PikeResearch
Cleantech Market Intelligence

Research Report

Intelligent Lighting Controls for Commercial Buildings

Sensors and Control Technology for Commercial Buildings and Common Areas of Multi-Family Residential Properties: Market Analysis and Forecasts

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Section 1

EXECUTIVE SUMMARY

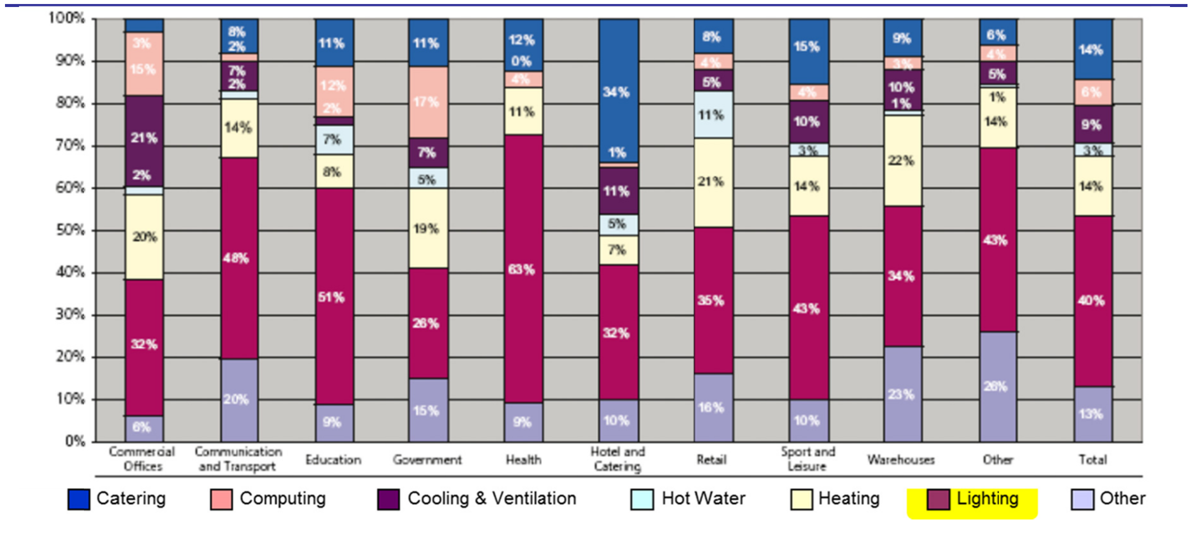
1.1 Global Energy Use for Lighting

According to the International Energy Agency (IEA), lighting accounts for about 17.5% of global electricity use. In fact, the annual energy used for lighting exceeds 2,200 terawatt hours (TWh), surpassing the amount generated by all the world's nuclear plants in a year. In dollar terms, the annual cost of energy for electric lighting is between $150 billion and $200 billion. Moreover, the executive director of the IEA has stated that electricity consumption for lighting could increase by 80% by 2030 unless concerted action is taken to implement new technologies.

Lawrence Berkeley National Laboratory (LBNL) estimated that the extensive implementation of even present-day technologies could result in a $70 billion to $95 billion global energy savings annually.

Figure 1.1 shows an estimate of the portion of energy consumed by lighting and other systems in various types of buildings.

Figure 1.1 Examples of Energy Usage by Building Type



(Source: BRE)

1.2 Lighting and Lighting Controls

From the perspective of energy reduction, the perfect control of lighting means that the least possible amount of light is supplied within the precise amount of space during only the time it is needed. Lighting specialists, however, would counter that the design of a lighting system must first take into account the needs of the people who function in the space. For example, in the foreword to his 2008 *Lighting Controls Handbook*, Executive Director of the Lighting Controls Association Craig DiLouie wrote, "A good lighting design includes a good controls design. The goal of an effective control system is to support the lighting application goals, which often translates to eliminating energy waste while providing a productive visual environment."

1.2.1 Why is Lighting Not More Controlled?

HVAC and lighting systems are the two largest energy loads in buildings. (In Figure 1.1, HVAC is represented by the combination of the purple 'Cooling & Ventilation' and the yellow 'Heating' categories.) It has become standard practice to control HVAC systems via programmable thermostats with set points and schedules that vary by time of day and day of the week, thereby adjusting them to the typical uses of the space. Lighting, however, has typically been controlled only by manual (i.e., not automated) ON/OFF switches. Part of the reason for this is that people are much more sensitive to temperature changes than light level changes. HVAC systems are also easier to control given that the majority of their major components occupy a single location. Lights, meanwhile, are spread throughout a building, making centralized control a more difficult prospect.

Lighting control not only suffers from lack of attention when compared to HVAC but also when compared to the focus on insulation and the building envelope. In fact, some regions show a near exclusive energy-efficiency focus on preventing air leakage and on the insulation factor of walls and roofs. Some in the industry believe this focus is almost to the exclusion of techniques and approaches that can make great contributions to the sustainability of buildings. For example, "advances" such as daylighting and thermal mass are being viewed as new concepts, though they have been around since ancient times. Chris Reardon from the Institute for Sustainable Futures at the University of Technology in Sydney has commented that, "Sustainable design is not a recent concept - it's a recently lost one."

From a controls perspective, lighting is some 20 years behind HVAC. To catch up will require the adoption of intelligent, centralized, building-wide lighting control systems.

1.2.2 Energy Savings Potential

The IEA estimates that the use of automatic controls to turn off lights when a space is not in use and dim the lights when daylight levels increase can reduce total lighting energy use by 20%. The IEA also states that buildings that are designed to take advantage of natural light can meet up to 75% of their lighting needs from the sun. According to the New Buildings Institute, advanced lighting controls can provide as much as 50% lighting energy savings in existing buildings and at least 35% savings in new construction. Despite this tremendous potential, the penetration of lighting control systems remains low in most parts of the world. This is unsurprising when you consider which lighting technologies are still in widespread use.

The potential savings from more efficient lighting (ignoring controls for the moment) is generally well known, but the installation of more efficient lighting technologies is proceeding slowly. In an article from March 2010, the National Electrical Manufacturers Association (NEMA) estimated that only 20% of existing commercial buildings in the United States have some type of upgraded lighting technology. In fact, NEMA suspects that the majority of the remainder use lighting systems that were installed prior to 1986.

1.2.3 Lighting Control Systems

Lighting is an extremely diverse market with hundreds of discrete applications. In addition, there can be major differences in the installation of lighting control systems depending on whether a project is new construction or a retrofit. If a retrofit, differing building ages, construction types, and business purposes will also have an impact on the appropriate lighting controls and their method of installation. In addition, availability of natural light will vary by geography and climate. Therefore, specifying the best lighting control solution for a particular customer is a complicated task. As much as in any other industry, “It depends.”

There are common elements of lighting control systems, however. These include sensors, ballasts and controllers.

1.2.3.1 The Progression of Lighting Control Technology

Time clocks were the first automated controls applied to lighting, allowing lights to be turned off when it could be assumed that no one would be using the space. Finer control of schedules followed. It became possible to define control schemes for operating schedules that might vary during the week. Manual overrides to turn lights on “after hours” also became common.

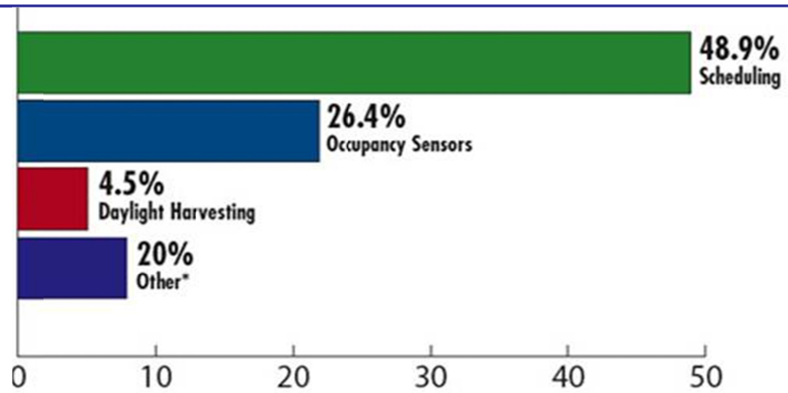
However, operating the lighting system according to a pre-defined schedule, and using time sweeps in the off hours to extinguish lights that might have been left on, really isn’t “intelligent.” For purposes of this report, Pike Research is defining intelligence as requiring some type of reaction to the actual conditions in the space, such as people occupying it and/or the natural light levels.

The first intelligent controls, then, were occupancy sensors. These react to the presence of a person in the space, or the lack of a person in the space, and signal the lights to respond to the situation. Occupancy sensors, when used in the right applications, can lead to significant energy savings. The U.S. Environmental Protection Agency (EPA) has stated that occupancy sensors may deliver energy savings as high as 90% in some cases.

However, when occupancy sensors are installed or calibrated improperly for the particular use of the space, they can be a great source of annoyance to the occupants. In fact, lighting controls are disabled relatively frequently, though the facility managers usually are not aware of it. Moreover, most lighting designers and building managers agree that if occupants are too aware of a control system, it is a failure.

A 2009 survey of building managers by NEMA asked the question, “How do you control lighting costs now?” Scheduling was the top response, and many respondents mentioned occupancy sensors. It is likely, however, that in many cases the occupancy sensors are in use only within specific rooms and not on a facility-wide basis.

Figure 1.2 Current Approaches to Controlling Lighting Costs (Survey Response)



(Source: NEMA)

The "Other" responses (marked by an asterisk) included "Regular reminders to our conservation-minded employees work for a while," and "We don't."

Occupancy sensors generally lead to the lighting being switched ON and OFF. Adjusting the light levels to somewhere between 100% and 0%, though, is called dimming. The use of controls and equipment for dimming can bring a variety of savings. Dimming can be used to reduce the light in a space that is overlit by artificial lighting, and can dim lights further when ample natural light is available. In many cases, dimming also extends the life of the lamps, providing an additional financial benefit. In addition, dimming makes it possible to better match the lighting levels to occupants' needs.

1.2.3.2 *Ballasts*

Ballasts are an important component of lighting control systems. Gas discharge lamps such as fluorescent and high-intensity discharge (HID) require ballasts to operate. The ballast provides the lamp with the required starting and operating electrical voltage and current. The ballast boosts the voltage at startup, and maintains a constant current during operation.

The primary types of lamp ballasts are electromagnetic, commonly referred to as magnetic, and electronic. Electromagnetic ballasts perform the essential functions required to start and operate a lamp. However, electronic ballasts are more efficient, have longer expected lives and virtually eliminate the flicker that electromagnetic ballasts sometimes produce. Any ballast can be a part of a lighting control system that is based on ON/OFF switching. In addition, any ballasts can be used within the lighting control approach known as "bi-level" or "stepped" switching, wherein some lamps are turned off while others are left on.

Dimming, however, requires special dimming electronic ballasts. These are generally more expensive than standard, non-dimming ballasts.

1.2.3.3 *Lighting Controllers*

In a simple lighting control system, sensors and ballasts may be connected to a single control panel. In a larger, more complex system, multiple control panels are usually connected to a master controller. The controllers maintain the logic that determines how the lighting should change based on various inputs from the sensors.

The controllers are also the primary user interface for the people who are managing the systems. A small control panel could be a box mounted on the wall in the space being controlled. Buttons or switches allow the user to enter settings, and a display – either indicator lights or a small LCD screen – provides feedback.

The master controller for a large lighting system usually takes the form of an application running on a computer or over the Internet. The user works with the system through a sophisticated graphical interface to configure settings and analyze performance data.

1.2.3.4 *Control Zones*

To provide light only where it is needed, a lighting control system must be able to address certain lights and not others. Control zones are composed of a luminaire or group of luminaires that are controlled in the same way at the same time by a controller. The smaller the control zones (i.e., the fewer lights per zone), the more precise the control of the lighting can be. A control system's complexity increases with the number of zones it controls.

1.2.4 New Construction and Retrofits

The challenges involved in installing a lighting control system in an existing building can be significant. Note that lighting system retrofits, which in some cases are almost as simple as swapping out old luminaires for new on a one-to-one basis, can be difficult to implement. Proof of that is the tremendous number of T12 fluorescent tubes still installed around the world, including in the most developed regions of North America and Western Europe.

Traditional lighting control systems required low voltage wiring to connect the sensors, the controllers, and the luminaires. The installation of a new wiring system in an existing building, especially an older one lacking dropped ceilings and sufficient open wall space for conduit, can lead to very high labor and material costs. Alternatives to low voltage wiring have been developed, including the transmission of control signals over power lines and, now, wirelessly, but these do not eliminate all retrofit challenges.

It is important to note that even if lighting controls are installed in every new construction project, this would only account for a couple percent of the total building stock each year. To really make progress toward achieving the energy savings potential of lighting controls, the retrofit market needs to receive major attention. Lighting control vendors are well aware of this and put a great deal of product and solution development focus on retrofit requirements.

1.3 Report Scope

The following is a summary of the scope of this report.

1.3.1 Building Industry Categories

This report covers the complete range of commercial buildings, plus the common areas of multi-family residential buildings.

Lighting controls for residences, both apartments in multi-unit residential buildings and detached single-family homes, will be covered by Pike Research reports on Home Energy Management. Lighting controls for outdoor stationary applications, such as street lights and parking lot lighting, will be covered in Pike Research's report on Outdoor Stationary Lighting.

1.3.1.1 Commercial Building Categories

This report uses Pike Research's standard segmentation of the commercial building sector. These eight categories are:

1. Office
2. Retail
3. Education
4. Healthcare
5. Hotels & Restaurants
6. Institutional/Assembly
7. Warehouse
8. Transport

1.3.1.1.1. *Entertainment and Theatrical Lighting*

Please note that this report does not include control of theatrical lighting. Although this represents a significant market for lighting control, with estimates that it is worth hundreds of millions of dollars a year worldwide, it does not fit within Pike Research's definition of "intelligent lighting control." The lighting is controlled not to save energy, but rather to create scenes and visual effects, and is carried out manually by production directors or through the use of software that has been pre-programmed to coordinate with the progress of a performance.

It is only the "theatrical" types of lighting controls that are excluded from this report, however. The general floor space for these buildings is included in the base data used in the forecast model. So, control of the more standard lighting for offices, hallways, stairwells, meeting rooms, etc. is reflected in the forecasts.

1.3.1.2 *Residential Building Categories*

1.3.1.2.1. *Multi-Unit Residential (Common Areas)*

The "Multi-Unit Residential" category includes all forms of attached housing – ranging from duplexes to row houses to high-rise apartment buildings.

In most multi-unit residential buildings, as exemplified by the typical apartment building, the residential units account for the majority of the floor area. However, a significant amount of the floor space can be considered common area including lobbies, hallways, staircases, storage areas, laundry rooms, mechanical rooms and offices. Larger and higher-end buildings may also include mail rooms, social rooms, health club facilities and retail services.

In this report, Pike Research forecasts the lighting control market potential only for these common areas and not the private residences.

1.3.1.2.2. *Single-Family Detached*

The "Single-Family Detached" category applies to residential buildings occupied by a single household that shares no walls with adjacent households. This category also includes mobile homes. As previously mentioned, this category is covered in other Pike Research reports.

1.3.2 Geography

For geographic forecasting, Pike Research uses a standardized list of 224 countries, territories and other geographic divisions. These are divided into the following five regions: Asia Pacific, Europe, Middle East/Africa, North America, and Latin America.

The baseline data for the forecasts in this report is Pike Research's Global Building Stock Database. The forecasts cover all five regions of the world.

1.3.3 Products

This report focuses on lighting control sensors, controllers, dimming ballasts, and lighting management systems.

Pike Research did NOT include the following types of controls, products, and other costs in these forecasts:

- Manual dimmers
- Theatrical lighting – programmed lighting used in spaces specifically for entertainment and similar effects
- Non-dimming ballasts
- Wiring, conduit, etc. used in the installation of lighting controls
- Labor of any type (installation, commissioning)

1.4 Market Drivers

A number of trends are impacting the adoption of lighting control systems around the world, with varying levels of influence based on the type of project. For instance, new construction projects will often have different drivers than major lighting retrofits, and minor lighting upgrades may be subject to still other factors. Energy codes, moreover, may apply differently or not at all, depending on the type of project.

For example, in a major lighting retrofit, the primary costs are for luminaires and ballasts, plus labor (especially if re-wiring is required). In that situation, lighting controls are only incremental on top of the project cost, and the additional labor cost associated with the controls is relatively small. If a facility already has upgraded lighting, but the owners want to consider additional options for energy savings or to expand control of their lighting system, the controls project becomes an effort and set of costs unto itself. Labor may then account for a greater part of the total cost and may make the payback less attractive.

