtures.

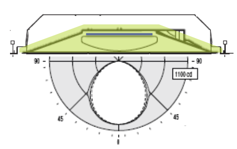
Fixture Replacement Options: There are several ways to incorporate LEDs into an existing space.

1 Lamp/Ballast Replacement
Replace existing fluorescent T12 or T8 tubes with a linear LED lamp. Replace ballasts if needed, depending on age.



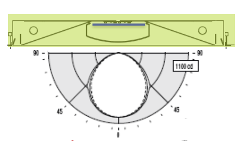
- Low initial cost
- Existing optics
- Existing appearance
- Lighting varies

2 Fixture Retrofit
Leave the housing in place and reconfigure the interior of a fixture with an LED array and improved optics, typically sold as a kit.



- Low installation cost
- New optics
- New appearance
- Same size/location

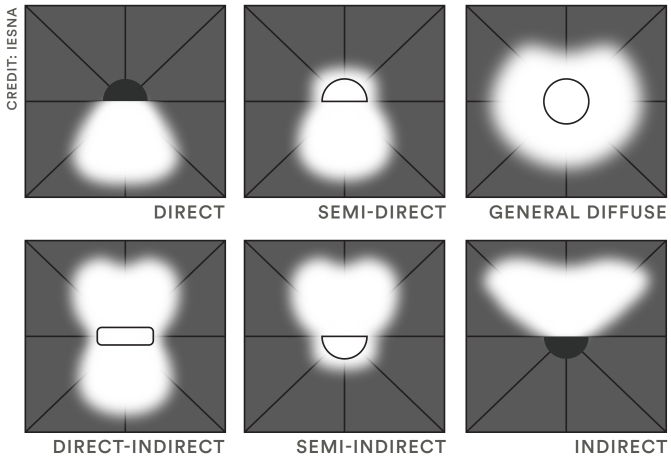
3 Fixture Replacement
For best performance, improved optics, significant energy savings, and an updated aesthetic, replace the fixture entirely.



- Highest cost
- New optics
- New appearance
- Flexible type/size/location

Lighting Distribution Types

Luminaires have various distribution types tailored to specific jobs, such as providing light to walls or ceilings, adding sparkle or ambient glow, or delivering focused task lighting. Some luminaires integrate multiple distributions for different functions. Energy effective lighting creatively combines luminaires with varying distributions to provide a balanced and functional luminous environment.



Color Quality

Our perception of color quality is affected by both color temperature and color rendering.

Color Temperature

Color temperature refers to the perceived warmth or coolness of a light source's color, and is measured in Kelvin (K). As seen in the chart on the right, LED light sources below 3,000 K appear warm white or yellowish (similar to incandescent lights), while sources above 5,000 K appear cool or bluish-white.

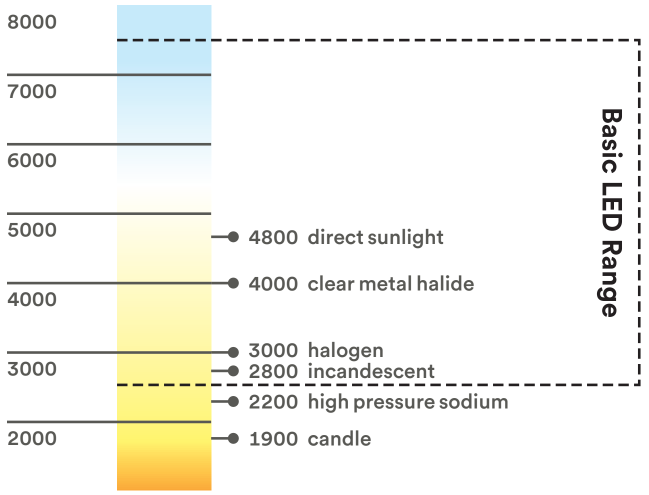
Correlated Color Temperature

Similar to color temperature (first used to describe incandescent and tungsten lamps), Correlated Color Temperature (CCT) is measured in Kelvin and is used to characterize the warmth or coolness of LED, fluorescent, and other types of lamps. CCT has a significant impact on the feel of a space, so it is important to select CCT values carefully. It is recommended that you do not mix and match lamp manufacturers on the same project, to avoid variations that sometimes occur between them.

