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Lighting Controls

Lighting controls help to make commercial buildings more comfortable, productive, and energy efficient. These controls can turn lights off when they are not needed or dim them so that no more light than necessary is produced. The two functions can be employed individually or, to provide even greater benefits, in tandem. The equipment used to achieve these functions ranges from simple timers to intricate electronic dimming circuits.

A well-designed control system will provide the right amount of light where and when it?s needed, and it will cut lighting energy use by 5 to 60 percent, depending on the baseline conditions and the control strategies used. A meta-study performed by Lawrence Berkeley National Laboratory (LBNL) reviewed 240 savings cases described in 88 papers and case studies (**Table 1**) and summarized the average savings achieved from all major control types.

Table 1: Energy savings from lighting controls

A variety of strategies are available to cut lighting energy use. A Lawrence Berkeley National Laboratory meta-study reported on the average savings found for a set of strategies, and manufacturers provide typical ranges.

Control strategy	Description	Average lighting energy savings from Lawrence Berkeley National Laboratory meta-analysis (%)	Manufacturer-provided energy-savings estimates (%)
Scheduling	On/off/dimming based on operating schedules	NA	10–40
Occupancy-based	On/off or dimming based on signals from an occupancy sensor, time clocks, or energy management system	24	20–60
Daylight harvesting	Light levels from electric lights adjusted based on photosensor signal indicating level of daylight	28	5–60
Personal tuning	Occupants control light levels	31	6–20
Task tuning	Dimmers and switches used to adjust light levels to suit tasks at hand	36	5–30
Combined strategies	Any combination of the above	38	NA

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In addition, lighting controls enable end users to participate in utility demand-response programs, and advanced lighting control systems can also improve maintenance by signaling lamp outages and monitoring output levels to indicate when they fall below required or desired levels.

Most of the studies reported on by LBNL covered fluorescent lighting. LEDs offer the potential for even higher percentage savings for several reasons. However, the total savings may not be as high because with LEDs in place, you may be starting from a lower power level to begin with.

Instant response, no cycling effect. LEDs respond instantly, and their lamp life is not shortened by frequent switching. Fluorescent lamp life decreases the more frequently the lamps are cycled on and off; high-intensity discharge (HID) lamps have a long delay time on start-up and restrike.

Dimming capability. LEDs can be dimmable, but care has to be taken to ensure that they?re compatible with the dimming controls employed. For some products, dimming can lengthen the life of LEDs because they run cooler when dimmed.

Color controllability. Good-quality LEDs can maintain a constant color temperature as they dim;, and controls can be used to change the color temperature of LED lighting, a feature that?s being used in a growing number of products to mimic the dimming behavior of incandescent lamps. Color-changing can also be used to support applications that are evolving out of a growing body of evidence that color temperature can play an important role in improving human health and productivity.

When LEDs and controls are combined in an installation, the savings can be dramatic. A Sacramento Municipal Utility District program found lighting energy savings of 50 to 90 percent in more than a dozen projects. About 60 percent of savings were from the light-source upgrade and 40 percent from the addition of controls.

WHAT ARE THE OPTIONS?

this section

The major categories of lighting control are on-off and dimming controls. Control systems, such as building automation systems (BASs), are also available that combine those capabilities. In fact, building operators can achieve the highest levels of energy savings through a combination of dimming and on-off strategies such as scheduling, occupancy control, daylight harvesting, personal control, task tuning, and demand response. However, the total savings achieved by implementing multiple strategies will be less than the sum of the savings gained by implementing individual strategies. The reason for this is simple. Take for example a system that combines occupancy sensing and dimming. Dimming cannot save energy when occupancy sensors have already shut off a lamp, and the occupancy sensors save less energy when they turn off lights that otherwise would have been dimmed.

On-off controls

The simplest way to reduce lighting energy consumption is to turn the lights off when they are not in use. All electric lights feature manual switches for that task, but switches are not used as often as they could be. The lighting industry has developed a variety of devices to solve that problem.

Occupancy sensors. Occupancy sensors are most effective in spaces where people move in and out frequently in unpredictable patterns: for example, private offices, lecture halls, auditoriums, warehouses, restrooms, and conference rooms. Occupancy sensors are less likely to be effective in open-plan offices, where one or more people may be present throughout the day, or in reception areas, lobbies, retail spaces, or hospital rooms. Occupancy sensors typically turn lights on when occupants are detected in a space. However, many systems are being installed today as *vacancy sensors* in which lights turn off when the space empties and have to be turned on manually when someone enters. In either case, systems are also being installed in ?partial on? configurations in which the lights turn on at less than full power, and can then be manually increased to full output.