1.4.1 Rising Energy Costs and Savings Opportunities

The direct monetary cost of electricity has trended higher and is anticipated to continue increasing. With lighting accounting for such a large percentage of electricity consumption within the commercial building sector, it has received increased scrutiny from those seeking areas for cost savings.

The cost of electricity, though, will be more or less of a motivator depending on geographic location. Even within the United States, electricity prices vary greatly – from highs of $0.21 per kilowatt-hour (kWh) in Connecticut to lows of $0.04/kWh in Oklahoma. The variance leads to great differences in ROI for projects, and a payback period of 2 years might be very attractive to a property owner while a payback period stretching out 7 years or more might not be.

Lighting control systems can provide facility managers with sufficient control over electricity consumption to gain other financial benefits. When actively monitored, lighting energy consumption can be cut at peak times to control peak demand charges. In addition, users may be able to take advantage of real-time pricing signals to reduce consumption during high-cost periods.

1.4.2 Building Codes and Energy Codes

In its Position Statement PS-05-10 – Standards for Energy Efficient Indoor Lighting, the Illuminating Engineering Society (IES) included the following statement:

> "The use of lighting controls, which has proved to be the biggest energy efficiency measure employed, should be the mainstay of energy policy."

Despite the views of parties with a stake in policy outcomes, lighting controls are generally not required under the national model energy codes. However, they do represent an important resource to building designers for improving the energy performance of new buildings.

In the United States, the two most commonly referenced energy code baselines are ASHRAE 90.1, which is maintained by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, and the International Energy Conservation Code (IECC), which is produced and published by the International Code Council (ICC). During the ICC's recent final action hearings for IECC-2012, a significant package of changes was approved. IECC-2012 is expected to provide a 30% improvement in building energy performance over IECC-2006. Additionally, the newest version of ASHRAE 90.1 will require approximately the same level of performance.

The move to more stringent energy codes can also be seen in other parts of the world. In Europe, the Energy Performance of Buildings Directive (EPBD) established a framework, and each member state develops its own energy efficiency targets. To comply with the EPBD, office buildings of more than 1,000 square meters (m^2) must track their energy performance and post an energy efficiency label. The classifications range from A for the most energy-efficient buildings down to F. In February 2009, a revised version of EPBD set more aggressive targets.

A major concern in the building community is the emphasis of energy codes on "lighting power densities," or the amount of watts used to power lights per square foot (ft^2) of building space. Lighting professionals believe there needs to be less emphasis on the availability of artificial light, which is what lighting power density really describes, and more focus on the actual consumption of energy for lighting. Therefore, they advocate for incentives for the use of lighting controls. Future codes are expected to take issues like this into account.

1.4.3 Integration with Building Energy Management

A building energy management system (BEMS) is similar to a building management system (BMS) yet focuses specifically on energy efficiency optimization and energy management. Some lighting control vendors report that more customers are requesting the integration of their lighting systems into their BEMS and BMS.

Lighting can become part of a single control system that maximizes the overall building efficiency and offers the greatest operational savings and shortest return on investment for lighting controls. The integration of lighting control with BEMS offers a number of opportunities for improved facility management and increased energy savings.

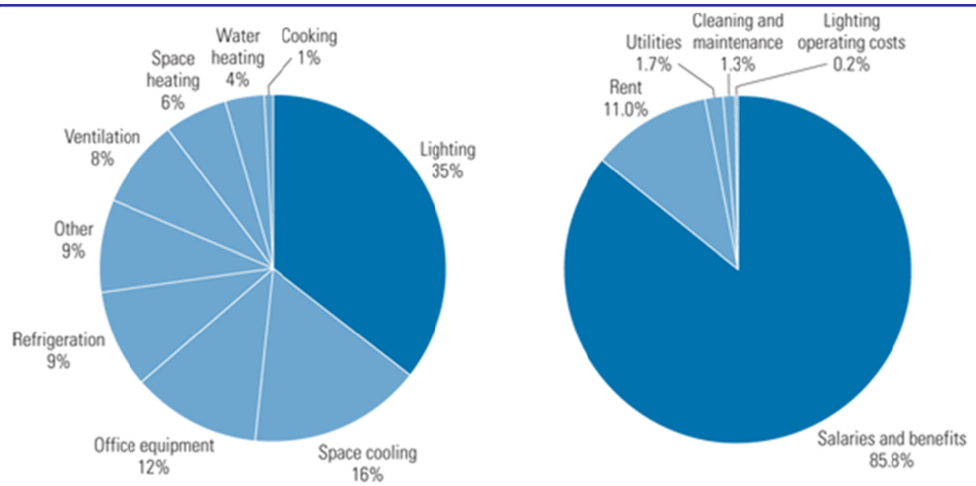
For example, lighting systems can become part of a demand response resource or an internal load shedding process. Toward this end, BEMS vendors are creating technology to not only enhance internal automation and energy management capabilities, but also to produce applications that will ultimately connect commercial buildings to the Smart Grid. In this model, the buildings will be able to "converse" with the utilities and grid operators in order to reduce their electricity consumption during times of peak demand on the grid. This kind of activity positions lighting as a managed service, not just an expense.

1.4.4 Relating to an Individual's Need for Lighting

Other trends that will impact demand for lighting controls relate to an increasing requirement to address the lighting needs of individuals. These trends include the desires to provide occupants with more natural light, to make lighting systems adaptable to people's varying visual needs, to supply task lighting, and to enable personal control of lighting.

Figure 1.3 illustrates much of the reasoning behind these trends. The fact is that while lighting is a major consumer of energy (35% in the pie on the left), by far the highest cost related to buildings is the compensation paid to the people who work in them (85.8% in the pie on the right). While energy cost savings are attractive, a slight improvement in productivity can far outweigh any other financial benefit.

Figure 1.3 Cost of Lighting Energy In Relation to Employee Costs



(Sources: E Source, 2005 Buildings Energy Book (left); Right Light Consortium (right))

The Building Owners and Managers Association (BOMA) reports that energy costs average out to about $2/ft^2$ in a typical commercial building in the United States. Worker salaries and benefits can add up to $130/ft^2$ or more.

1.4.5 Sustainability and Green Building Certification

Green building certification programs are becoming increasingly prominent around the world. There are thousands of buildings registered with the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) systems in North America and many hundreds more elsewhere in the world. The BREEAM system is very popular in Europe and is experiencing increased interest in Asia. Many countries also have their own specific green building certification systems, including CASBEE in Japan, Three Star in China, and NABERS in Australia.

In the United States, a number of state and local governments require LEED certification or the equivalent for their buildings. The U.S. General Services Administration (GSA), which is effectively the federal government's landlord, recently increased its requirement for all buildings owned by GSA to qualify for LEED Gold certification.

Most green building certification systems do not explicitly require lighting controls to improve energy performance, but designers know that such systems can contribute to better energy utilization profiles, which are sometimes worth many points or credits in a rating system. In addition, points are sometimes awarded for personal lighting control and for access to natural light. If natural light is part of the design, why not incorporate photosensors and the ability to reduce artificial light levels when natural light is available?

1.4.6 Product Costs and Advancing Technology

Dimming ballasts were previously limited to special applications in theatrical lighting or special circumstances in architectural lighting. Compared to standard ballasts, dimming ballasts were very expensive and were difficult to justify based on ROI. Over the last few years, however, ballast suppliers have introduced products that are not quite as feature-rich as the high-end offerings, but still provide good functionality for basic dimming applications. Moreover, the price premium for these compared to standard, non-dimming ballasts has come down sharply.

Digital technology is also finally catching on in the world of lighting controls. Control systems had been dominated by analog signaling among the devices and controllers. With digital controls, commands are managed by software rather than physical connections. Digital communication is greatly reducing the need for long runs of wire to connect each system component to a controller, and is enabling two-way communication of information (e.g., from the ballasts back to the controllers). The additional information is opening up possibilities for more energy-saving applications and processes that can improve operations. It is also making the potential ties to BEMS even more valuable.

1.5 Market Barriers

As much as the aforementioned trends may be prompting property owners to consider the use of lighting controls, a number of barriers also exist. In fact, like most companies seeking to sell their wares, lighting control vendors are trying to understand the motivations of the various influencers who could be involved in the decision making process for lighting control system purchases. Where they should be focusing as much, if not more, energy is on how to overcome these barriers – why people *are not buying* lighting control systems. It is not a lack of motivation holding back the purchase order; it is an overabundance of concerns. The lighting controls industry needs to address these concerns.

For the most part, barriers boil down to three basic issues:

- **High initial cost:** Can the upfront cost of the system be justified? How can it be paid for?
- **Basic lack of knowledge and risk of the unknown:** Many of the parties involved in the decision-making process, including building owners and managers, lack product knowledge. Moreover, many of the advanced lighting control systems are perceived to be new and untested, which screams "Risk!" to many decision makers. Even if these fears are unfounded, they exist and need to be addressed. The desire for proof of payback must also be addressed. This is in contrast to replacing T12 lamps with T8, which has verified savings associated with it. Also, lighting controls are not "mission critical," so may not be viewed as worth the risk.
- **Difficulties installing and properly commissioning the systems:** Expertise is weak throughout the distribution chain. The limited number of specialists, distributors and electrical contractors that really know the systems can only help so many lighting control systems reach the market. In addition, installers who are not lighting control specialists often view the systems as complex and fraught with potential problems. Furthermore lighting controls are usually ascribed a lower priority than systems such as fire safety, HVAC and security.

1.6 Lighting Control Strategies and Technologies

For clarity of discussion, Pike Research makes a distinction between lighting control strategies and lighting control technologies.

Strategies are conceptual descriptions of the triggers for a lighting change, along with a high-level indication of how the lighting system should react.

Technologies are the specific product types, communication protocols, and physical connections that are combined to execute the strategies. There will usually be a number of alternate technical approaches for executing the same strategy; the most appropriate depends on the specific facts about the building and how the occupants use it. If management has other interrelated goals, these factors could also influence the choice of technologies.

1.6.1 Lighting Control Strategies

There are as many as eight basic lighting control strategies:

- **Scheduling:** A change in lighting based on a schedule
- **Occupancy:** A change in lighting based on presence of or lack of people in a space
- **Daylight harvesting:** A change in lighting in response to the amount of available natural light
- **Task tuning or adaptive compensation:** Light levels that people need and prefer differ depending on the task at hand and time of day
- **Load shedding:** A change in lighting to reduce energy consumption during a particular time period, either in response to a signal from the utility (demand response) or for some internal purpose such as controlling a facility's peak demand
- **Personal controls:** An individual can change light levels according to personal preference
- **Lumen maintenance:** Adjusting the level of power delivered to light sources to compensate for the fact that light output declines over the life of the source
- **Interface with temperature control:** Through a connection with an HVAC system, adjust lighting to reduce the load on the building's cooling system

1.6.2 Lighting Control Technologies

Each component of a lighting control system and its design usually has technology options. The following are some examples:

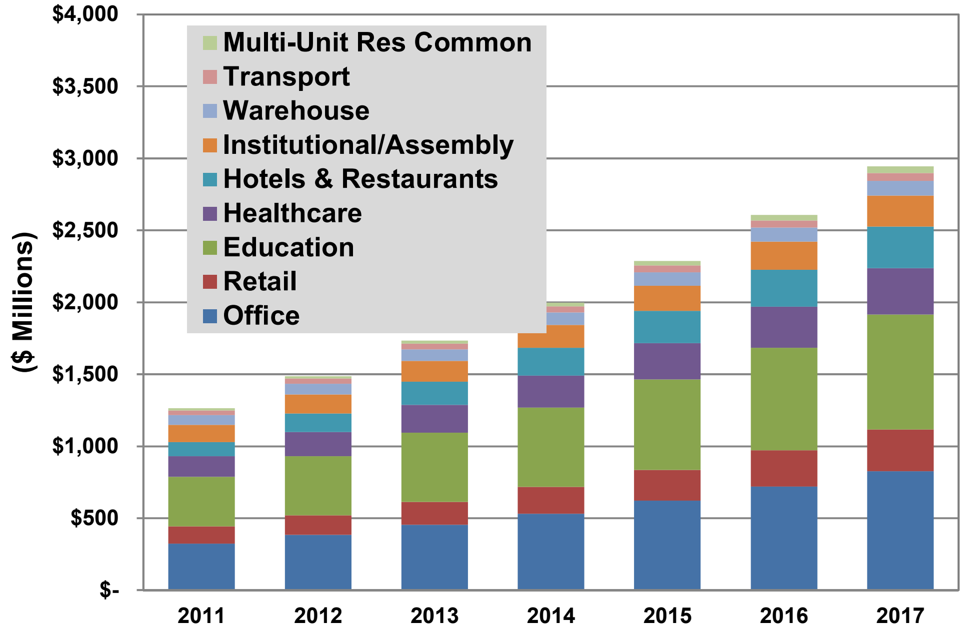
- **Occupancy sensors:** Passive infrared, ultrasonic, or dual-mode
- **Ballasts:** Standard electronic, step-dimming, continuous dimming
- **Control signals:** Analog, DALI digital, LonWorks digital
- **Control signal carrier:** Low-voltage wiring, power line communication, wireless communication
- **System scope:** Standalone control of one or more luminaires, building-wide networked control, campus-wide networked control

1.7 Lighting Controls Market Forecasts

Chart 1.1 illustrates Pike Research's Global Base Case forecast for lighting controls from 2011 through 2017. Each bar segment represents one of the nine building categories.

Pike Research forecasts the 2011 global market at $1.26 billion, growing to $2.95 billion by 2017. That is a 15% compound annual growth rate (CAGR).

Chart 1.1 Lighting Controls Revenue by Building Category, World Markets: 2011-2017



(Source: Pike Research)

Pike Research expects the Office and Education categories to comprise the largest shares of lighting control sales through the forecast period due to large existing building stocks in those categories, high rates of new construction around the world, and high anticipated control installation rates for both new construction and retrofits.

Sales of lighting controls in the Retail category will be the fastest growing, with a 20% CAGR despite low control installation rates. The global Retail category is by far the fastest growing building category in terms of floor area.

Section 2

MARKET ISSUES

2.1 Building Industry Segments

This report covers the complete range of commercial buildings, plus the common areas of multi-family residential buildings.

2.1.1 Commercial Building Categories

This report uses Pike Research's standard segmentation of the Commercial Building Sector. Note that while theatrical lighting applications are not included in this report, lighting applications that exist within buildings that contain theatrical lighting applications are included. The following sections present a brief overview of the commercial building categories.

2.1.1.1 Office

The Office category encompasses private office buildings as well as public administration buildings. It includes Class A, B, and C office building space. Globally, this is the largest of the commercial building categories in terms of total square meters.

Roughly one-half of office space is owner-occupied, about one-fourth is under commercial lease, and the remainder is under public sector or government ownership. Ownership is a critical issue, especially for commercial lease properties, in determining who assumes the costs for any energy efficiency upgrades and who benefits from the reduced energy usage. In non-owner-occupied commercial buildings, tenants often pay for energy consumed either as a direct billing from the utility provider or as an additional direct cost as part of the rent. The result of this arrangement is that there little or no incentive for the building owner to improve the energy efficiency of the building because there is no assurance that the cost can be recovered through higher rents.

Within office building space, conference rooms and corridors account for approximately 10% of the floor area, and storage areas, which are only accessed intermittently, account for as much as 15%.

2.1.1.2 Retail

The Retail category includes individual shops, shopping centers, malls, and other enclosed retail venues. It includes grocery stores and other non-restaurant food vendors, as well as basic service buildings such as hair salons, beauty parlors, and auto repair.

From a real estate perspective, the Retail category is similar in many aspects to the Office category: Both are characterized by a large amount of property that is owned and managed by one entity, but occupied by another. This has a significant impact on the willingness of, and even the legal ability for, one party or the other to invest in energy-efficient technologies, and creates a need to determine which party will benefit from the investments.

Big-box stores and wholesale stores already make up a significant portion of non-mall retail space and represent one of the fastest-growing segments of the construction market. Big-box stores typically occupy more than 50,000 ft^2 (about 4,700 m^2) and range up to 200,000 ft^2 (about 185,000 m^2). They are characterized by open structures with ceiling heights of 16 feet (5 meters) or more; in fact, ceiling heights of 20 to 30 feet are common.

2.1.1.3 *Education*

The Education category includes primary and secondary education facilities, as well as university and vocational buildings. The category covers both classroom and non-classroom (e.g., school libraries, school gymnasiums, cafeterias, etc.) spaces associated with an educational institution.

2.1.1.4 *Healthcare*

The Healthcare category includes public and private healthcare facilities, including outpatient and inpatient facilities.