Color Rendering

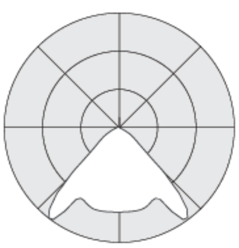
Light sources with the same color temperature can render surfaces differently. The Color Rendering Index (CRI), a scale from 0 to 100, measures a light source's ability to reveal colors of objects faithfully, compared to natural daylight. Objects viewed under sources with a high CRI value appear the most natural.

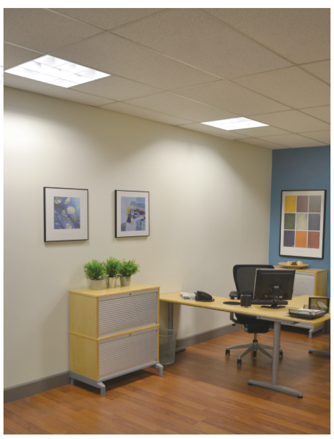
Kelvin Scale Color Temperatures



Sharp Cut-Off Lighting

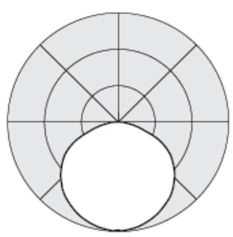
Popular in the 1970s, this luminaire style has a parabolic louver rather than a lens. The louver spreads light fairly well, but leaves the lamp directly visible to the eye (creating glare) and produces a distribution pattern with a sharp edge, casting shadows on adjacent surfaces.

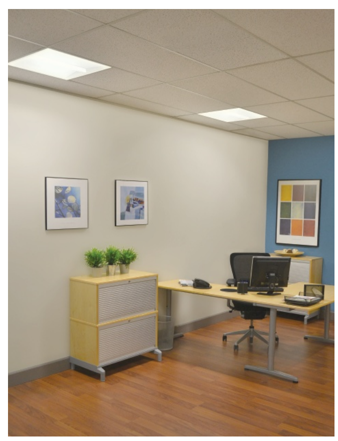




Soft Lighting

The more contemporary style today, these fixtures typically feature a lens that covers the lighting source and produces a soft pattern that illuminates adjacent surfaces and provides more light at the ceiling.





controls selection

Each component of a lighting control system helps to optimize energy savings and occupant comfort. Today's lighting control systems feature myriad options, including real-time scheduling, occupancy and daylight response, task-tuning, color-tuning, and circadian programming.

Deciding which control and network strategies to implement depends on your specific project circumstances, and, most importantly, on the physical characteristics of your space (such as floor plate geometry, interior layout, window distribution, and ceiling height).

Network Options

Wired
Until recently, nearly all lighting control systems communicated via low voltage wiring, also called "data" or "control" wiring. Being commonplace, wired systems are familiar to most contractors. In some cases, wired systems are required by clients with heightened security concerns (such as financial institutions).

Wireless
Wireless controls eliminate wiring from switches, sensors, and gateways, while typically retaining a wired connection between the energy manager and server. Though hardware costs are similar, wireless networks reduce disruption and installation costs, while retaining features and reliability similar to fully wired systems. The communication range of wireless components, and dense obstructions like elevator cores, must be considered carefully. Security sensitive clients should research compatibility with available communication protocols.

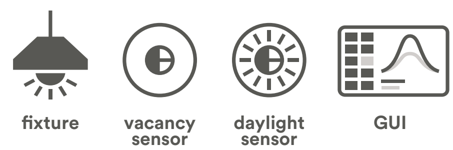
Autonomous Systems
Autonomous systems utilize luminaires with integrated sensors and control modules that communicate with one another, rather than with a central server. After initial setup, the system adjusts (as guided by scheduling, occupancy, daylight, etc.), providing most of the performance of more advanced systems, but limiting system complexity.