The three most common types of occupancy sensors are passive infrared (PIR), ultrasonic, and those that combine the two technologies.

PIR devices are the least expensive and most commonly used type of occupancy sensor. They detect the heat emitted by occupants and are triggered by changes in infrared levels when, for example, a person moves in or out of the sensor’s field of view. PIR sensors are quite resistant to false triggering and are best used within a roughly 15-foot radius.

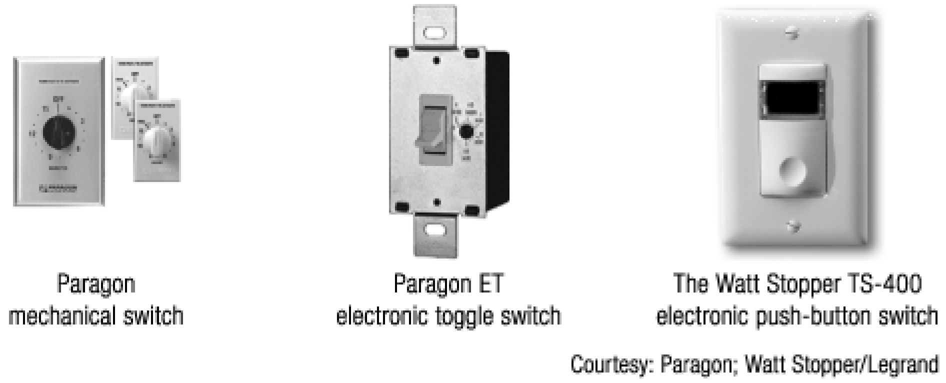
Ultrasonic devices emit a sound at high frequency—above the levels audible to humans and animals. The sensors are programmed to detect a change in the frequency of the reflected sound. They cover a larger area than PIR sensors and are more sensitive. They are also more prone to false triggering. For example, ultrasonic sensors can be fooled by the air currents produced by a person running past a door, moving curtains, or the on-off cycling of an HVAC system.

Hybrid devices that incorporate both PIR and ultrasonic sensors are also available. These take advantage of the PIR device?s resistance to false triggering and the higher sensitivity of the ultrasonic sensor. See our guide on occupancy sensors for more information.

Timed switches. Timed switches operate based either on elapsed time after triggering or on programmed schedules using clock time. Elapsed-time switches, also called timer switches, typically fit into or over a standard wall-switch box and allow occupants to turn lights on for a period that is determined either by the occupant or by the installer (**Figure 1**). Lights go off at the end of that interval unless the cycle has been restarted by the occupant or manually turned off sooner. Time intervals typically range from 10 minutes to 12 hours. Elapsed-time switches are much simpler to specify than occupancy sensors, are less prone to user maladjustment, and are low in cost.

Figure 1: Elapsed-time switches for lighting control

Elapsed-time switches are an inexpensive means of controlling lights in irregularly used spaces.



Elapsed-time switches may be mechanical or electronic. Mechanical units, which are typically set by the user, are basically spring-wound kitchen timers connected to a relay, and they are subject to mechanical failures if used in high-traffic areas. Time intervals on electronic switches are typically set by the installer using a hidden set-screw. These electronic devices look like conventional toggle switches, so occupants are usually unaware of the presence of the device, which reduces vandalism and theft.