2.1.1.5 *Hotels & Restaurants*

The Hotels & Restaurants category includes hospitality buildings whose primary purpose is to provide lodging, as well as restaurants and other food service buildings. It excludes grocery stores, which are covered within the Retail category.

2.1.1.6 *Institutional/Assembly*

The Institutional/Assembly category serves as a catchall for small, medium, and large institutional buildings, both public and private. Examples of such buildings include public libraries, museums, concert and assembly halls, convention centers, and religious buildings.

The most significant common feature among the buildings that make up the Institutional category is that they are almost all publicly owned or owner-occupied. This characteristic avoids the split-incentive problem that poses an obstacle to a great deal of energy efficiency improvements. With owner-occupied or publicly owned space, investments with longer-term paybacks are more likely to be undertaken.

As previously mentioned, this report does not cover entertainment and similar lighting controls. A majority of the buildings that would include these controls are in the Institutional/Assembly building category. Specific applications for theatrical type lighting controls that are not included in Pike Research's forecasts include theaters and other performance spaces, convention centers, sports arenas, art galleries, museums, mega-churches, and casinos.

2.1.1.7 *Warehouse*

The Warehouse category covers buildings whose primary purpose involves storage and logistics. Both refrigerated and non-refrigerated warehouses are included.

2.1.1.8 *Transport*

The Transport category includes all major transit-related buildings such as airports, train stations, and bus stations. The figures in the Pike Research database apply to the conditioned, occupied portions of transport space such as concourses and exclude unconditioned enclosures such as airplane hangars or garages.

2.1.2 Residential Building Categories

2.1.2.1 *Multi-Unit Residential*

The Multi-Unit Residential category includes all forms of attached housing ranging from duplexes to row houses to high-rise apartment buildings. In this report, Pike Research forecasts the lighting control market potential only for the common areas and not the private residence portions of these buildings.

On average, common areas in apartment buildings account for approximately 20% of the total floor area. However, not all multi-unit residential buildings are apartment buildings. Townhouses, two-flats and three-flats and similar small buildings are attached housing but have little, if any, common area. Since these small multi-unit buildings account for approximately 50% of the total number of housing units in the multi-unit residential category, the forecasting model in this report uses around 10% of the total category floor space as the estimate of the multi-unit residential common area. (Pike Research adjusted this percentage slightly for different countries and regions.)

2.1.2.2 *Single-Family Detached*

The Single-Family Detached category applies to residential buildings occupied by a single household that shares no walls with adjacent households. This category also includes mobile homes. This Pike Research report does not forecast lighting controls for single-family detached residences.

2.2 General Drivers and Trends Impacting the Use of Lighting Controls

A number of market and technical factors will have an increasingly positive impact on the demand for lighting controls; however, these trends will vary in terms of level of influence based on the type of project. For instance, new construction projects are likely to have different drivers than major lighting retrofits, and minor lighting upgrades may be subject to still other factors. In addition, energy codes may apply differently, or not at all, to various types of projects.

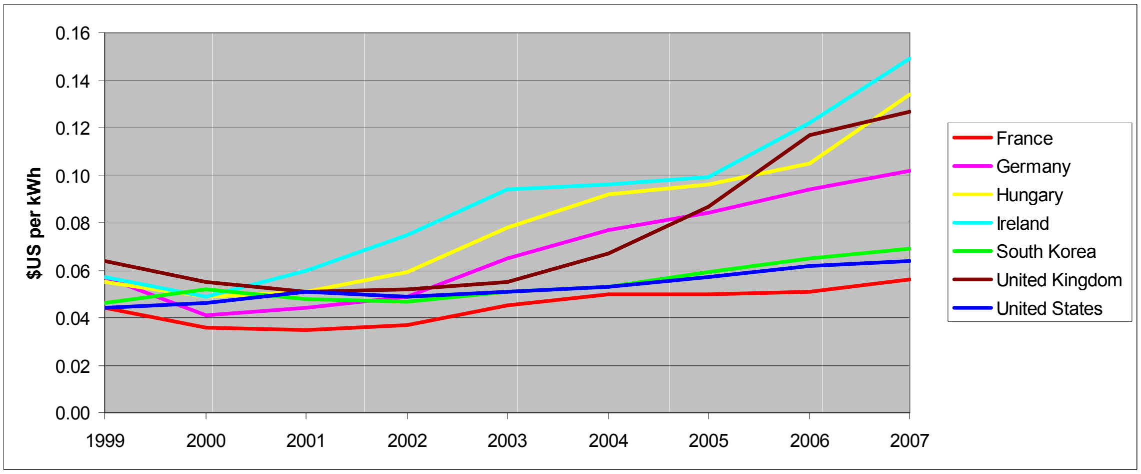
Section 0 discusses barriers – trends that are having a negative impact – to the growth of the lighting controls market.

2.2.1 Rising Energy Costs

2.2.1.1 Electricity Costs

Lighting constitutes about 25% of the commercial sector's energy use. This is the largest single user of energy and by far the largest single user of electricity. Electricity costs around the world have generally been on the rise over the last few decades.

Figure 2.1 Electricity Prices by Country, 1999-2007



(Sources: Energy Information Administration, International Energy Agency)

The direct monetary cost of electricity has trended upward and is expected to continue to rise. A number of factors in addition to cost have been prompting the drive to reduce electricity consumption. For example, there has long been recognition of the pollution created by most forms of electricity generation. Historically, this has been handled by increasingly high-tech power plant retrofits to capture the pollutants before they enter the atmosphere, and the costs of these measures have been incorporated into the price of the electricity. However, the costs to the larger environment of the pollutants that escaped were borne not only by the customers of the generating facility; these pollutants would drift downwind and cause damage and health problems farther away.

More recently, the costs due to a major byproduct of electricity generation, carbon dioxide, have become of increasing concern. Although the specifics of proposed solutions do not fall under the purview of this report, these solutions – whether cap and trade programs or carbon taxes – could potentially increase the price of electricity. It is, of course, possible that policy makers will attempt to shield segments of the economy from such impacts.

2.2.2 Drive to Reduce Costs

Business has become increasingly competitive due to the expanding size of markets, and globalization is the ultimate expression of this trend. Increased competition is often accompanied by pressure to keep prices low, so organizations have had to focus on cost reduction to maintain or improve profit margins. Energy costs have more recently become a focus of these cost-reduction efforts.

The first target for energy cost reduction in commercial buildings has typically been the HVAC system. High-efficiency equipment and sophisticated control systems have become the norm in new construction, and the retrofit business in this field is robust. In contrast, lighting has been much less of a focus for savings. More recently, however, and especially over the last decade, upgrades to lighting systems that use more efficient lighting technologies have become much more common. Fluorescent lighting has been the primary product solution. In addition, solid-state lighting (SSL) based on light-emitting diodes (LEDs) has already had major impacts in some specific applications, and its use will continue to expand.

Beyond lighting technologies, lighting controls have a significant potential to reduce electricity use. Table 2.1 shows potential savings from various lighting control technologies. The technologies and strategies themselves will be discussed in further detail throughout this report.

Table 2.1 Typical Energy Savings with the Use of Advanced Lighting Controls

Space Type	Controls Type	Lighting Energy Savings Demonstrated in Research or Estimated as Potential
Private Office	Occupancy sensor	38%
	Multilevel switching	22%
	Manual dimming	6% to 9%
	Daylight harvesting (sidelighting)	50% (manual blinds) to 70% (optimally used manual blinds or automatic shading system)
Open Office	Occupancy sensors	35%
	Multilevel switching	16%
	Daylight harvesting (sidelighting)	40%
	Personal dimming control	11%
Classroom	Occupancy sensor	55%
	Multilevel switching	8%
	Daylight harvesting (sidelighting)	50%

(Source: Lighting Controls Association)

Reducing lighting levels also has the effect of decreasing the thermal load on a building's cooling system when the air conditioning is running. In cooling-dominated climates, where lighting can account for as much as 40% of the building's cooling load, this effect alone could add significantly to the potential energy savings derived from lighting controls.

2.2.3 Building Codes and Energy Codes

Building codes are often based on a standard developed and maintained by an international or national standards body. Governments may adopt these standards "as is" or modify them to address local needs (or political realities). Many of these standards are updated on a periodic basis to incorporate new information and newly proven technologies. It is usually up to each government to explicitly adopt new versions of the standards that underlie its codes.

For the most part, energy codes have only been incorporated into building codes in the last couple of decades. Some jurisdictions, such as California, have been leaders in this area, while the rest of North America follows at varying rates. In Europe, the European Union has developed guidelines for the energy consumption of buildings. However, only a few countries in the region, including the United Kingdom and Germany, have energy codes that can be considered aggressive. Across the rest of the world, mandatory energy codes are the exception rather than the rule.

In general, commercial building codes are "prescriptive." In the case of lighting controls, this means that some mandatory requirements for using controls are established. There are also limits placed on the allowable amount of lighting load, usually described by lighting power density (LPD) in watts per square foot. Table 2.2 provides examples of LPD limits for types of spaces discussed in this report. Note how high the retail sales area limit is and how low the limit is for the corridors.

Table 2.2 Examples of Lighting Power Density Requirements

Space Description	Typically Associated Building	Model LPD
Classroom/Lecture/Training	(typical all buildings)	1.43
Dining Area	(typical all buildings)	0.86
Restrooms	(typical all buildings)	0.86
Conference	(typical all buildings)	1.25
Corridor/Transition	(typical all buildings)	0.46
Lobby	(typical all buildings)	1.32
Office - open plan	(typical all buildings)	1.06
Office - enclosed	(typical all buildings)	1.13
Living quarters	Dormitory	1.09
Living quarters	Hotel	1.11
Patient Room	Hospital/Healthcare	0.68
Medium/Bulky Material	Warehouse	0.93
Department Store Sales Area	Retail	2.61
Playing Area	Gymnasium	1.35

(Source: ASHRAE 90.1-2004)

The key trends for energy codes around the world are:

- They are becoming more stringent
- More countries, states and municipalities are adopting these more stringent codes, and the adoption of even stricter "stretch codes" is on the rise
- Compliance and enforcement are improving

2.2.3.1 Types of Lighting Control Code Requirements

Various types of requirements for lighting controls appear in energy codes. Any particular energy code may include any, all, or none of these requirements.

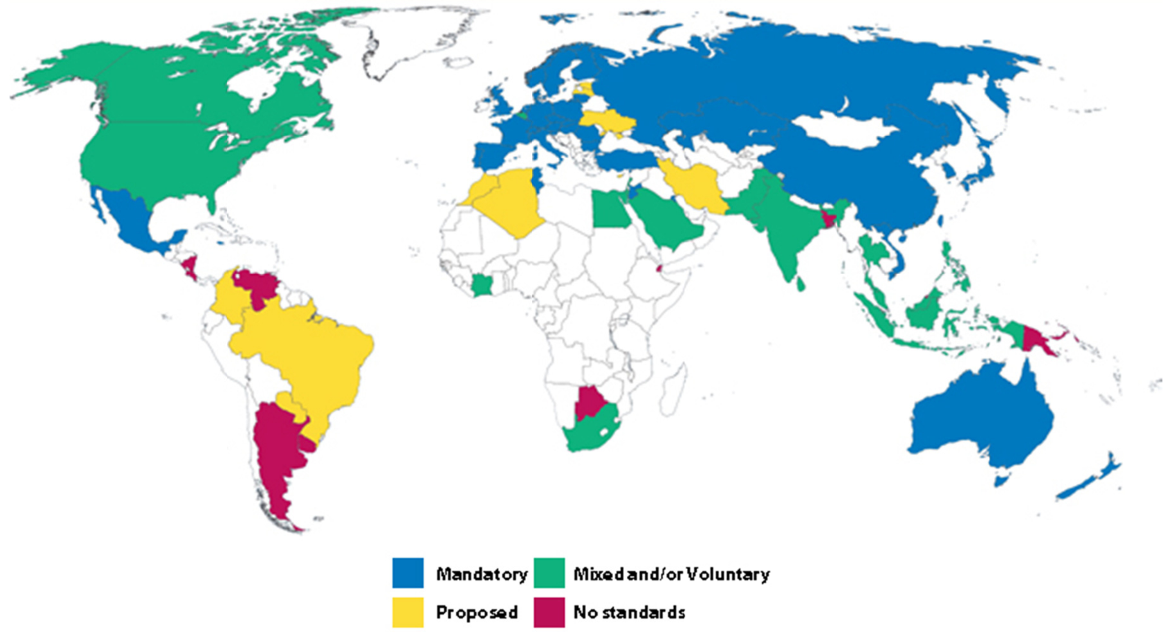
- Automatic lighting shutoff:
  - Methods: Occupancy sensors, time-of-day scheduling, occupant intervention on an unscheduled basis, signal from another control or alarm system.
  - Examples:
    - Occupancy sensors must turn lights off within 30 minutes of occupant leaving the space.

  - Must have independent scheduling program that turns off lights in areas of 25,000 ft^2 maximum size and not more than one floor.

- Space Controls:
  - For building interior spaces enclosed by ceiling-height partitions.
  - Methods: Manual control, remote manual control, occupancy sensors.
  - Examples:
    - If the space is a classroom, conference room or employee break room, lights must be activated by occupancy sensor (with maximum 30-minute time delay).
    - If the space is a “sleeping unit” in a hotel, motel, boarding house or similar building, a master switch must be provided at the entry door that controls all permanently installed fixtures and switched receptacles except the bathroom(s).
    - A time-scheduled automatic shutoff cannot be overridden for more than two hours.
- Daylight Zone Control:
  - Building interior spaces are daylight zones if they are under skylights or adjacent to windows. Codes define the size of daylight zones based on the sizes of windows and skylights and the ceiling height.
  - Methods: Manual or automatic switch or dimmer; if automatic, photosensors can be used to measure light level and initiate lighting control based on the daylight contribution.
- Display/Accent Lighting Control:
  - Display or accent lighting must be controlled independently of the general lighting.
  - Energy Codes around the World.

Figure 2.2 is compiled by the Online Code Environment & Advocacy Network (OCEAN), a program of the Building Codes Advisory Project (BCAP). The map displays the adoption status of non-residential energy codes. If all known codes and standards are mandatory, the country is shaded blue. If any existing code is voluntary, the country is shaded green. If a country has shown progress toward code development, it is shaded yellow. If OCEAN's research indicated that no codes or code development exists, the country is shaded red.

Figure 2.2 International Non-Residential Code Status



(Source: OCEAN)

2.2.3.2 Future Energy Codes

As mentioned above, energy codes normally state a maximum allowable LPD for a particular type of space. The problem with this approach is that as codes become more stringent (i.e., decreasing LPD allowances), options for lighting design become limited. In addition, while such LPD allowances ensure that a facility is built or renovated to a certain efficiency standard, they do not necessarily constrain the amount of lighting energy used by the building. The codes do not account for how much time the building or the spaces within it are in use.

Code authorities are considering different approaches to defining energy codes. One approach favored by many is performance-based, wherein the building would be designed to consume at most a specified maximum amount of energy – in contrast to the current prescriptive approach. The primary metric would be annual kWh/ft^2 rather than just W/ft^2. As Eric Richman, senior research engineer for the Pacific Northwest National Laboratory, has commented, "Limiting energy use is, after all, the true goal of energy codes." And a performance-based code is more directly linked to the expected energy use of the building.

This approach may also allow for tradeoffs between building systems as a means to higher energy savings. If the required energy consumption can be achieved through the use of lighting controls, for example, LPD limits would not need to be as strict.

The IES' *Lighting Handbook* (informally known as the "Bible of Lighting") reflects the evolving approach to lighting design. Traditionally, the *Lighting Handbook* was written from a purely engineering point of view, requiring a specific number of foot candles of illumination for an application – effectively treating lighting as a commodity. The 10th Edition of the *Lighting Handbook*, due out in early 2011, takes more of a designer's approach and asks such questions as, "What is going on in the space?" and "Who is using the lighting?" and "What kind of daylighting is available?" Instead of providing instructions on what to do, it has shifted toward providing guidance on how to perform, with a focus on the objective to be achieved. It is not clear, however, how soon this type of approach will work its way into energy codes.

2.2.4 Green Building Certifications

Another factor driving investment in lighting controls is the increased interest in green building certifications. There is strong evidence that green buildings increase employee satisfaction and productivity, allowing building developers and owners to command premium prices and lease rates for certified green buildings. In addition, many companies want to associate themselves with certified property to improve their environmental image. Moreover, though controversy exists as to whether green certification automatically equates to lower energy costs, it is fairly clear that the highest levels of certification in most rating systems should indicate that the buildings are more energy efficient.