Power over Ethernet (PoE)
PoE systems use ethernet cables to transmit both power and control data. These DC-powered systems offer significant flexibility for controlling individual fixtures while limiting installation costs and avoiding AC to DC conversion losses.

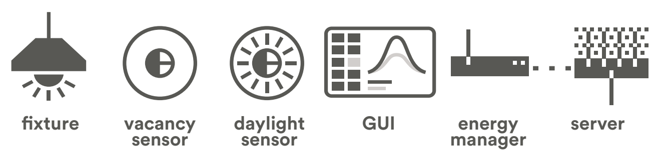
Controls Options

Good: Stand-Alone Controls
Simple stand-alone, or "plug and play," controls and sensors are not connected to a broader network. They are inexpensive, but functions are limited and reprogramming typically is not feasible.
Example: Wall switch, vacancy sensor, and ballast.

Better: Centralized Control System
In a centralized control system, luminaires and sensors are grouped and controlled by a local control panel or a simple cloud-based interface. Fully wireless and mixed systems are available. These systems provide most performance advantages and are reasonably flexible, cost-effective, and easy to operate.
Example: Integrated, autonomous lighting system.



Better Yet: Connected Network
A connected network is a complex and high performance system driven by a central server. Typically, each luminaire (or group of luminaires) is directly addressable using a control panel or cloud-based software. These systems provide maximum flexibility and make both BMS integration and demand-response program participation possible, but require complex commissioning and ongoing management.
Example: Multi-space networked control system, driven by a BMS.



Control Strategies

Design teams can choose from a variety of lighting control strategies that can be combined to deliver high-quality lighting environments that yield substantial energy savings.

Zoning – An essential lighting control prerequisite, "zoning" is the creation of various lighting control zones that can be independently controlled to turn on, off, or dim all luminaires within the zone. Zoning alone yields no energy savings, but it enables other control strategies to be effective. Zoning is particularly important for larger, open-plan spaces where lighting needs may vary across the floor plate.

Smart Time Scheduling – Scheduling controls save energy by turning lighting systems off during unoccupied periods, based on a set daily schedule. They are suitable for spaces with predictable occupancy patterns, and should be supplemented with override switches or additional control schemes to accommodate activities outside of scheduled hours.

Occupancy & Vacancy Sensors – Occupancy sensors automatically turn lights off when a space is unoccupied for a given amount of time, and are best suited for spaces with unpredictable occupancy patterns, like conference rooms. Vacancy sensors also turn lights off automatically, but require a manual control to turn lights on, thereby preventing unnecessary over-lighting. Vacancy sensors are required in some NYC spaces per Local Law 48.

Daylight Harvesting – Daylight harvesting, or "daylighting," controls use photosensors to monitor interior lighting levels and reduce electric lighting levels in proportion to available daylight (see *Daylighting,* p. 10).

Personal Dimming & Tuning – Dimmable fixtures enable occupants to tune workspace lighting to meet specific needs. Office workers exhibit a wide range of light level preferences for different tasks. Allowing workers to adjust their own lighting increases satisfaction and productivity, while enabling a reduction in energy use.

High-End Trim – High-end trim refers to dimming lights to deliver only the desired level of illumination to a task surface, thereby eliminating excess (also called "high-end") lighting. High-end trim can be implemented as an active system (using a photocell to measure task surface illumination and automatically adjust lights), or as a passive system (relying on a facility manager or office occupants to manually adjust lights).

Circadian Programming – Circadian programming is based on the premise that the human visual system needs and prefers less light at night than during the day. At night, facilities can reduce their interior illumination by as much as 50% without compromising usability or safety. As a result, spaces won't appear overly bright compared to their surroundings, and will provide an environment more in line with natural systems. Some controls also adjust the color of interior lighting to mimic the changes in natural lighting color that occur over the course of a day.

Demand Response – Demand response refers to the reduction of lighting power based on a request or signal from the electric utility. Participants typically receive a special utility rate for participation. During peak power periods, such as hot summer days, the utility may send a signal to the customer that results in the dimming of their lights by an average of 10%, freeing up capacity for the utility to meet peak power demand.