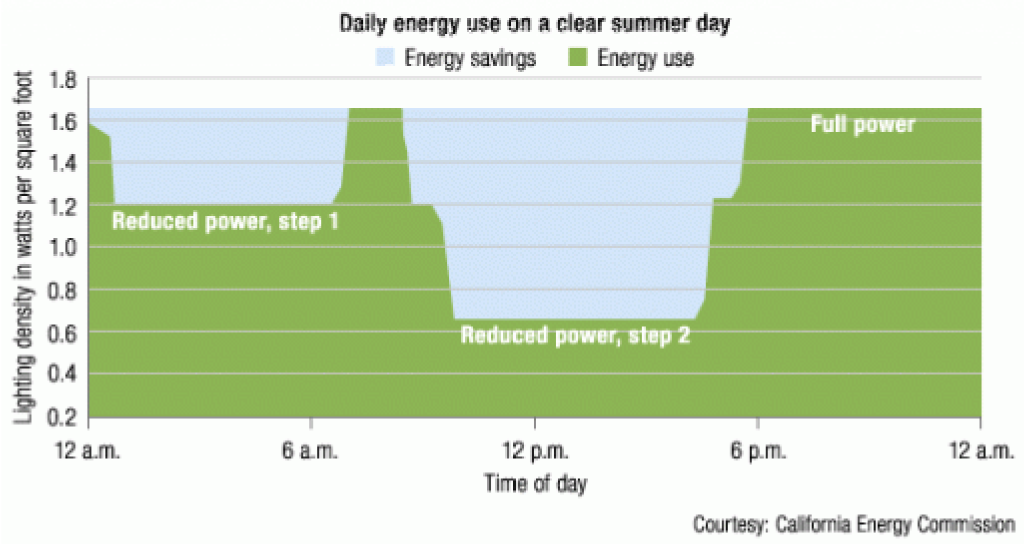
Clock switches control lights by turning them on and off at prearranged times, regardless of occupancy. They are most useful in locations where occupancy follows a well-defined pattern, such as a retail outlet. They are typically placed in electric closets that house lighting power panels. These devices cost relatively little to install and can control large loads with a single set of contactors. Equipment may consist of mechanical devices?motors, springs, and relays?or sophisticated electronic systems that handle several schedules simultaneously. Mechanical switches may require correction for daylight saving time or after a power failure unless battery backup is available, but battery backup can triple the device?s price. Electronic devices routinely include battery backup and can be easily programmed to adjust for shifts to and from daylight saving time or for holiday schedules. High-end electronic clock switches may include long-life lithium batteries and the capability to receive time signals from the National Institute of Standards and Technology to keep the clocks current. Electronic clocks can be integrated with software that enables managers to monitor system performance, check for overrides, and determine whether the schedule needs to be changed.

Dimming controls

Dimming controls are usually used to match lighting levels with human needs and to save energy. When combined with photosensors that measure local light levels, dimming controls can correct for dirt buildup in fixtures and lamp lumen depreciation. Dimming controls are also used to modulate lamp output to account for incoming daylight, sometimes called daylight harvesting. Dimming may be accomplished in either a stepped (**Figure 2**) or continuous fashion.

Figure 2: Step dimming provides big savings

A grocery store in Valencia, California, used skylights and photocells to reduce lighting energy use by 30 percent during a monitored two-week period. This lighting energy profile shows that electric light use decreased by two-thirds during peak daylight hours.



Step dimming. The most familiar form of step dimming is the three-way incandescent lamp. For non-incandescent lamps, two means of step dimming are available: banks of lamps may be put on different switching circuits, or ballasts (or drivers, in the case of LEDs) designed specifically for step dimming may be applied.

The first of these two methods is often referred to as bilevel switching, even though more than two levels may actually be available. For example, in a system with three-lamp fluorescent fixtures, one switch may operate the center lamp in each fixture, while another operates the outer lamps. This arrangement makes three lighting levels possible (one lamp, two lamps, or three lamps lit), yet the term “bilevel” is still often used to describe such a system.

Step-dimming ballasts offer more light control and energy savings than nondimming ballasts but cost less than the more versatile continuous-dimming ballasts. Step-dimming ballasts typically offer two or three lighting levels, and they can be used with occupancy sensors so that the sensors are able to dim the lamps rather than turn them off, which can reduce on-off cycling and extend lamp life, and increase safety in areas like stairwells and hallways where building managers may be reluctant to turn lights completely off when areas are unoccupied. These units also offer a viable way to reduce lighting levels during noncritical hours and to shed peak demand in common areas such as corridors.

Step-dimming ballasts are especially useful for high-intensity discharge (HID) lamps, which typically require long warm-up and restrike times, so they are not suited to being switched on and off by occupancy sensors. (See the guide on HID lamps for more information.) Better results can be obtained by switching the lamps between low power (typically about 50 percent) and full power.

Continuous dimming. Continuous-dimming controls let users adjust lighting levels over a range of lighting output. They offer more flexibility than step dimming and are used in a wide variety of applications, including mood-setting and daylight dimming (see the daylighting controls topic). Dimming can be accomplished on all lamp types found in commercial buildings: incandescent, fluorescent, HID, and LED.