Energy consumption, whether designed or actual, is a key component of virtually every rating system. Moreover, lighting has a significant impact on the total energy profile of buildings. In the U.S. Green Building Council's (USGBC) LEED program, the LEED V3 for New Construction rating system includes a number of points where lighting control can have a significant impact.

Table 2.3 Influence of Lighting Controls on LEED V3 for New Construction

Credit No.	Credit Title	Points Available	Comments
SS C8	Light Pollution Reduction	1	Limited override of night shutoff of interior lights
EA P1	Fundamental Commissioning	prerequisite	Lighting and daylighting controls must be commissioned, so this is an important consideration in design and planning
EA P2	Minimum Energy Performance	prerequisite	Lighting controls contribute to improved energy performance
EA C1	Optimize Energy Performance	19	Lighting controls contribute to improved energy performance beyond the required minimum.
EA C3	Enhanced Commissioning	2	Lighting and daylighting controls must be commissioned, so this is an important consideration in design and planning
EA C5	Measurement & Verification	3	An advanced lighting control system will provide the data required to determine post-construction performance
IEQ C6.1	Controllability of Systems	1	Personal control of lighting
IEQ C8.1 IEQ C8.2	Daylight Views	1 1	Photo controls on the lighting system can help projects that achieve these credits also control the overall building energy performance
Total points impacted		**28 (out of 100 total points)**	

(Sources: LEED Documentation; Pike Research)

2.2.5 Financial Incentives for Energy Efficiency

To encourage investment in energy efficiency, governments, utilities and other organizations are providing direct financial incentives to companies and lighting control systems are normally eligible under such incentives. Some programs that are specific to certain countries will be covered in later sections of this report; however, the following types of incentives, with some examples, are more widely available.

- **Government Grants:** In the United States, the 2009 American Recovery and Reinvestment Act (ARRA) included many billions of dollars for building retrofit and other energy efficiency projects.
- **Tax Incentives:** Tax credits and/or tax deductions are available in countries around the world including the United States, Japan, and Thailand.
- **Utility and other Rebate Programs:**
  - These energy efficiency rebates may either be prescriptive, where a set financial amount is offered for installation of a specific energy-saving product, or custom, where the overall energy savings for a project is estimated and a rebate is issued based on that savings.
  - In the United States, as much as 80% of this rebate money is being paid out for lighting and lighting control upgrades. In some cases, the rebates are generous enough that occupancy sensors are almost free to the end user.
  - Some utilities are looking at mandating the use of occupancy sensors as a condition of awarding lighting rebates.

In addition, financial instruments are increasingly being made available to facilitate investments in energy efficiency. These include government-backed loans and revolving loan funds, energy efficient mortgages, on-bill financing, and property assessed clean energy (PACE) bonds.

2.2.6 Integration with Building Energy Management Systems

A building energy management system (BEMS) is similar to a building management system (BMS), yet is specifically focused on energy efficiency optimization and energy management. The size of a BEMS can vary widely, ranging from a relatively small system for a moderate-size building to one that could include thousands of controls, multiple networks, multiple applications, and internal and external support services for very large commercial and institutional campuses.

Historically, lighting systems have been only minimally controlled beyond on/off switches, if at all. In most cases, the only type of centralized control would have been a connection to a timing system to sweep lights out after normal building operations have ended for the day. With the increased use of networked lighting control systems, the opportunity to tie into the buildings' larger BEMS has become very attractive. Becoming part of a single control system that maximizes overall building efficiency can offer the greatest operational savings and shortest return on the investment for lighting controls.

Some lighting control vendors report that more customers are requesting the integration of lighting systems with BEMS and BMS. While it is more likely that large lighting systems will be integrated with these broader systems, some large companies with a number of smaller facilities are also doing this. The ability to centrally monitor and control major energy uses across all locations is worth the expense, though the cost of this type of interface could equal the cost of the rest of the control system for a small facility.

The integration of lighting control with BEMS offers a number of opportunities for improved facility management and increased energy savings:

- Lighting systems can become part of a demand response resource or internal load shedding process.
- Lighting systems can send information to HVAC controllers to indicate the amount of energy being used for lighting, thereby signifying the level of cooling that will be required. In addition, when occupancy sensors are involved, the lighting system can provide information on which parts of the building are not in use, helping to mitigate some level of HVAC operation cost.
- In addition to the cost of electricity that is paid per kWh, most commercial customers face a demand charge. This is a cost associated with the customer's peak demand for electricity at a point in time and is measured in kilowatts (kW). An annual demand charge could be based on just the 20 minutes with the highest demand during the year. Some utilities are even considering additional penalties for the use of too much electricity during peak periods.
- If a lighting control system is integrated with a BEMS, the BEMS can monitor the electricity consumption in relation to the facility's peak and send instructions to dim or turn off certain lights as part of an internal load shedding process.

If the facility has a broader BMS, even more linkages are possible:

- Lighting systems can take input from card access systems to, for example, turn on the lights for only those areas that identified people are authorized to use.
- Information on burned out lamps or problem ballasts can be transmitted to an automated maintenance system for job scheduling and work order creation, bringing savings to the maintenance process, too.

2.2.7 Demand Response and Dynamic Pricing

In most developed markets, peak demand for electricity increases at about the same rate as growth in GDP. Peak demand is the most expensive to satisfy because it requires the use of the least efficient generators, and eventually new generating capacity must be built. One method that utilities and regulators are using to limit the growth of peak demand is Demand Response programs.

In the past, the BMS would commonly manage and automate a commercial building, detached from any type of grid network. Moving forward, BEMS vendors are creating technology to not only enhance internal automation and energy management capabilities, but also produce applications that will ultimately connect the commercial building to the Smart Grid. In this model, the building will be able to "converse" with the utilities and grid operators to reduce its electricity consumption during times of peak demand on the grid.

A BEMS can store information about the internal costs of reducing lighting levels in various spaces. For example, management may be able to assign a value to the anticipated loss of productivity in an area if lighting is reduced below a certain level. The BEMS could then evaluate the tradeoff between the benefits from a reduced lighting level and the costs before sending the load-shedding signal to the lighting control system.

Furthermore, this technology will allow building managers to take advantage of dynamic pricing structures so that the building, in theory, uses energy only when it is cheapest. It would also be possible to sell energy back to the grid to earn additional revenue while helping to maintain grid stability.

Opportunities such as demand response have led to a change in perspective: from energy as an unavoidable cost of doing business to an asset to be managed.

2.2.8 Increased Use of Natural Light

The highest building-related cost is not energy, it is the people that work in the building. A slight improvement in their productivity, whether from getting more work done while on the job or even reduced absenteeism, can have a significant impact on an organization's success.

One of the factors shown to improve employee satisfaction and productivity is access to natural light. Moreover, natural light that penetrates into buildings can reduce the demand for electric lighting, if the systems are in place to accomplish what is known as "daylight harvesting." This should be a major driver for the installation of lighting controls.

Access to daylight is being included in green building certification systems. LEED's Indoor Environmental Quality section, for example, awards points for providing "the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building." BREEAM has a Health & Wellbeing Credit if a sufficient percentage of the floor area is adequately daylit. Daylight can be captured through sidelighting, such as through standard vertical windows, or toplighting, such as through skylights.

However, there are complicating factors involved with daylighting. To ensure energy savings from reduced artificial light, the heat gain and loss through the windows must be controlled. It is also important to avoid excessive glare, which is a significant drawback of sidelighting. Otherwise, the building occupants might draw the blinds, effectively negating any benefit from this element of lighting control.

2.2.9 Visual Needs

Ultimately, light is provided so that people can accomplish their desired activities. An efficient space that does not meet a need is essentially worthless. Therefore, it is important to ensure the availability of the necessary amount of light. Energy efficiency cannot be the primary goal of a lighting design.

The *Lighting Controls Handbook* describes how different types of business benefits related to visual needs can be the drivers of lighting control projects.

- Adapt the lighting for multiple uses of a space, such as a conference room or gymnasium
- Adapt the lighting to evolving space needs resulting from employee churn and office strategies such as hoteling and hot-desking
- Mood-setting for restaurants and similar applications
- Increasing worker satisfaction by providing personal control of their lighting systems in office and other environments
- Enhanced aesthetics and image, greater space marketability, and pollution prevention

Over the last decade, there has been a general decline in the overall lighting requirements for many applications. For example, hallway lighting levels have declined and hospitals are increasingly adjusting light levels according to the time of day, with dimmer lighting during nighttime hours. These trends have been the result not only of energy codes that reduce the allowable power densities for ambient lighting, but also, in many cases, of user preferences. Too much light can be a negative if it is not desired by the occupants of the space.

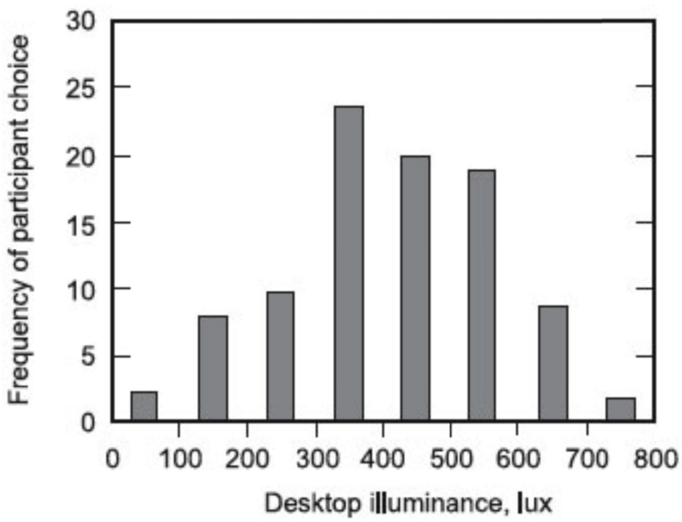
2.2.10 Task Lighting and Personal Control

The current design philosophy is to put light only where it is needed. While task lighting has always been prevalent in manufacturing settings and workshops, there is an increased used of task lighting in offices and other commercial environments.

People's preferences for lighting conditions can vary significantly. Age, for example, is a factor in how much light someone may prefer. In addition, various tasks often require different types of lighting and different light levels even though they will be executed in the same place. For example, working on a computer with a vertical display may require different lighting than reading from or writing on paper that is lying flat on a desk surface.

In an office lighting study conducted by the National Research Council (NRC) Canada, participants expressed a range of preferences for light levels.

Figure 2.3 Occupant Preferences for Light Levels



(Source: National Research Council Canada)

The ability to control one's workspace lighting has a direct impact on employee satisfaction and productivity. A 1997 American Society of Interior Designers (ASID) study determined that 68% of employees complained about the light in their offices. A 1991 Steelcase survey conducted by Louis Harris & Associates discovered that 44% of office workers and 64% of computer users considered eyestrain (due to glare) to be the leading hazard to their health in the office. While these studies may be somewhat dated, millions of people are likely still working in conditions that are similar to those in place when the studies were conducted.

One way to address these situations is the availability of task lighting. Task lighting in an office can be furniture mounted, such as a luminaire mounted below a storage cabinet that provides illumination to areas that overhead lighting may not reach; a desk or table lamp; or a floor-standing lamp or torchiere.

A more advanced solution to these old problems is known as "personal control." Beyond the simple provision of task lighting, systems with personal control capabilities enable workers to interact with the larger lighting system through a PC interface or other remote device to control the local light level. In addition to task tuning, adjustments can be made for different daylight levels. Systems like this require good dimming control of the ambient artificial lighting.

Studies find that after lighting control is offered, occupants report significant improvements in mood, satisfaction with their productivity, and visual comfort. They also feel more positive about their workspace, the lighting it offers, and generally more satisfied with the work environment. As a bonus, this use of dimming results in lighting energy savings of 10% or more.

2.2.11 Create Architectural-Grade Lighting in More Environments

In addition to enabling energy savings, lighting control systems can create more usable spaces through their capabilities to produce architectural grade lighting conditions. An example would be classrooms where the overhead lights can be dimmed in a controlled manner while other lights focus on the board at the front of the room. Similar effects can be used in meeting rooms to darken most of the space for better viewing of an image projected onto a screen.

2.2.12 Lower Prices for Dimmable Ballasts

In the past, the dimming of lights had been oriented toward special situations. For example, theatrical lighting uses a lot of dimming, and it has also been widely used to create ambiance, such as in hotel lobbies and restaurants. These lighting systems and their specialized ballasts were designed to dim the lights in very fine increments – from 100% (full brightness) down to 1%. Dimming was not often viewed as an approach for saving energy.

As interest in lighting control as a means of energy reduction began to grow, the solution most often implemented in more mundane commercial settings was "bi-level switching." This was most commonly implemented through the use of three-lamp fixtures with the ability to turn off the center one independently of the outer two. Although a second ballast is required for each fixture, the ballasts themselves could be very inexpensive, basic models. In fact, price points for such ballasts can be well under $20.

Daylight harvesting requires finer control over electric lighting levels, but dimming ballasts that permit such control were expensive, priced as much as $100 higher than standard ballasts; consequently, the low return on investment made them difficult to justify. Part of the expense of dimming ballasts was the ability to dim down to as low as 1%. Recently, however, Philips Advance introduced the EssentiaLine family of ballasts, which only dim down to 20%. The company is able to sell these ballasts at much lower prices – on the order of $50 per unit or less. Compared to the two ballast bi-level approach, this is only slightly more expensive for greatly increased functionality.

2.3 Barriers and Challenges to the Use of Lighting Controls

The following sections discuss many barriers and challenges to the use of lighting controls, but they mainly boil down to three basic issues:

- High initial cost
- Basic lack of knowledge and risk of the unknown

- Difficulties installing and properly commissioning the systems

2.3.1 Financial Barriers

Implementations of lighting control systems face the same types of financial barriers as other types of energy efficiency investments. Among the most significant of these are:

- **Initial Cost**: Despite the longer-term savings, the need for an initial outlay of money often poses a serious hurdle.
- **Capital not Available or Competition for Capital**: All entities have some limits on the availability of capital, and the recent economic conditions have made it difficult to procure borrowed funds. Energy efficiency investments usually compete for capital with other potential investments; consequently, even when internal or borrowed funds are available, other projects may be deemed higher priority. (These may be in the company's primary business and therefore viewed as a better use of funds.) Also, capital is sometimes used to fix things that are broken, and lighting is rarely broken.
- **Strict ROI Thresholds**: Many organizations have very strict ROI or payback requirements. Just because a project has a positive net present value does not mean it will be funded.
- **The Split-Incentive Problem in Leased Buildings**: Most leases are constructed so that the tenants pay the utility costs, so there is no incentive for the owner to invest in efficiency improvements in space that is already occupied. Tenants are often prohibited from making such improvements, or are not sure they will be leasing the space for a long enough time to recoup the investment.
- **Materiality**: A building's energy expenses may be only a tiny fraction of the total cost of running a business.
- **Analysis Paralysis**: Is now the right time to invest in a lighting control system? Will the systems get cheaper? Will they get better?

2.3.2 Need to Justify Savings

Whether or not there are non-financial benefits associated with lighting controls systems, the decision to implement such a system often comes down to rate of return. There is a perception that lighting controls cost more than they deliver. Consequently, designers and their vendors need to be able to show what the financial benefits will be. The decision process – particularly for large companies – may be totally driven by a project's internal rate of return (IRR).

In a new construction project, the estimate of the financial return will be based on a complex energy model. Over time, a model's ability to predict energy consumption by a lighting system has improved as assumptions about a building's projected operating hours are easily incorporated. Lighting control systems, however, add a number of new variables: How much of the time will each space be occupied? What kinds of natural light levels can be expected in the different daylighting zones on various sides of the building? What effect will personal controls have on energy consumption? Fortunately, lighting designers and engineers, and the suppliers that provide the modeling software, are quickly learning how to incorporate these factors.

Retrofit projects face similar challenges; however, the key in a retrofit is to determine the baseline from which the savings will be computed. First, the number of kW to be controlled must be determined through the use of sub-meters (though these are uncommon) or some other approach to isolate the lighting in the area to be impacted. Then, data loggers can be put in place for a month or more to track the presence of the occupants and, if appropriate, light levels coming in from the outside. Data loggers and their associated software can track and analyze, for example, how long the lights were on while no one occupied the space. From this data, assumptions can be made regarding how occupancy and light sensors would have impacted the lighting system's energy consumption over that period. The designer can then compute the estimated savings and compare this to the cost of the proposed system.

One factor with a likely impact on the adoption rates of lighting control systems is that lighting technologies (specifically LED) with higher efficacies than those currently available are on their way. While some fluorescent lighting proponents may contend that LED's actual advantage in this area is exaggerated, there is certainly a perception that future lighting will use less energy. If proven true, the opportunity for savings from lighting controls would be proportionally lower.