Writing a Lighting Control Intent Narrative

The following steps can help your team create a Lighting Control Intent Narrative – an essential communication tool for all phases of design, construction, and operation.

1. **Define**
   Start by writing a simple description of how each space is to be controlled. This step serves to develop a consensus between the design team, building owner, and occupants.
2. **Delineate**
   Supplement the written narrative with diagrams to indicate zones or groups of lights intended to be controlled together.
3. **Disseminate**
   Share the narrative with manufacturers for discussion and further refinement.
4. **Commit**
   Include a final version of the narrative with the contract documents.
5. **Certify**
   During shop drawing review, manufacturers should state in writing how they are meeting the performance criteria established in the narrative.
6. **Commission**
   The narrative will assist the Commissioning Agent during final calibration. Calibration settings should be recorded for future re-commissioning.
7. **Maintain**
   Keep the narrative on file so the facilities manager, occupants, and recommissioning agent can reference it.

daylighting

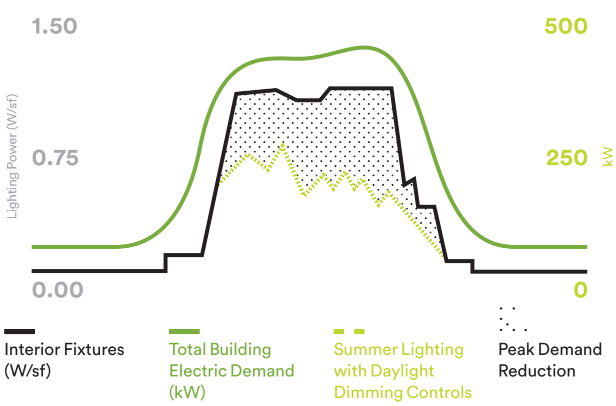
Daylight harvesting, or "daylighting," systems save energy by reducing the level of electric lighting in response to available daylight. By introducing daylighting controls, New York City building owners can collectively save $70 million, or enough electricity to power 16 Empire State Buildings, every year.[7]

Why Daylighting?

Most offices have their lights on even when they are not needed. In New York City, many existing buildings were designed to maximize daylight. Spaces near exterior walls often receive enough daylight to work by without the aid of electric lighting, but most often, lights are left on anyway.

This is critical, because the times when daylight is most available (workday afternoons) coincides with peak demand – the time when our business districts are demanding the most energy from the grid. Peak energy is the most expensive energy, and typically the dirtiest and most harmful to our global climate, because the oldest, least efficient plants are brought online to meet peak demand.

The Building Energy Exchange's 2012 study, *Let There Be Daylight*, found that building owners and tenants in New York City alone could save $70 million every year by introducing daylight responsive lighting systems.[8] Balanced, day-lit spaces are typically also the most pleasant to spend time in. Studies suggest these spaces promote our health and well-being, improve productivity, and reduce absenteeism.[9] A variety of lighting control systems that respond to the presence of daylight by reducing electric lighting levels are available, but these systems are not standard.



Advanced daylight controls reduce peak lighting power demand. (Source: BE-Ex Analysis, Let There Be Daylight, 2012.)

Daylighting Strategies

Nearly every office with a window has some form of shading, if only simple horizontal louvers or roller shades. In most cases, these shades are manually operated, which can be effective in small offices with advocates for daylight. But more often, manual shading serving an open office area is pulled down during a period of over-brightness, and left down for long periods thereafter.

As a result, the most effective daylighting is achieved by an automated control system. This typically consists of photosensors and controllers that adjust window shades and electric lighting levels in response to available daylight. Lighting can be adjusted by either dimming or switching. Dimming is preferable in workplace environments, since it avoids sudden, noticeable changes in the amount of light provided. It also allows for steeper lighting energy reductions. LED lighting makes dimming a viable option for most applications, without the added cost of fluorescent ballasts.