Incandescent lamps are the easiest to dim. The use of semiconductor-based dimming controls for these lamps means that dimming is accompanied by a reduction in energy consumption. These dimmers cause the filament to run cooler, reducing color temperature and making the lamp appear more yellow. In many environments, such as homes and restaurants, occupants have come to expect and appreciate this ?warm? effect from dimmed lights?an effect that is not reproduced when fluorescent or HID lights are dimmed. However, some LED products are available that mimic that color-change effect.

In addition, lamp efficacy is reduced during incandescent dimming. But voltage is also reduced, a factor that increases the life of standard incandescent lamps though it may reduce life in halogen bulbs under certain conditions.

LEDs are inherently dimmable with the right dimmable drivers and controls, but they may not dim well on existing residential dimming circuits. For example, an LED driver connected directly to a line-voltage incandescent dimmer may not receive enough power to operate at lower dimming levels, or it may be damaged by spikes in current.

Some LED products can be used with conventional incandescent dimmers, but the dimmer and the LED driver electronics must be carefully matched. Manufacturers of LED light fixtures typically publish lists of specific dimmer products tested and approved for use with their fixtures. More-sophisticated LED dimmers are available that use low-voltage controls—either variable resistors or 0- to 10-volt direct-current (DC) control—connected separately to the electronic driver. Full alternating-current (AC) power is provided to the driver enabling the electronic controls to operate at all times, thus allowing LEDs to be uniformly dimmed (typically down to 5 percent or lower). However, they may require additional low-voltage wiring for retrofit applications.

For fluorescent lamps, there are four types of electronic dimming ballasts:

- *Low-voltage-controlled ballasts,* which are controlled by low-voltage analog signals, are among the most popular and are the least expensive type of fluorescent dimming ballast available. Most use a standardized 0- to 10-volt DC signal to control the light output, which makes them compatible with a wide range of sensors, controls, and BASs manufactured by other companies.
- *Power-line-controlled ballasts* work with phase-control dimmers, with signals running over existing power lines. These are very similar to standard incandescent dimmers and eliminate the need to run additional wiring. In fact, most or all of the phase-control dimmers designed for these fluorescent ballasts can be used to dim incandescent lamps, but not all incandescent lamp–quality phase-control dimmers can be used to dim power-line-controlled fluorescent ballasts. Most manufacturers of power-line-controlled dimming ballasts list compatible phase-control dimmers on the ballast specification sheet or associated documents.
- *Three-wire power-line-controlled ballasts* are controlled using a third power-line voltage wire connected to a special control switch. This type of ballast enables dimming to very low levels and does not need a separate low-voltage control wire. However, these ballasts would be hard to retrofit into an existing installation if the third voltage-level line was not already available.
- *Low-voltage digitally controlled ballasts* use either open control protocols—such as Digitally Addressable Lighting Interface (DALI), LonWorks, and BACnet—or proprietary protocols. One key advantage of digitally controlled ballasts is that each is assigned an identifier, or address, and can be controlled individually on a single network. This allows the lighting to be easily controlled from a central location without requiring a dedicated control wire between each ballast and the central control point. The control protocol can be delivered over a dedicated control network, over the Ethernet network already present in most office buildings, or wirelessly. Some protocols, such as DALI, are designed for use over a dedicated low-voltage network, but DALI-to-Ethernet converters are available so that DALI can be used in buildings with existing Ethernet networks without the need to run additional control wires. Some digitally controlled ballasts include a built-in DALI interface; others use a proprietary protocol. You can also add

conventional low-voltage-controlled dimming ballasts to digital lighting control systems by using special interfaces that connect to DALI systems and convert the DALI commands to standard 0- to 10-volt DC control signals. DALI controls are available to interface with most lamp types, including linear fluorescent lamps, CFLs, halogen lamps, HIDs, and LEDs; and can be used with wireless communications.

Personal dimming controls, which allow individuals to control light levels in their own work areas, are also becoming more widely available. Such dimming controls have been shown to cut energy use and increase worker satisfaction levels. (See our advice on personal dimming controls .)

HID dimming is more limited because it is accompanied by color shifting, reduced color-rendering index, increased flicker, adverse impact on lamp life, and inadvertent lamp shutdown during line-voltage variations. New electronic dimming ballasts for metal halide lamps promise to reduce the severity of some of these problems and make HID dimming more feasible. (See the guide on metal halide ballasts .)

HID and fluorescent lights may also be dimmed with panel-level controllers, commonly called power reducers, that lower circuit voltage upstream of the ballasts. This approach is best applied in overlit situations with large banks of lights that are switched simultaneously, such as in retail stores, supermarkets, and large open-plan offices. Dimming levels are usually limited to 25 percent or less. (For more information, see the power reducers topic.)