2.3.3 Construction Practices

The most common approach to designing and constructing a building is exactly that – first the building is designed and then it is built. Often, to achieve speed and lower costs, designers use standard or previously implemented designs. Adding something new to the mix involves additional time and cost, not to mention risk. In addition, the communication among disciplines is more difficult when such a sequential process is employed. All of this works against the successful integration of complicated cross-system features such as lighting controls.

2.3.4 Insufficient Knowledge and Experience

Building controls are not generally well understood by many of the key parties in the building industry. For one, owners and property managers are not necessarily aware of the capabilities of modern lighting systems; consequently, despite opportunities to include higher efficiency lighting and lighting controls, these items are seldom placed high on the list of priorities. In addition, designers who have not yet worked with some of the sophisticated control systems may be reluctant to suggest adding them to projects; they will expect the learning curve to be steep, and may feel their reputations are at risk if something does not work as planned. Moreover, bringing an expert on board introduces additional cost and potential coordination problems, so this may only be done if an owner specifically requests a control system.

In a study co-sponsored by the Lighting Controls Association, distributors responded that they are motivated to sell dimming systems because the inclusion of such equipment tends to raise the profit margin on a project. However, while a majority of distributors reported having a lighting specialist on staff relatively few have an in-house controls specialist.

There are other indications that the distributors do not have the necessary expertise to undertake as much lighting control business as might be available to them. The research suggested that distributors usually quote dimming systems by working directly from a product and price list supplied by a manufacturer. Also, many distributors and electrical contractors report that the systems are most often commissioned by technicians employed by the manufacturers.

2.3.5 Distribution Channels Not Optimal

Even if the owners and designers are interested in lighting controls, other participants in the distribution channel might not be supportive. Just like designers, the distributors and contractors could be very sensitive to the risk that the systems will not perform as planned.

Contractors, in particular, may be concerned that they will have to expend significant extra labor trying to figure out why the controls are not working.

A large part of this concern stems from historical problems with older technology. In the past, occupancy sensors were difficult to tune and did not always operate as intended. The fear persists, for example, that a person sitting in a bathroom stall could suddenly be left in total darkness because an occupancy sensor could not detect any motion. However, lighting control experts say that current technology allows for easily implemented solutions that prevent this from occurring.

The Lighting Controls Association asked the following question as part of a survey of Lighting Designers, Architects and Engineers:

Table 2.4 "Overall, in what percentage of your building projects do you specify…?"

Requirement Type	Lighting Designers	Architects	Engineers
Dimming systems for localized applications such as training rooms	47%	58%	37%
Facility-wide dimming systems (lighting control integrated with other types of building control systems)	32%	19%	12%
No dimming systems	21%	23%	51%
Total Number of Respondents	68	15	52

(Source: Lighting Controls Association)

As evidenced by the results, there are still a number of professionals who do not make it a regular practice to specify lighting controls. Also, since the percentage of buildings being built with facility-wide dimming systems is nowhere near 32%, it is clear that the recommendations of some lighting professionals are often not followed.

2.3.6 Primary Responsibility for Integration

Building systems such as fire alarms, HVAC, and access control are installed by specialists. The reason that lighting control specialists are not brought in to install lighting controls is that these systems are most often installed at the same time as lighting systems and many control elements may be combined with the luminaires. This is obviously the case in a new construction situation, but it often applies to retrofits, too.

The root of the problem is that the lighting system is the responsibility of the electrical contractor. Even if the electrical contractor is not a controls expert, the contractor is not going to allow the controls vendor to be the integrator and take charge of the entire lighting installation. So, rather than having to take overall responsibility for the control system, the electrical contractors may try to use their influence to keep them out of a project.

2.3.7 Cost and Competition at the Contractor Level

There are, undoubtedly, many contractors and distributors who are convinced of the value of lighting control systems and would be interested in proposing such an enhancement. However, because of the cost of such a system, their proposals would come in at a higher price than those of competitors that do not incorporate lighting controls. If the contractor is at all concerned that price will be an issue, there is a strong tendency to leave out the controls rather than enter the bidding at a disadvantage.

2.3.8 Installation Problems – Real and Perceived

Not too long ago there were apparently frequent anecdotal reports from the field that suggested fluorescent lamps failed prematurely when they were operated on dimming ballasts. A detailed study of such a situation in a big-box store found that most of the failures were due to either improper wiring of the ballasts during installation or even incorrect lamp installation. Manufacturers have focused on training and documentation to overcome such problems, but these legends persist.

Many electrical contractors, and therefore many of the other parties who would be involved in decision-making, tend to believe that the installation of dimming systems with photosensors is a difficult, time-consuming, and expensive process. Such perceptions have probably prevented daylight harvesting systems from being installed in projects where they could have provided significant net benefit. Most systems that were installed were probably put in by manufacturer employees or other highly specialized sub-contractors.

Even much more simple shut-off controls, while readily installed in new construction situations, can meet resistance in retrofit projects. There is a definite perception that the problems and costs associated with replacing the existing manual controls are too great to be worth the effort.

2.3.9 Inadequate Application Guidelines

The preceding discussions often mention how complicated the design and installation of lighting controls systems can be and how insufficient the education of the industry has been to date. This has not resulted from lack of effort; there have been innumerable white papers written, training sessions offered, and consulting engagements paid for. What has been lacking is a real design "roadmap" of how to connect the required system elements, or even how to identify the elements that are required to address each specific application that must be handled. The designers do not know how to write the "narratives" of the systems..

The industry continues to work on addressing this problem. During the past year the Illuminating Engineering Society (IES), with assistance from the Lighting Controls Association (LCA), has been developing a design guide. *The Commissioning Process Applied to Lighting and Control Systems*, IES document DG-29-10, is being prepared for release in early 2011. A primary purpose of this guide is to provide instructions on how to design a controlled lighting system and commission the system to make sure it meets the design criteria.

2.3.10 Lack of Standardization

Until the last decade or two, most dimming ballasts were part of fully integrated proprietary systems. Many of these were used in the specialized theatrical lighting industry. Lutron developed its commercial-oriented systems over time to optimize their capabilities at the system level. So, application intelligence could be put where it made sense for Lutron's objectives. The result was that much of this intelligence resides in Lutron's ballasts, while most current control vendors include this type of functionality in the system-level software.

Over time, more vendors developed ballasts that responded to a 0 to 10 volt analog control standard set by the American National Standards Institute (ANSI) and used in the entertainment industry. However, standards have not been adopted for commercial and industrial applications. Since the needs of most commercial markets differ from those in entertainment applications, many of these commercial use ballasts, then, vary from the

ANSI standard. Moreover, the products from various manufacturers support different features, making it somewhat more difficult to mix and match products from different vendors. In addition, even when designed to be compatible, ballasts from different manufacturers sometimes produce different light levels when operated under the same controller, requiring an additional calibration effort during installation.

Standardization, or the lack thereof, continues to be a concern as the industry migrates to digital control methods. The Digital Addressable Lighting Interface (DALI) is an early digital standard that has caught on in Europe, and is discussed in the Technology section of this report. While used occasionally in other regions, DALI has yet to become a major factor outside of Europe.

In the meantime, proprietary systems continue to find success in the market among customers who appreciate the advantages of working with a single vendor that is responsible for full system integration and migration to new features. Other customers have very strong preferences for open systems with multi-vendor capability. One energy manager interviewed for this report expressed a view that multi-vendor compatibility is a very important factor, but later mentioned (in that same conversation) that a new high-end project was going to incorporate a Lutron lighting control system. It is likely that the majority of customers are stuck in the middle and do not know which way to go, resulting in more analysis paralysis.

Open systems with vendor interoperability are thought to result in lower initial costs to customers, due to competitive pressures, and more innovation on the part of vendors trying to differentiate themselves to the large available market. The issue of differentiation, however, drives some vendors to take the proprietary route. It is much easier for a company to add features and new capabilities when it has end-to-end control of the system.

2.3.11 Product and Technology Risks

Architects and lighting designers tend to be risk-averse and are reluctant to put their reputations on the line to support unproven products and systems. At the same time, few customers are inspired to be on the “bleeding edge” of technology innovation; most want to purchase a system that is fully developed and tested, and cannot afford the distraction that may be associated with being a test site for a new product or system. Along those lines, customers love to see documented case studies showing the successful installation and operation of a system as close to identical as possible to the one they are considering. Such evidence is important to overcome all of those perceptions about expensive, complex systems that are difficult to install and do not operate as promised.

Energy service companies (ESCOs) that are considering installing lighting control systems need accurate cost and energy savings projections to make their performance contracts work properly for both parties. Similarly, utilities that are running rebate programs need to know that the claimed savings will be achieved in order to justify the money paid out.

2.3.12 Other Customer Concerns

A number of other concerns could lead decision-makers to conclude that a lighting control system may be more trouble than it is worth.

Owners may be concerned about dissatisfaction resulting from taking control of lighting away from the occupants, whether employees or tenants. Will occupants get annoyed at the way lights turn on and off or dim? Or, in the case of a strategy such as personal control, owners may be concerned about forcing people to think about things they never had to think about before.

Owners and facility managers may have concerns about a lighting control system being too complicated. Given the number of possible control points (lights) and inputs (sensors), lighting control systems can be far bigger and more complex than all other building control systems combined. There could be a need to manage enormous amounts of data. Management may not want to have to hire specially trained people to make the technology work properly at startup and for the long term. Will the maintenance staff be able to manage and make necessary adjustments to the system without having to call in a specialist? Will the high turnover that is typical among maintenance workers, especially in industries such as hotels, mean that the staff will not even have sufficient basic knowledge of the system to operate it? Will any of these factors lead to people overriding the system or turning it off? What about the installation process? Will there be disruption to normal operations?

Additionally, there will be concerns about the reliability of the system and the procedure to follow if something goes wrong. Which party is the primary contact in case of a problem? Is it the contractor, the commissioning agent, or the equipment vendor? What if the system is composed of products from multiple vendors?

Owners and facility managers also want to know that they are purchasing a "future-proof" solution. They will want to understand the plans for future enhancements to the system and how expandable it is. They will want assurances that it will not become obsolete.

2.4 Drivers and Trends by Building Category

The following discussions highlight some typical lighting applications for each of the building categories and the factors that could influence adoption of lighting controls.

2.4.1 Office

The predominant type of lighting in offices has been four-tube, two-ballast fluorescent ceiling fixtures. These have provided good efficiency and, over time, acceptable light quality. However, such fixtures often provide far more than the recommended amount of light to work surfaces – sometimes as much as twice the recommended amount. In some places, it has become common practice not to replace one or two of the lamps in a four-lamp fixture when they fail. Lighting in new construction and major renovation situations is, or should be, dominated by T5 and high-output T8 lamps.

Many office environments have been able to reduce the amount of general ceiling light in use by providing task lighting at workstations. A common implementation of this has been small, under-cabinet fluorescent tubes. It is commonly believed that LEDs, which are very good at providing directed light and reducing glare, will become the dominant source of task lighting over time.

The general lighting in office buildings has commonly been shut off after operating hours by a timer connected to the lighting panels. There is also a history of using standalone occupancy sensors in individual offices and conference rooms.

Owners of commercial real estate have gone through periods, such as most of the 2000s, when there was limited interest in holding buildings for the long term. This led to requirements for very short payback periods of one to three years, at the most, for any investment. More advanced lighting control systems could not meet such payback requirements.

With the global downturn in the economy, more owners are expecting to retain properties for longer durations, and are therefore more seriously considering investments with longer payback periods. However, capital is still difficult to come by. Consequently, owners are increasingly interested in arrangements that spread payments out over three to five years, with the ability to use the energy cost savings to provide these funds. The owner would then accrue the benefits on into the future. Yet, not all owners will want to enter into such extended agreements. Many will fear the complexity it would add to a transaction should they decide to sell the property.

2.4.2 Retail

Lighting is a critical feature of the retail environment. It is extremely important that products look good in the stores, and that they do not appear different when the consumer gets them outside. Stores must be perceived as clean and neat, and bright lighting often supports this. In addition, it is possible that even one or two burned out lamps will give the impression that the facility is not well maintained, so failed lamps are replaced quickly. Given these realities, it is not surprising that energy efficiency is not the topmost feature that retailers desire in a lighting system.

Retail lighting can be categorized into three primary types: general, display, and special effect/decorative. General lighting is provided by fixtures in or mounted to the ceiling, which supply the desired overall light level in the store. Fluorescent fixtures are the most commonly used for this purpose. Secondly, display lighting is focused on making merchandise and other specific areas, such as window displays, have the intended look to the consumer. Accurate color rendering is extremely important for these applications, and incandescent lamps have historically dominated. Halogen lamps, a more efficient type of incandescent technology with excellent color rendering capabilities, have taken a lead role in retail display lighting. It is expected that display lighting will be the first major application for LED technology in Retail. In fact, good quality LED replacements are already in existence for the widely used MR-16 halogen lamp and for other low-power, reflector-type lamps. Lastly, lighting is also used to achieve special effects or decorate parts of the store. These applications often call for specialty lamps or fixtures to disperse or color the light in specific ways. LEDs have already enabled new types of design creativity due to their small size and ability to be turned on and off rapidly by electronic controls.

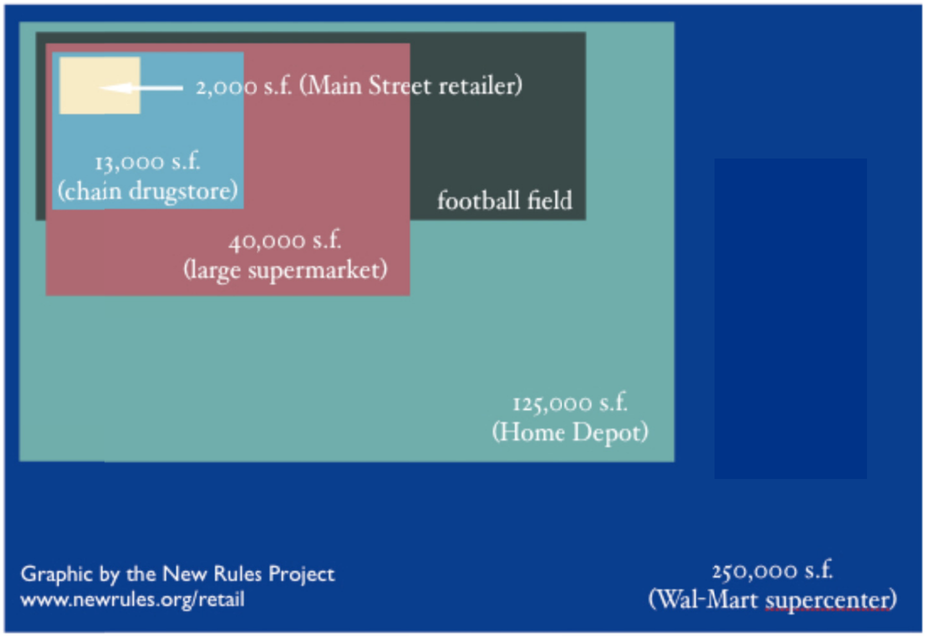
Common spaces in malls are less bright than the insides of stores. More indirect lighting is used. Some malls try to give the common enclosed areas more of a “homey” feel. Others use creative lighting and décor to simulate outdoor spaces. The stores inside the malls will need more lighting than their standalone or strip mall counterparts as mall stores tend to have virtually no daylight penetration.

In grocery stores, lighting is especially important in the sale of fresh foods, including produce and meats. The light will have a direct impact on how the products look and consumers’ willingness to purchase them.

The general, ceiling-installed lighting is usually controlled by timers as there is no real reason to dim or turn off these lights during operating hours. The exception to this is the increasing use of skylights in big-box stores. These buildings are characterized by large, open spaces so most of the lighting has been provided by ceiling fixtures. Some major retailers, led by Costco and Wal-Mart, have been implementing daylight harvesting systems to take advantage of the light coming in through skylights.

Figure 2.4 compares the typical sizes of the different types of retail stores in North America. In most other regions of the world, retailers tend to be smaller on the whole. The distinctions between the lighting and control needs of larger and smaller spaces should apply just as well, however.

Figure 2.4 Comparison of Retail Store Sizes



(Source: New Rules Project)

2.4.3 Education

Lighting tends to account for an even greater share of a school's utility costs than most other types of buildings. It can represent 30% to 40% of the total utility bill.

The primary light source in school hallways and classrooms is often ceiling-mounted or recessed fluorescent fixtures. In many cases, these fixtures use older, less efficient T12 lamps that can be replaced with T8 or T5 lamps and luminaires. To maximize the savings from the more advanced lamps, the old style magnetic ballasts are being replaced with more efficient electronic ballasts.