Successful daylighting depends on:

- Availability of sufficient daylight
- Physical conditions that promote daylight distribution (such as high window headers and light-colored interior finishes)
- Effective control mechanisms to avoid unwanted glare and solar heat gain
- Lighting control performance that is not distracting or disruptive to occupants (i.e. no sudden changes in illuminance levels)

Daylight Hour

To demonstrate the availability of daylight and draw attention to this important issue, Building Energy Exchange organizes an annual global media campaign – Daylight Hour – a single hour when offices all over the world turn off the light in day-lit spaces and post their involvement to social media.

Visit daylighthour.org to learn more.

design for lighting

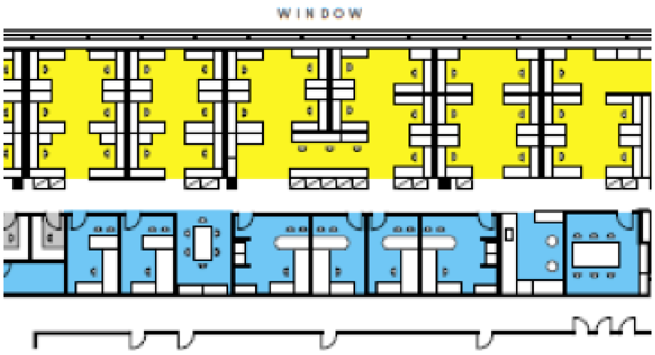
Interior design decisions have tremendous influence on lighting efficiency, both in terms of cost and energy usage. Planning smart interior layouts with low-cost, passive design solutions can improve energy savings and enhance occupant comfort.

Interior Design Can Save Energy

Successful lighting design results from a carefully considered analysis of a space's functional and programmatic requirements, physical characteristics, available daylight, surface finishes, and strategies to avoid glare and contrast.

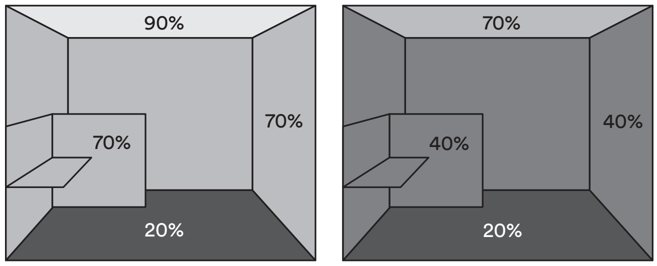
Good interior design tries to maximize opportunities for daylight harvesting by carefully laying out the various functional areas and incorporating low-cost passive design solutions, rather than utilizing expensive technologies.

Designing for Daylight



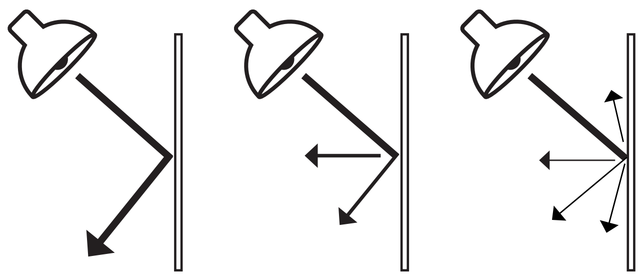
Open-plan offices with work stations located near windows are typically more energy efficient than closed-plan offices, with a higher number of occupants benefiting from access to daylight and views. The placement of interior walls, clerestories, and fixed furniture determines to what extent daylight can penetrate deeper into a space to benefit workers not situated along the perimeter. For example, low desk partitions, or partitions with translucent materials, can reduce a space's lighting energy use.

Brighter Colors, More Light



A small increase in room surface reflectance produces a big improvement in illuminance and lighting efficiency. As indicated in the diagrams above, lighter colored surfaces (left) have higher reflectance values than darker colored surfaces (right). In this example, the lighter colored room provides about 50% more light on the task area using the same amount of energy.[10] It also provides far better brightness ratios, user comfort, and daylight distribution.