CFL dimming has been problematic but has become easier in recent years. New screw-based, step-dimmable, and continuously dimmable CFLs provide dimming capabilities down to the range of 10 to 20 percent, and these products work well with most existing incandescent dimmers. However, most CFLs don’t dim as smoothly as incandescent lamps, nor do they produce the same color shift (toward warmer tones) when dimmed. In addition, dimmable lamps cost two to three times more than standard CFLs. Pin-base CFLs have better dimming capabilities than screw-base lamps because product designers are not faced with the same tight space constraints for the dimming ballasts. New hardwired CFL dimming products are available that provide opportunities to dim lights to 5 percent of maximum output or even lower.

Building automation systems

A BAS (also known as an energy management system) performs the same function for lighting as a clock switch or dimmer, but with more sophistication and additional features. A typical BAS is designed to handle a variety of loads, including HVAC, but pure lighting-management systems are also available. BASs are now becoming available that combine on-off and dimming capabilities and can address individual ballasts for ultimate flexibility in setting up lighting control zones. A common BAS feature is a sweep mode that automatically cycles lights on or off, one section or floor at a time, signaling occupants that lights will soon be shut off. Occupants can then override the shutdown in their area by pressing a local switch or by sending a code to the BAS.

Open communications protocols, such as BACnet and LonWorks, also make it easier than it used to be for a BAS to communicate with dedicated lighting control systems, providing even more flexibility. For example, gateways are available that enable a BAS to interface with lighting control systems based on various communications protocols—including DALI, which enables a computer to communicate with individual lighting fixtures equipped with DALI-compatible ballasts.

Advanced lighting controls

A new term, advanced lighting controls, has recently come into use in the lighting industry. Although there is no formal definition, common elements of such systems include:

- A graphical user interface that provides a near-real-time view of lighting fixture status on a floorplan view of the facility
- The ability to modify schedules for each control zone
- The ability to regroup fixtures into a new zone structure
- A range of communication methods such as software, Internet, and smartphone
- The ability to track energy use, demand, and energy and cost savings
- The ability to modify settings from a computer or tablet for occupancy sensors, photosensors, and task tuning
- Demand-response capabilities

Wireless controls

The control capabilities described above may be implemented in the conventional manner, with all components linked by wires, or wirelessly. The leading approach to wireless building controls is the mesh network, in which control is split up among the different points in the network (which may be sensors, switches, or other addressable devices) so that you have multiple, redundant paths through the network. This makes it possible to communicate between two nodes that might temporarily have no direct link to each other because of some transient problem. And it makes it possible to cover large distances with limited transmitting power because the nodes can hand off data to each other. Mesh networks are also scalable to larger sizes.

You can establish a mesh network in many ways, but the leading approach comes from the ZigBee Alliance . Formed in 2002 as an independent nonprofit organization, ZigBee consists of hundreds of companies working together to develop an open global communication standard for low-power, wireless networks. ZigBee?s ultimate goal is to build wireless intelligence into a variety of devices. Although the group is growing rapidly and products are already on the market, the ZigBee approach still needs to prove itself in terms of reliability, scalability, and cost.

Many facility managers are skeptical of wireless systems because of concerns about security and the maintenance requirements associated with the batteries needed to power wireless sensors and switches. One approach that may help overcome this latter obstacle is battery-free technology. Various products eliminate the need for batteries by using energy from the environment (a process known as scavenging): The kinetic energy of pushing on a switch, the energy in ambient light, and the energy in a temperature difference as small as 7° Fahrenheit can all be converted to electrical energy to power the network devices.

HOW TO MAKE THE BEST CHOICE

this section

Select the type of control based on the usage of the space, and make sure that your selections conform to local code requirements. Consider occupancy sensors and timers if the space use is unpredictable. Typical examples might be warehouse aisles, hotel hallways, or any space that is unoccupied in an unpredictable fashion for more than 30 percent of the time. Consider timed switches if space use is predictable and not part of a

24-hour operation. Light-sensitive photoswitches and timed switches work well for exterior lighting used on facades, signs, and in parking areas. If daylight is available, consider dimming systems or multilevel systems with photosensors. In daylit spaces, vacancy sensors will be more effective than occupancy sensors because the lights will be turned on only if the occupant sees a need.