As with other market segments, lighting controls can lead to energy savings. Occupancy sensors may be appropriate for classrooms, restrooms, offices, and libraries. In addition, the ability to manually adjust lighting to the appropriate levels for various activities can be a valuable tool in the classroom. However, there is currently little lighting control in use other than in some classrooms and performance spaces.

2.4.3.1 Kindergarten through Secondary School

A number of studies regarding appropriate lighting for classrooms have been conducted, including a major report by the New York State Energy Research and Development Authority (NYSERDA) from 2006. The recommendations usually fall along these lines:

- A dedicated luminaire with a dedicated switch to illuminate the whiteboard on the main teaching wall.
- Ceiling-mounted indirect/direct luminaires mounted perpendicular to the main teaching

wall (parallel to window wall).

- Sensors mounted on the ceiling in the center of the classroom. Sensors always include occupancy. Daylight harvesting is added where appropriate.
- Teacher control is at the front of the classroom, near the whiteboard. Switches for:
  - General mode: Downlight OFF, uplight/downlight ON
  - A/V and Reading Mode: Downlight ON, uplight/downlight OFF
  - A/V Dimming Mode: Turn on and then dim the inboard lamp providing the downlight component (this requires a dimming ballast)
  - A "Quiet Time" switch: Overrides the occupancy sensor for a set time, such as one hour, to keep the lights on during occupied periods with little movement such as during testing.
- A master ON/OFF switch is by every door to the classroom.

2.4.3.2 College and University Campuses

Increasing interest in sustainability on university campuses has led to initiatives to reduce energy use. In recent years, new construction projects have incorporated many energy efficiency features, and academic institutions are among the largest groups pursuing green building certifications.

The campus setting offers both advantages and challenges to sustainability efforts. Many institutions have a number of old and historic buildings. These are much more difficult to retrofit, and sometimes nearly impossible to bring up to the highest current standards without drastically altering the structure or greatly increasing (two times or more) the cost of the entire lighting upgrade. So, while the installation of basic room-level lighting controls is common when lighting retrofits are performed, these buildings are rarely outfitted with sophisticated, networked lighting control systems. Wireless controls will offer an option to overcome this hurdle.

A campus that has many similar buildings has a special advantage when it comes to planning retrofits. The school is able to try certain types of systems in one building, and then apply the learning to later retrofit projects. As with most institutions, though, money for capital improvements is limited. Therefore, even basic retrofits of existing buildings are taking place at only a very gradual pace.

Many campuses have reasonably extensive meter and sub-metering configurations. This allows energy consumption to be more closely monitored from a central facility. Centralized monitoring has a number of management advantages, including that the energy use data can be made available to the public. For example, real-time data on energy use and energy generation at Cornell University in Ithaca, New York is viewable at portal.emcs.cornell.edu.

Especially in an academic setting, many people are interested in energy performance and want to do the right thing. In fact, there have been requests for increased sub-metering at the floor- or even zone-level to facilitate energy saving competitions among departments.

Networking all of the buildings together usually necessitates that the lighting control systems are compatible with the existing BMS. Such communication options are discussed in the Technology section of this report.

2.4.4 Healthcare

Hospitals have a wide variety of lighting needs. In addition, many of the spaces within hospitals are in operation 24 hours a day, seven days a week. Fluorescent lighting is the dominant lighting technology used. However, certain tasks – examining patients or lab samples, for instance – may require incandescent lighting due to the importance of accurate color rendering.

Healthcare facilities have a large number of private offices, conference rooms, storage rooms and similar spaces that can benefit from occupancy sensors, either independent setups or in networked systems. Other spaces could also benefit from controls; cafeterias and lounges, for example, often have a lot of windows, presenting the opportunity for daylight harvesting systems. And while much of the facility may be in use all the time, other sections may be accessed only occasionally, and possibly only rarely during the night. Occupancy sensors and dimming or step-dimming capabilities can lead to energy savings with no effect on operations.

2.4.5 Hotels & Restaurants

Hotels have among the most complex lighting needs since they have such a wide variety of spaces. Some areas need to be lit continuously to support the 24 hours a day, seven days a week operation of the facility.

Lighting for the "back of the house," where only the employees go, is pretty straightforward: Basic, efficient fluorescent fixtures dominate these spaces. Other spaces, however, are meant to remind guests of home and must avoid feeling institutional. In addition to guest rooms, areas such as hallways, which generally have no natural lighting, must also have a residential feel. Consequently, fluorescent tube fixtures, a frequent hallway lighting option across most of the Commercial sector, are avoided in favor of recessed lighting (normally with CFLs).

Conference and meeting rooms require bright light, but also extensive controllability to dim or darken the whole space or parts of it. These requirements often necessitate a combination of lighting technologies, with different lighting providing for the various needs. The situation in lobbies and other common spaces is similar. The design flexibility of SSL has already enabled this technology to penetrate the upper end of the lodging business. Use will spread as prices decline in the coming years.

Hospitality companies often operate on very tight profit margins, so capital investments usually require fast payback periods. However, energy is a major cost in the industry, so opportunities to reduce consumption are highly desired. One innovation that has been around for a while is a type of master switch that reduces energy consumption in guest rooms, including lighting, to a minimum when they are unoccupied. The room key card is often the activator for the system: The card must be plugged in for the lights to come on, and the lights and HVAC go back to default settings when the card is removed. Other systems are based on more standard occupancy sensors in the rooms, which control some, if not all, lights. Integrated HVAC control is also not universal.

Lighting controls can also be used for hotels' storage rooms, workout and spa facilities, hallways, and staircases. While it is unlikely that lights would be totally turned off in a hallway or staircase, they could be dimmed during overnight hours, with an override capability initiated by a motion detector.

In restaurants, meanwhile, ambiance is a very important factor. Consequently, lighting is often designed with that in mind rather than energy savings. The types of dimming used are more similar to those in entertainment venues than offices.

Sustainability is an important factor in the hotel industry. Many of the major lodging companies have extensive sustainability efforts. A recent poll of corporate travel managers confirmed that they are aware of sustainability initiatives, though it is unclear how heavily this factors into purchasing decisions. LEED, specifically, was not given much importance by the poll respondents. An executive from the company that conducted the poll said, "LEED certification is an important and highly valuable contribution to the building and operating performance of hotels. However, the average guest has no idea what LEED is or what benefit it has on their hotel experience."

2.4.6 Institutional/Assembly

A common characteristic in the institutional/assembly category is the prominence of large, high-ceilinged indoor spaces. Lighting technologies must be powerful enough to illuminate the spaces from fixtures high above the floor. In addition, a large percentage of buildings that make up this category have significant theatrical-type lighting requirements. Theaters and sports arenas are obvious examples, but museums and casinos also share these needs.

These large structures also contain a variety of more standard types of commercial space – offices, hallways, meeting rooms, food preparation areas, lavatories, etc. – with lighting requirements more typical of those applications. These spaces are described in the preceding discussions of building categories, so that information will not be repeated here.

The fact that some of these buildings are publicly owned has an important bearing on financing considerations. Federal, state, and municipal governments are usually able to take on longer-term contracts, providing time for energy cost savings to pay for upgrades or new advanced systems. Note that public administration buildings are included within the Office category.

2.4.7 Warehouse

Lighting in warehouse spaces is dominated by "high bay" fixtures and high power lamps. These are designed for ceilings that range from 25 to 40 feet above the floor and the need to spread light over a relatively large area. Historically, high wattage mercury vapor or high pressure sodium lamps were used in this application, but the use of mercury vapor lamps has been in decline for some time due to concerns about mercury pollution. High pressure sodium lamps are efficient, but have poor color rendering. Today, metal halide is the HID technology of choice in these "high bay" applications.

2.4.7.1 Lighting Upgrades

With advances in fluorescent technology, fixtures known as "T-bay" have been increasingly installed. These hold six to eight fluorescent tubes and provide better light quality than high pressure sodium lamps. The fixtures have built-in redundancy, preventing the need for someone to service it until more than one or two of the lamps have failed. High power CFLs are also increasingly being installed in high bay applications.

People in the industry say that fixtures with six T5 lamps are quickly becoming the standard for lighting retrofits in North American warehouses. They may consume as little as one-half the amount of electricity of the metal halide lamps they are replacing. In fact, the RFPs from some companies seeking space specify these types of energy saving luminaires. In other parts of the world, 8-lamp T8 fixtures are still the primary upgrade option; these also provide an energy savings when compared to metal halide, though not as much.

Unlike metal halide and high pressure sodium lamps, fluorescent tubes do not have slow warm-up times and there is no re-strike delay (the time before the lamp can be turned on again once it is totally turned off). Therefore, fluorescent lamps provide more options for control with occupancy and photo sensors. In addition, if the luminaires and sensors are networked to a central controller, the software can provide instruction as to how many of the six lamps should turn on or off.

2.4.7.2 *Some Uses of Lighting Controls*

Many warehouses run their operations for two shifts, if not around the clock, and often six or seven days a week. The need to light a facility for so many hours poses a great opportunity for energy savings. Often, the need for lighting is intermittent during the operating hours. For example, if a forklift only goes down a certain aisle once every half hour, why keep the lights on all the time? There is an added incentive to reduce lighting use in refrigerated warehouses, since lights can generate a great deal of heat.

Warehouse owners are less interested in green building certifications than property owners in many other building categories. However, they are very interested in reducing operating costs. With lighting accounting for as much as 70% of the operating cost of a warehouse, lighting system upgrades are a relatively easy way to achieve savings. Many warehouses are owner occupied, but a large percentage are leased. Since tenants pay energy costs, the leased properties face the same split-incentive problem as is common for office buildings. However, the recent economic climate has led to a great deal of turnover in warehouse leases in the developed countries, and a lot of vacant space. Many owners are upgrading their lighting systems to make the properties more attractive to tenants. In countries such as the United States, Canada, the United Kingdom, and Japan, this may include not only high efficiency lighting technologies but also lighting controls.

In most countries, though, including most of Western Europe, the use of lighting controls in warehouses is not the norm. Even some of the most progressive developers of warehouse properties do not believe lighting controls are worthwhile investments. Throughout the world, the majority of warehouses, especially smaller ones, have no energy management system of any kind; the last person out simply flips the circuit breaker to OFF at the end of the day.

There is some history of using occupancy sensors with warehouse lights. In some cases, a single sensor is connected to all the lights in an aisle or part of an aisle. Other times, each luminaire will have its own sensor. These sensors are generally not networked to any kind of central control system. Some newer warehouses have skylights and may have similarly independent photosensors in each aisle or on each luminaire.

Advanced, networked lighting control systems are occasionally installed in new warehouses. However, relatively little warehouse construction is occurring in the developed countries due to the availability of vacant warehouse space. Construction does continue at a healthy pace in the developing markets, especially in Asia, but interest in even basic lighting control systems there is minimal.

2.4.7.3 *New Approaches*

The Warehouse category is not the largest in terms of floor space, but at least a couple of companies feel that there is plenty of opportunity to serve this market better with custom-built product. Their immediate targets are large companies with a number of warehouse facilities throughout North America that are seeking common, highly efficient lighting solutions that can be monitored from a single location.

Lumetric, based in Fremont, California, and Digital Lumens, based in Boston, Massachusetts, are each taking different approaches toward a lighting solution focused on warehouse, industrial and other "large area" applications. Each company has developed a specialized, dimmable luminaire that incorporates the light source and sensors, and then networks these luminaires to custom control software. Both tout capabilities to connect to the Smart Grid for demand response and other applications. The main difference between the two is the core light technology used. Lumetric's SmartPod is a modernization of HID technology, using a "solid state direct driver" in place of a traditional ballast. Digital Lumens' luminaires use LEDs and communicate wirelessly with each other and with the central controller. Both Digital Lumens and Lumetric are among the companies profiled in Section 4 of this report.

There is plenty of room for innovators in the lighting market. Both Lumetric and Digital Lumens have only a handful of customers as of the writing of this report. It will be interesting to see the kind of traction they develop during 2011.

2.4.8 Transport

The types of buildings in the Transport category vary widely, so it is difficult to make too many generalizations about lighting needs. Airport terminals, especially newer ones, will have high ceilings and often make use of a great deal of natural light. Bus stations and train stations around the world tend to be smaller buildings with an emphasis on functionality over ambiance.

Similar to the comment made about buildings in the Institutional/Assembly category, Transport buildings will also contain many types of spaces that are characteristic of other building categories. These, too, will house offices, hallways, and lavatories, and sometimes retail spaces and restaurants.

2.4.9 Multi-Family Residential, Common Areas

Common-area lighting in apartment buildings differs somewhat by the age of the building; however, with the exception of lobbies in newer high-end buildings, most of the lighting is fairly basic. Older buildings were designed with standard Edison sockets in the hallways, staircases, storage rooms and utility rooms. Most of the incandescent bulbs that were in these sockets have probably been replaced by CFLs. It is likely that lobbies, laundry rooms and meeting rooms, and possibly hallways and staircases in nicer properties, were constructed with luminaires that use T12 fluorescent tubes. By now, some of these may have been replaced with T8 luminaires, but many of the T12 variety are undoubtedly still in use. Unless an inspired building manager or maintenance worker installed an occupancy sensor in a storage room or similar space, it is unlikely that there is any control scheme for lighting on the inside of the building. Meanwhile, outside lights are probably on timers or use photosensors.

Newer buildings use mainly fluorescent lighting – generally modular CFLs in hallways and staircases and linear fluorescents in other common areas. However, smaller metal halide HID luminaires may be in use in mechanical rooms and other spaces that are out of the public eye. Higher-end buildings may have more decorative lighting in lobbies and health clubs, and those buildings constructed in just the last few years may have begun to integrate LED lighting into lobbies and other spaces. Very few, however, have installed

LEDs extensively throughout building hallways and other areas.

Some common areas such as laundry rooms and meeting rooms may have occupancy sensors that control the lighting, but it is unlikely that many other internal areas would include controls, and dimming control would be extremely rare. The exceptions to these generalizations would be the few apartment buildings that have pursued some type of green building certification.

2.5 Drivers and Trends by Geography

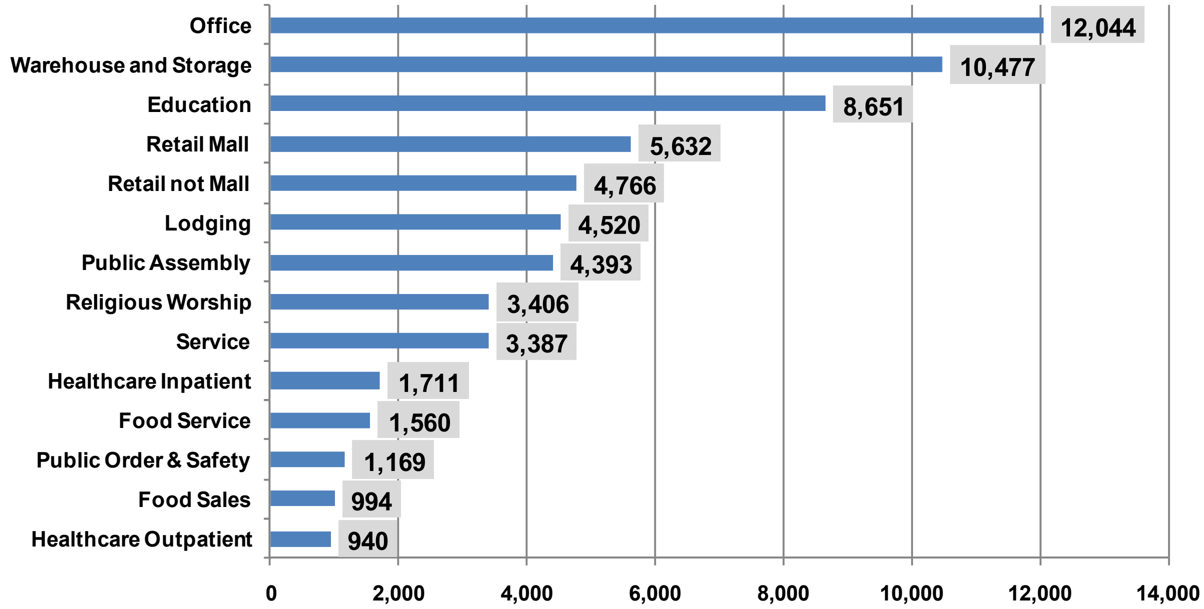
Across the globe, trends related to energy efficiency and energy management are leading to increased adoption of lighting controls, particularly trends related to legislation, regulation, and incentives. In addition, region- or country-specific drivers also exist.