Shiny Doesn't Mean Brighter



Specular Surface, HIGH GLARE

Semi-Specular, SOME GLARE

Diffuse Surface, LOW GLARE

Matte (diffuse) surfaces reflect light uniformly in all directions, while shiny (specular) surfaces reflect light in one direction, creating contrast, glare, and visual confusion. Matte finishes typically look brighter and require less light and energy than shiny surfaces.

Design Tips

Good lighting design should create an overall luminous balance within a space by avoiding glare, under- or over-lighting of areas, and excessive contrast. Within well designed spaces, sufficient and comfortable task-surface illuminance levels can easily be realized. The following design tips can guide project teams toward the achievement of optimal lighting outcomes.

1. Optimize space layout and partition heights
2. Select high reflectance finishes with bright, matte colors
3. Employ a task and ambient lighting strategy, not just bright general lighting
4. Use high-efficiency luminaires (like LEDs) and consider direct/indirect fixtures
5. Select appropriate control technologies

about

This Report

This report draws on insights from the *Living Lab Demonstration Project*, a collaboration between the Building Energy Exchange and Lawrence Berkeley National Lab that explored innovative lighting, daylighting, and shading systems in a working office environment. *Living Lab* vetted technologies, documented retrofit processes, and evaluated the savings of deploying and operating multiple lighting technologies.

Learn more at:

- facades.lbl.gov/nyclivinglab
- be-exchange.org/resources/project/46

Building Energy Exchange

The Building Energy Exchange connects the New York real estate communities to energy and lighting efficiency solutions through exhibitions, education, technology demonstrations, and research. We identify opportunities, navigate barriers to adoption, broker relationships, and showcase best practices at our resource center in the Surrogate's Courthouse.

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Goldman, Sachs & Co.

Technical Partner

Lawrence Berkeley National Lab

Project Supporters

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Additional Resources

To learn more about the topics covered in this report, see the following resources:

- Building Energy Exchange, *Let There Be Daylight*: be-exchange.org/resources/project/31
- Con Edison: coned.com/energyefficiency
- The Illuminating Engineering Society (IES): ies.org
- Lawrence Berkeley National Lab: buildings.lbl.gov and facades.lbl.gov
- NYS Energy Research and Development Authority (NYSERDA): nyserda.ny.gov
- New York City Energy Efficiency Corporation (NYCEEC): nyceec.com

Endnotes

1 In 2007, the most recent year for which Con Edison has published data, interior lighting accounted for 26% of commercial electricity consumption in their service territory, while exterior lighting accounted for an additional 6%. (Source: *Energy Efficiency Potential Study for Consolidated Edison Company of New York, Inc.; Volume 2: Electric Potential Report*, Global Energy Partners, LLC, Walnut Creek, March 2010, p.8.)

2 Energy savings will vary depending on the scope of work, granularity of controls, and baseline conditions (i.e. existing equipment, lighting use patterns, and building size and orientation). (Source: Building Energy Exchange analysis, 2017.)

3 LL87 auditors recommended lighting upgrades in 18% of office buildings audited. (Source: *New York City's Energy And Water Use 2013 Report*, Urban Green Council, August 2016, p. 26.)

4 "Large" refers to buildings over 50,000 square feet, while "mid-sized" refers to those over 25,000 square feet. Large commercial buildings have been required to comply with NYC Local Law 88 since 2009. Mid-sized buildings have been required to comply since October 2016, when the City Council passed Local Law 134, which amended the LL88 compliance threshold.

5 This payback range assumes installation of new fixtures and centralized controls. (Source: *Living Lab* research, Building Energy Exchange, 2014.)

6 ibid

7 Let There Be Daylight, Building Energy Exchange, 2012, p. 19.

8 ibid

9 A Literature Review of the Effects of Natural Light on Building Occupants, L. Edwards and P. Torcellini, National Renewable Energy Laboratory, July 2002.

10 The illuminance level of a room varies based on surface reflectance, lighting fixtures, room size, and cavity ratios (distances between the ceiling, fixtures, task surface, and floor). Average illuminance can be calculated using the Zonal Cavity Method, also known as the Lumen Method.

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