In choosing between step-dimming and continuous-dimming controls, it is helpful to know how occupants will use the space. Step-dimming controls are more practical in spaces that receive ample amounts of sunlight; where fixtures are mounted outside the field of view; and where there is little concern for distracting occupants, such as hallways and atriums. In contrast, continuous-dimming controls are best in areas where the fixtures (or lamps within the fixtures) are in the field of view and where there is a concern for distracting occupants, such as in classrooms and office spaces.

As more systems become available and prices come down, wireless solutions are becoming attractive for some applications. These include small buildings that have been underserved by technology in the past, office buildings where high churn rates lead to frequent reconfiguring of space, and old buildings that are being converted to modern office spaces. Wireless systems may pay off now in buildings eligible to participate in demand-response programs, where a high incentive is paid to shed load. As the systems become more widely used and costs come down, the market may expand to larger buildings and then to new construction.

In spaces where there is a need to vary light levels, either during the day or after hours, manual dimmers or multilevel switching will work well.

Select the right type of control for the expected load profile. For a space with predictable nine-to-five work hours and limited weekend use, select controls that will reduce peak demand. In that scenario, occupancy sensors and photosensors will help reduce demand in tenant spaces, and timed switches can be used in public areas. In a facility with extended hours of occupancy, occupancy sensors and manual dimming or multilevel switching can help to reduce wasted energy. In spaces that are always open, use photosensors in conjunction with dimming ballasts to cut daytime energy use, and use manual dimming and multilevel switching to account for lighting preferences and cut energy use at night. Manual controls work best in spaces such as gymnasiums or conference rooms that are lit for specific events. Manual dimming and multilevel switching are the best energy-saving options in those situations.

Evaluate cost-effectiveness. Users will achieve varying levels of energy savings based on the types of spaces in which they implement occupancy sensors. More precise estimates require random surveys of occupant patterns or the use of dataloggers to record current usage. For daylighting, actual scale models or full-scale mockups are sometimes used to estimate the savings potential. Once building operators estimate potential savings, they can use the incremental cost of the controls to calculate a simple payback period or perform a life-cycle cost analysis.

Test system compatibility. All the components in a lighting control system—including ballasts or drivers, controller, photosensors, occupancy sensors, and switches—must be compatible. Achieving this can be tricky when each item may come from a different manufacturer. A small-scale test will help sort out compatibility issues before a large installation is attempted.

Commission lighting control systems. Almost all lighting controls require commissioning so that they operate as intended. For occupancy sensors, time delays and sensitivity need to be adjusted for each workspace. When it comes to photosensors for daylighting systems, the sensitivity must be set for local room conditions. Commissioning may initially be done by a professional, but the best results come when occupants are involved in fine-tuning the system to meet their needs. Controls should also be periodically recommissioned.

WHAT’S ON THE HORIZON?

this section

The use of lighting controls is expected to grow as wireless technology makes retrofit options more cost-effective; evolving national and local codes demand more control capabilities for new facilities; and sustainable building guidelines, such as the US Green Building Council?s Leadership in Energy and Environmental Design (LEED), encourage their use. The US Energy Policy Act of 2005 also provides tax credits to encourage the use of lighting controls (see NEMA’s “Commercial Building Tax Deduction ”). And the ASHRAE 90.1 building energy-efficiency code is continually increasing the requirements for lighting controls. For example, the 2010 version triggers automatic shutoff requirements any time more than 10 percent of a facility?s lighting systems are modified. Previously, the threshold was 50 percent. Also, buildings of any size are now required to employ automatic shutoff controls?prior to 2010, that requirement was for buildings larger than 5,000 square feet.

Those controls must provide the capability for manual turn-on or to turn on automatically to 50 percent of full power. The new code also has more requirements for daylighting and requires many more types of space to use occupancy sensors than the previous version. Spurred by these trends, controls manufacturers are introducing sophisticated new systems that provide whole-building lighting control and monitoring capabilities.

The ability to control LED lighting to produce variable color temperature could also lead to the introduction of a growing number of products that might impact health, education, and productivity.

WHO ARE THE MANUFACTURERS?

this section

- Daintree Networks
- Delta Controls
- Digital Lumens
- Encelium
- Energy Resources Inc.
- Enlighted
- Enocean
- Exergy Controls
- Fulham Lighting Controls
- Limelight
- Leviton
- AcuityBrands
- Lutron
- nLight
- Philips OccuSwitch
- PLC-Multipoint
- Schneider Electric
- Synergy Lighting Controls

- WattStopper

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