A growing interest in green building certification is one driver in many regions. Note that while some green building certification programs are mentioned here, this is only a sampling of the many programs that are in place around the word. Pike Research's 2010 report titled *Green Building Certification Programs, Global Certification Programs for New and Existing Buildings in the Commercial and Residential Sectors: Market Analysis and Forecasts* has an extensive discussion and analysis of dozens of global, regional, and national green building certification programs.

The following discussions provide examples of the trends influencing some of the largest markets for lighting controls.

2.5.1 United States

Chart 2.1 Percentage of Commercial Buildings with Energy Efficiency Efforts in Place, United States: 2009



(Source: Energy Information Administration)

It is likely that only about 20% of commercial buildings in the United States have any type of intelligent lighting control. Moreover, standalone occupancy sensors in offices, conference rooms, and storage areas probably account for the majority of this. However, though relatively small as a percentage of the total, there are a number of buildings that have occupancy sensors, and sometimes daylight harvesting systems, that are networked to a control panel.

The following describes the market environment for lighting controls in the United States, covering regulations, codes, incentives, and other market factors.

2.5.1.1 Federal Regulation

2.5.1.1.1. Energy Policy Act of 2005

The Federal Energy Policy Act (EPAct) of 2005 included a wide range of product and energy efficiency standards. It also established the Commercial Building Tax Deduction (CBTD) program for making buildings more energy efficient, including a deduction for lighting system upgrades that achieved performance at least 40% better than the standard in ASHRAE 90.1-2001. The ASHRAE 90.1 standards have since been updated and the requirements for the tax deduction have been revised upward. The CBTD was recently extended through the end of 2013.

EPAct 2005 also included new ballast efficiency standards and prohibited the manufacture or importation of mercury vapor lamp ballasts after January 1, 2008.

2.5.1.1.2. Energy Independence and Security Act of 2007

Some of the main stated purposes of the Energy Independence and Security Act (EISA) of 2007 were to improve energy independence, increase the production of clean and renewable fuels, and boost the energy efficiency of products, buildings, and vehicles. Important provisions for energy efficiency in commercial buildings include:

- Creation of the Office of Commercial High Performance Green Buildings
- New standards and grants for improving energy efficiency in government buildings (e.g., all new federal buildings must be carbon-neutral by 2030)
- Loans and programs targeting small businesses to encourage the adoption of energy efficiency technologies
- New initiatives for promoting energy conservation in buildings
- Establishment of a program to make general lighting more efficient by 2020

Among other products, the program that affects general lighting has impacts on T12 lamps and the magnetic ballasts often used to drive them. Rules concerning these ballasts have been getting tighter since 2006 and they are known to be very inefficient compared to more modern alternatives. Yet, NEMA reports that 7% of all ballasts sold in the United States are still of this type. Production and import of these ballasts ended as of July 1, 2010 and sales of existing stock must end by July 1, 2015.

While no longer popular in new construction, an estimated 30% of fluorescent 4-foot lamps sold every year are T12, according to NEMA market data. On July 14, 2012, DOE regulations will take effect that will also eliminate the manufacture and import of T12 lamps. Sales can continue until stock runs out.

EISA also authorized the Net-Zero Energy Commercial Building Initiative to support the goal of net zero energy for all new commercial buildings by 2030, and specifies a zero-energy target for 50% of U.S. commercial buildings by 2040 and net zero for all U.S. commercial buildings by 2050.

2.5.1.2 *Building Codes*

The U.S. EPA estimates that implementing and enforcing energy codes can bring a 30% to 40% reduction in energy usage for new buildings compared to standard building practices.

In the United States, the two most commonly referenced energy code baselines are ASHRAE 90.1, which is maintained by the American Society of Heating, Refrigeration and Air Conditioning Engineers, and the International Energy Conservation Code (IECC), which is produced and published by the International Codes Council (ICC).

ASHRAE 90.1 is revised on a 3-year cycle, and ASHRAE 90.1-2007 is the most current version. The IECC is also on a 3-year revision cycle. The current version is 2009 IECC, and it includes requirements that are roughly equivalent to ASHRAE 90.1-2007.

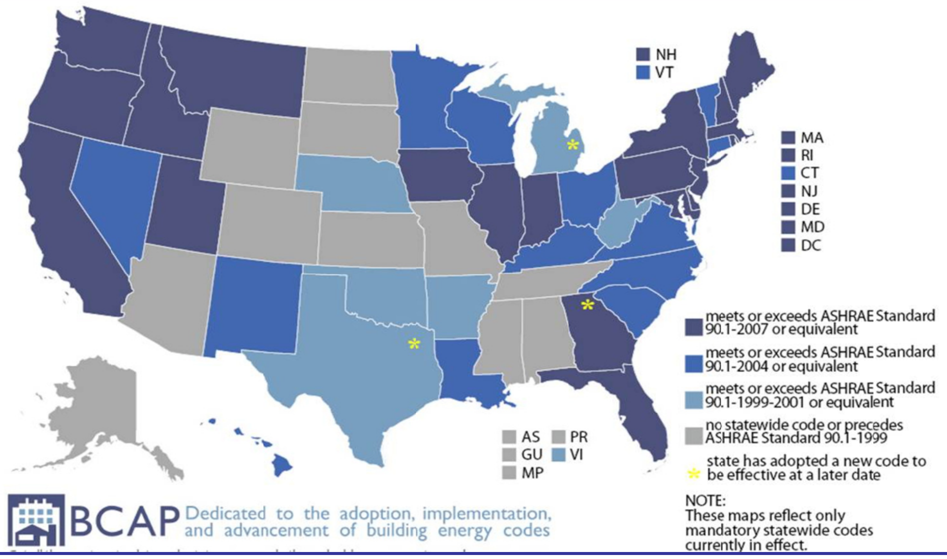
2.5.1.2.1. *The Energy Policy Act of 1992*

The United States' Energy Policy Act of 1992 required states to establish minimum energy codes for commercial buildings. An analysis conducted by the DOE determined that commercial buildings that meet or exceed the ASHRAE 90.1-2004 standard consume approximately 12% less energy at the site than buildings that do not meet the standard. On December 30, 2008, the DOE recognized 90.1-2004 as the new national energy standard effective two years later, on December 30, 2010.

ASHRAE 90.1-2004 and the corresponding state regulations cover the energy efficiency of virtually all mechanical and lighting systems in new buildings, major additions to a building, and new systems and equipment in existing buildings. These standards are applicable to almost all commercial buildings.

Building codes still vary significantly from state to state. Right now, there is a patchwork of adoption of the DOE-approved ASHRAE building codes for commercial buildings. More than 40 states and the District of Columbia have adopted a version of the model energy building code, but only 20 have adopted the 2004 version of the code. Within those states that have yet to implement the building codes, there are, however, a number of local jurisdictions and municipalities that have adopted versions of the model energy code.

Figure 2.5 Commercial State Energy Code Status: 2011



(Source: Building Codes Assistance Project - Online Code Environment & Advocacy Network)

A number of more progressive communities and states are adopting "stretch codes." For example, the voluntary Massachusetts "Stretch" Energy Code for commercial construction is designed to be 20% more stringent than the state's baseline code, which is based on 2009 IECC. On November 17, 2010, Boston became the 59th community in the state to approve the stretch code.

A major difficulty with building codes, however, is consistent enforcement. Many states adopt codes, but leave it up to the local counties and municipalities to enforce them. And while lack of enforcement may at times be a resource issue, it is more often an education problem. A number of policy initiatives are working to address this information gap and lighting codes are increasingly being enforced.

2.5.1.2.2. ASHRAE 90.1

ASHRAE 90.1-2010 was just published in January 2011, so as of the writing of this report there has yet to be a comprehensive analysis of the elements of the standards that impact lighting controls. Table 2.5 highlights some of the key elements of ASHRAE 90.1-2007 that deal with lighting control.

Table 2.5 Summary of Lighting Control Provisions in ASHRAE 90.1-2007

Requirement Type	Provision Description
Automatic Shut-Off	Occupancy sensor that turns the lights off within 30 minutes of the space being vacated (required in certain spaces).
	Shut off due to signal from another system, such as a building automation system.
Space Controls	Lighting in enclosed spaces must be controlled by manual switches or occupancy sensors. In some spaces, the owner has a choice of occupancy sensing or multi-scene control, such as a dimmer. An occupancy sensor is a required control to turn the lights OFF within 30

	minutes of the occupant leaving the space in classrooms, conference/meeting rooms, employee lunch/break rooms. Maximum override of scheduling program: 4 hours.
Task Lighting	Automatic shut-off of task lighting is encouraged by exempting task lighting from interior power calculations if controlled by automatic shut-off.

(Sources: LC&D Lighting Controls; Pike Research)

The following list represents an edited version of comments regarding lighting control-related changes incorporated into ASHRAE 90.1-2010 that was recently posted on the Lighting Controls Association's website:

- Automatic shutoff control requirements must be met for lighting alterations, including lamp and ballast retrofits, as long as more than 10% of the connected lighting load is replaced. This is a big change that dramatically expands application of the Standard into existing buildings.
- Automatic shutoff control is no longer limited to buildings >5,000 ft^2.
- Occupancy sensors are now required in an expanded list of applications.
- Parking garage lighting controls are now required.
- Automatic daylight harvesting controls are now required.
- Guest room hotel/motel/etc. lighting control requirements have expanded.
- Stairwell lighting must now have a control device that automatically reduces lighting power by at least 50% when the area is unoccupied.
- Lighting control devices and control systems must be functionally tested to ensure "control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's installation instructions." Occupancy sensors, time switches, programmable schedule controls and photosensors are subject to specific functional testing requirements listed in the Standard. The construction documents must identify who will conduct and certify the testing. The tester cannot be the designer of the system.
- Documentation must be turned over to the owner at the completion of the project, including drawings, manuals, and a "complete narrative of how each lighting control system is intended to operate including recommended settings."
- Additional power allowance for the design using the space-by-space method by using lighting controls not required by the code.

2.5.1.2.3. 2009 IECC

2009 IECC is the most current version of this standard.

Table 2.6 highlights some of the key elements of the standard that deal with lighting control.

Table 2.6 Summary of Lighting Control Provisions in 2009 IECC

Requirement Type	Provision Description
Automatic Shut-Off	Occupancy sensor that turns the lights off within 30 minutes of the space being vacated (required in certain spaces). Shut off due to signal from another system, such as a building automation system. Intent: Eliminate after-hours lighting waste.
Space Controls	Lighting in enclosed spaces must be controlled by at least one manual switch. Intent: Allow occupants to control unneeded lighting. Maximum override of scheduling program: 2 hours (longer in some spaces).
Light Level Reduction	Lighting in enclosed spaces must allow occupants to reduce lighting uniformly by at least 50%, or be controlled by an occupancy sensor. Intent: Allow occupants to moderate light levels to save energy.
Daylight Harvesting	Lighting adjacent to vertical fenestration (windows) must be separately circuited and controlled from general lighting (required controls may be manual or automatic).

(Sources: LC&D Lighting Controls; Pike Research)

Note that 2009 IECC addresses daylighting control for the first time, though no particular method of control is specified.

2.5.1.2.4. 2012 IECC

During the ICC's final action hearings for 2012 IECC, which were held from October 27 to October 31, 2010 in Charlotte, North Carolina, a significant package of changes was approved. 2012 IECC is expected to provide a 30% improvement in energy performance over 2006 IECC.

The New Buildings Institute summarized the lighting-related provisions of 2012 IECC as follows:

- **Lighting:** Reduces energy needed for lighting based on more efficient illuminating equipment and the use of several lighting control strategies.
- **Daylighting:** Includes additional availability of daylight sources combined with automatic daylight controls, and comprehensive control strategy for all lighting zones. Daylighting can be a major energy-efficiency asset provided electric lighting is reduced when daylight is available.

2.5.1.2.5. ASHRAE 189.1 Model Green Building Code

In January 2010, ASHRAE, in conjunction with the Illuminating Engineering Society of North America (IES) and the USGBC, published Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*. This is the first commercial green building standard in the United States written in model code language and intended to serve as a basis for building codes.

The goal of the standard is to provide significant energy reduction over the levels in ANSI/ASHRAE/IESNA Standard 90.1-2007. Standard 189.1 offers a broader scope than Standard 90.1 and is intended to provide minimum requirements for the siting, design, and construction of high-performance green buildings.

Section 7.4.5.1 of ASHRAE 189.1 requires peak electric load reduction (demand response) capability. The building must contain automatic systems capable of reducing peak electric demand by at least 10%. Lighting control systems would enable lighting to contribute to this load reduction.

Lighting itself is covered in Section 7.4.6. This section, in turn, is based on Section 9 of ASHRAE 90.1 with several significant additions and modifications to increase energy savings, including:

- Lighting power densities are capped at 90% of ASHRAE 90.1.
- Manual-ON or bi-level automatic-ON occupancy sensors are required in offices smaller than 250 ft^2, all classrooms and other spaces. Otherwise, all occupancy sensors must be manual-ON.
- Occupancy sensing to switch or dim to at least 50% of power required in hallways in hotels, motels, dorms, multifamily buildings; industrial and commercial storage stacks; and library stack areas.
- Emergency lighting capped at 0.1 W/ft^2, but additional lighting is allowed if it is controlled by an automatic shutoff device.
- Daylight zones larger than 250 ft^2 must be automatically controlled by daylight sensing coupled with continuous dimming or stepped switching (with several exceptions).

2.5.1.2.6. State of California Codes and Regulations

California has a long history, going back to the 1970s, of employing regulation and building codes to make commercial buildings more energy efficient. Many of the rules are written into Title 24 of the California Code of Regulations, the Building Standards Code. Title 24, Part 6 covers building standards for new and re-commissioned buildings and specifically addresses energy conservation and energy efficiency. The state is often held up as a model for federal, state, and local efforts. With the Executive Order known as the “Green Building Initiative” signed in December 2004, California has what is thought to be the most comprehensive and far-reaching commercial building energy efficiency codes. For example, the standard energy allowance for office lighting in California is 0.8 watts per square foot. This compares to the 1.0 or 1.2 watts per square foot that is more typical across the United States.

Title 24-2008, the latest version of this regulation, became effective January 1, 2010. A new feature is the requirement for demand-responsive lighting controls in retail buildings that have a sales floor area larger than 50,000 ft^2 – i.e., big-box retailers. The controls must be able to reduce the power drawn by the lighting system by at least 15%. Buildings that have at least half of their lighting wattage controlled by daylight harvesting systems are exempt from this requirement. Interestingly, there is not yet a law or regulation that these buildings actually enroll in a demand-response program.

Another prescriptive provision of the new Title 24 requires skylights in big-box stores that are greater than 25,000 ft^2 and have ceilings higher than 15 feet. These skylights need to diffuse the natural light and incorporate controls that will turn off the lights when daylight is available. At least one-half of the floor area must be daylit using skylights.

Title 24 Part 11, also known as "CalGreen," is the nation's first statewide green building code. It went into effect January 1, 2011. CalGreen's roots are in sections of the California building code that started out as voluntary provisions. CalGreen was adopted in 2008, with a timeline leading to establishment of a set of mandatory provisions that set a minimum threshold for the state. CalGreen also includes voluntary measures that projects can adopt for higher levels of achievement.

Section A5.204.3 of CalGreen includes requirements for demand response for HVAC and lighting systems. The lighting requirement states that, "the pre-programmed demand response strategies shall be capable of reducing the total lighting load by a minimum 30% through dimming control or bi-level switching."

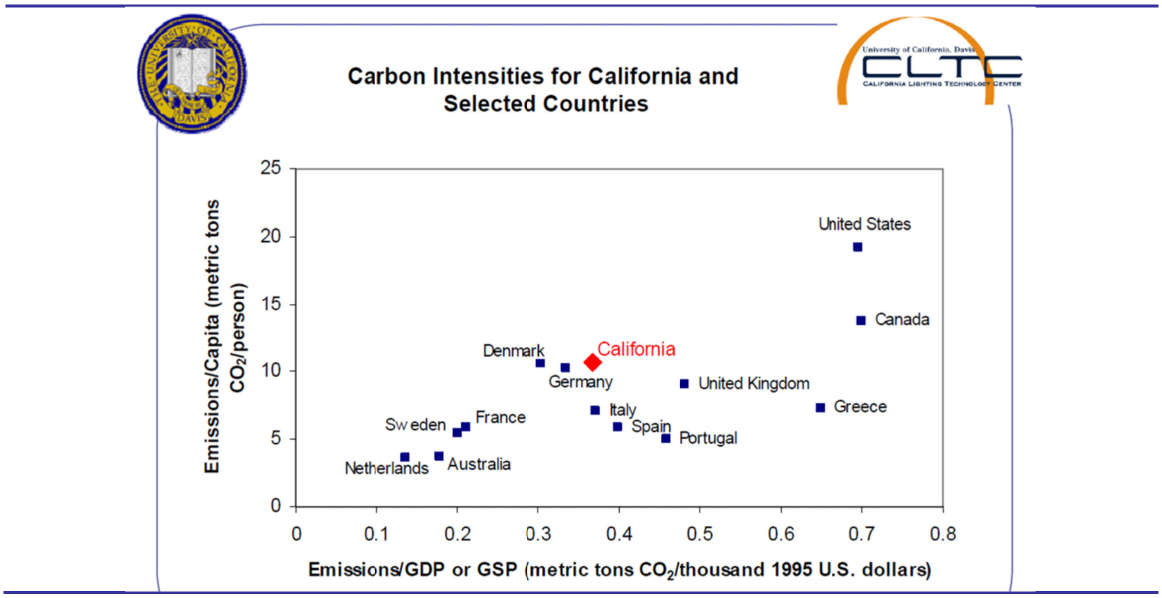
Other sections of CalGreen require, "individual task lighting and/or daylighting controls for at least 90% of the building occupants" and "inspections of energy systems for nonresidential buildings that are larger than 10,000 square feet to 'ensure that all are working at their maximum capacity according to design efficiencies.'"

2.5.1.3 *Other Information*

2.5.1.3.1. *Carbon Emissions*

Though much of the world has paid considerable attention to the reduction of carbon emissions during recent years, the United States has generally been much less concerned with this issue. The notable exception is California. Figure 2.6 illustrates where the United States, Canada, and California stand in relation to a number of European countries on the measures of carbon emissions per person (vertical axis) and carbon emissions per unit of GDP (horizontal axis).

Figure 2.6 Relative Carbon Intensities



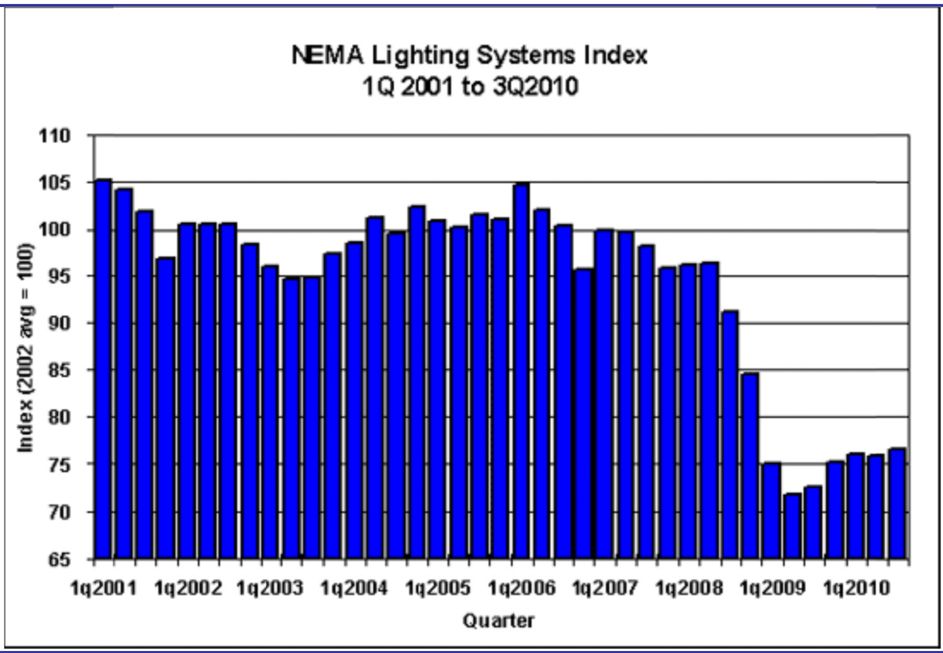
(Source: California Lighting Technology Center)

Thanks go to Professor Charles Hunt of the California Lighting Technology Center at the University of California, Davis for authorizing Pike Research to use this chart.

2.5.1.3.2. Market Indicators and Trends

Although the lighting industry in the United States does not publish sales figures, NEMA provides a quarterly Lighting Systems Index. The most currently available Index as of publication was for the third quarter of 2010. The Index shows a slight increase from the previous quarter and a 5.6% gain compared to the third quarter of 2009, though that quarter was the second lowest in the Index's history. NEMA reports that there was very moderate growth across all five of the groups followed, but shipments of fluorescent ballasts did show a relatively significant increase in demand. This is a good indication that the market for lighting upgrades is strong and growing.

Figure 2.7 NEMA Lighting Systems Index through Third Quarter 2010



(Source: NEMA)

One important trend affecting lighting control is that large companies with many locations – be they office buildings, stores, restaurants, warehouses, etc. – are not only interested in reducing their energy costs, but also in the ability to monitor energy use remotely from a central location. Some companies are starting to require that all eligible facilities enroll in demand-response programs.

California's CalGreen building code has now required daylight harvesting. It will be interesting to see how long it will take other states to follow California's lead on this. 2012 IECC does have some requirements for daylight harvesting, but it will be a couple of years before any states adopt this version of the model code.

California is not the only state paying attention to energy efficiency, though progress is not easy for all to achieve. The following are examples of a failed effort from the state of Washington, which is located in the more progressive Pacific Northwest, and a successful initiative in Georgia, part of the Southern region not typically known for its attention to energy efficiency or conservation issues.

2.5.1.3.3. *State of Washington*

The Washington Schools Energy Efficiency Projects (Referred Bill 52) was defeated by 53.8% of the vote on November 2, 2010. The bill would have provided $500 million in bonds for energy efficiency projects in K-12 schools.

Proponents said the bill would create 38,000 jobs and result in a permanent reduction in energy bills. Opponents countered that not only was the job creation claim overestimated, but that too much of the bill was effectively borrowing money to pay for "disposables" like light bulbs. In the anti-stimulus environment that prevailed in the United States on election day, this was seen as just another case of taking on additional debt for matters viewed as not important enough.

2.5.1.3.4. *State of Georgia*

An amendment to the Georgia constitution was approved by 60.8% of the voters in the November 2, 2010 election.

Amendment 4: Shall the Constitution be amended so as to provide for guaranteed cost savings for the state by authorizing a state entity to enter into multiyear contracts which obligate state funds for energy efficiency or conservation improvement projects?

The state constitution previously included a ban on multi-year state contracts.

Proponents pointed out that the state is paying utility bills for 15,000 buildings, many of which are old and inefficient, and that allowing multiyear contracts for energy efficiency projects could save the state millions of dollars with no cost to taxpayers. They claimed that the program could save the Georgia government as much as $225 million a year, and that the resulting retrofit work would add 7,500 to 11,500 jobs to Georgia's labor market.

Opponents, in addition to stating that there was no need to amend the constitution for something like energy saving projects, claimed that it was better policy to be able to review vendors more frequently. They also expressed concern about red tape and administrative hurdles for local governments to undertake any kind of energy saving project.

2.5.1.4 *Federal Funding – American Recovery and Reinvestment Act*

The American Recovery and Reinvestment Act (ARRA) of 2009 included approximately $16.8 billion for the DOE's energy efficiency and renewable energy programs, including:

- $6.3 billion for energy efficiency grants to states, local governments, and Indian tribes to reduce energy usage and increase energy efficiency, including in government buildings.
- $346 million for building energy efficiency, including $53.5 million specifically targeted for the commercial buildings initiative. This overall effort includes the development, deployment, and use of energy-efficient technologies in commercial buildings.

In addition, ARRA 2009 provided funds for improving energy efficiency in 500,000 government buildings. Lighting accounts for about 50% of the projected energy savings.

- $4.5 billion to the GSA for renovations and repairs to federal buildings focused on increasing energy efficiency and conservation. By 2015, existing buildings must use 30% less fossil energy compared to 2005 levels. New buildings and major renovations must use 55% less fossil energy than 2003 levels by 2010, and use no fossil energy by 2030.
- $4.2 billion to the Department of Defense to invest in energy efficiency projects and to repair and modernize facilities.

- $1 billion for repairs, including energy efficiency projects, at Veterans Administration medical facilities.
- $884 million to be used for construction activities and energy retrofits at the U.S. National Park Service, U.S. Fish and Wildlife Service, and the Bureau of Land Management.

ARRA also provided:

- $8.8 billion to fund renovation, repair, and modernization of education facilities. These measures are to follow the guidelines of one of four recognized green building rating systems.
- $2.4 billion of Energy Conservation Bonds issued to states to finance a variety of projects that reduce energy use.

Of course, not all of the funds listed above go toward energy efficiency improvements, and not all of the funds spent on energy efficiency will be on lighting systems. However, Pike Research has included this information to draw attention to the scale of the funds that are being made available to the market in just the next couple of years. Lighting has always been seen as “low-hanging fruit” for energy efficiency and a good percentage of this bump in funding will certainly go toward lighting projects.

2.5.1.5 Ratepayer- and Utility-Funded Programs

Ratepayer-funded programs represent an increasing source of funding for energy efficiency upgrades. These are usually mandated by regulators in each particular state. In addition, individual utilities are sponsoring efficiency programs with their own funds as a way to avoid the capital costs associated with building new generating capacity or the financial risk of having to purchase power on the spot market.

Such programs most often provide a range of cash incentives to customers who implement energy-saving measures. The simplest type is known as Prescriptive Incentives. These are usually set rebates for purchasing a specific product, such as a new fluorescent fixture and lamps or a high-efficiency electric motor, to replace an older version. Rebates may provide a certain dollar figure for each dimming ballast or each occupancy sensor installed. For example, in northeastern Illinois, ComEd is offering rebates for occupancy sensors of $0.09 per watt controlled.

Custom rebates are also usually available for more far-reaching system upgrades. In these cases, the customer presents a design that the administrator evaluates for its energy-saving potential. A rebate is determined based on the projected savings.

Despite the significant amount of lighting upgrade activity in recent years, there is still plenty of opportunity to save energy and, over the longer term, money by updating lighting systems. Rebates tend to pay about 25% of the cost of the retrofits, many of which would not be undertaken otherwise. As much as 90% of the current rebate activity is associated with lighting upgrades. Importantly, these savings are available through the use of well-understood and mature technologies such as T8 and T5 fluorescent lamps with electronic ballasts.

2.5.1.6 Rebate and Incentive Program Information

A number of sources of information on types of funding and rebate programs are available in different parts of the United States. The most comprehensive is the Database of State Incentives for Renewables & Efficiency, commonly known by its acronym, DSIRE. (The DSIRE web site also provides information on federal programs.)

The website for California's Flex Your Power energy conservation program provides, among other information, links to a range of incentives and rebates available for both commercial and residential buildings. These include both government- and utility-sponsored programs. Some of these are targeted grant or loan programs that focus on, for example, upgrades for elementary schools.

2.5.1.7 Green Building and Certification

By 2013, McGraw-Hill Construction projects that the green building market in the United States will grow to 25% of all new construction starts by value, equating to a $140 billion market. Not all of these projects will be certified by a green building rating system, but many will be. At a minimum, rating systems like the U.S. EPA's ENERGY STAR for Buildings and the USGBC's LEED have greatly raised awareness of green building.

ENERGY STAR is the most commonly used rating system in the United States. Its focus is on energy, so it is narrower in scope than LEED. ENERGY STAR has special programs for Healthcare, Hospitality, Retail, Congregations, and Small Businesses – among others. As of January 2011, there are over 12,800 ENERGY STAR qualified buildings in the United States, more than 33,000 LEED registered projects, and more than 7,300 LEED certified buildings. In addition, LEED is referenced in dozens of laws, policies and incentives in at least 34 states, 138 cities and 14 federal agencies and departments.

A few years ago, the U.S. General Services Administration (GSA), which is effectively the federal government's landlord, initiated a requirement that all new construction and renovation projects in buildings owned or leased by the GSA would have to attain LEED Silver certification. In November 2010, the GSA increased its minimum requirement to LEED Gold for owned buildings. The requirement for leased buildings remains at LEED Silver.

LEED also has rating systems specifically for Schools, Healthcare and Retail. Many school districts are looking to LEED for Schools certification when new buildings are being constructed, and this is helping to drive the use of advanced lighting and controls into the Education segment.

2.5.1.8 Federal Markets

Government buildings make up a large percentage of the Office category. As mentioned above, the GSA has implemented aggressive energy efficiency programs for its existing and new buildings.

Despite the current generous allocations of federal dollars to energy efficiency programs, not all facilities have the funds to pay for complete lighting retrofits in any particular budget year. Energy Savings Performance Contracts allow federal agencies to accomplish energy-saving projects without up-front capital costs and without special Congressional appropriations. The contractors are paid out of the resultant energy cost savings. This is the government version of performance contracting, which has been available in the private sector for some time now.

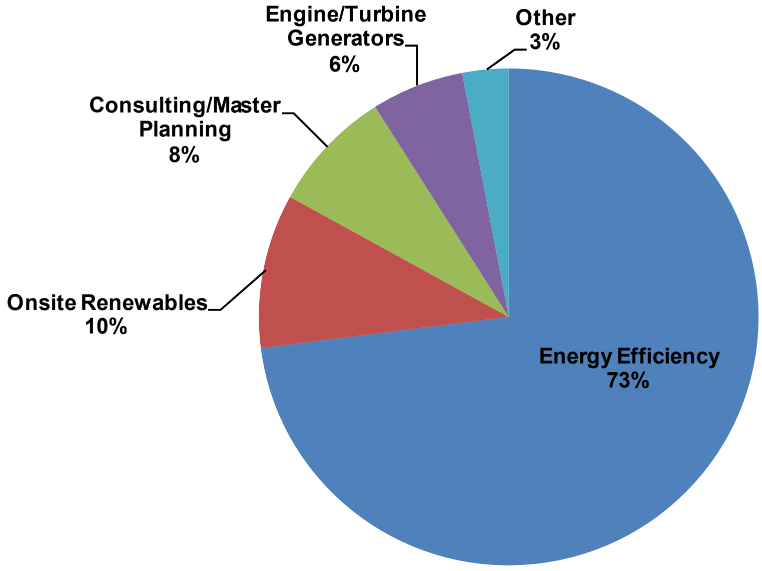
With the slow economy of the last few years, the government has been the primary growth market for lighting controls.

2.5.1.9 ESCOs

The U.S. ESCO market has been operational since the 1970s and has expanded to encompass the full suite of energy-efficient services and products, as well as evolving renewable energy services and products.

The National Association of Energy Service Companies (NAESCO) defines an ESCO as a "business that develops, installs, and arranges financing for projects designed to improve the energy efficiency and maintenance costs for facilities over a seven to 20 year time period." Although the ESCO industry does not work exclusively on energy efficiency projects, this type of project does account for the dominant share of the business.

Chart 2.2 ESCO Industry Revenue by Technology or Project Type: 2006



(Source: Pike Research)

In 2006, almost 60% of ESCO business was in the Municipal, University, School, and Healthcare (MUSH) sector. The major point of penetration was schools, including both K-12 and post-secondary institutions. The ESCO federal market is also very strong. This sector has legislation and a financing mechanism in place to enable Energy Service Performance Contracts in federally owned buildings with no up-front capital costs.

The primary means for a commercial building to obtain a high level of energy efficiency is through Energy Performance Contracting (EPC). About three-quarters of ESCO projects are performance-based, as opposed to design/build contracts. Through this mechanism, building owners are provided a turnkey service contract, supplying them with an all-encompassing suite of efficiency, distributed generation, and renewable energy source services, as well as guaranteed savings. These provisions are customized, and each building receives all or some of the services provided by the industry, including but not limited to: HVAC units, efficient lighting, demand response, and utilization of sustainable materials. This customization is an important feature, as each commercial building is inherently different with regard to square footage, age, and geographic.

At present, the industry is riding the stimulus wave. The peak of the ARRA-funded business will appear in 2012, so the year-to-year growth rate from 2011 to 2012 will be greater than 20%. Many in the industry think this peak will arrive sooner, but Pike Research believes the ARRA funding will take longer than expected to work its way through the system. Beyond 2012, ESCO growth in the United States will remain strong.

To date, most ESCOs have been unable to do much with lighting control systems. Many of them tend to sub-contract the lighting portion of the project to electrical contractors or lighting companies that may not have much expertise with controls.

2.5.1.10 Distribution

The lighting controls business in the United States relies heavily on manufacturers for information. Architects, consulting engineers, and even lighting designers are generally not inclined to become lighting control system experts. The products and systems themselves are usually sold through electrical distributors and purchased by the electrical contractors according to specifications provided by the prime contractor on the project.

2.5.2 Canada

2.5.2.1 Legislation and Regulation

Building-related policies in Canada are often established at the national level, with enforcement left to the provinces and territories. Canada has two codes related to building energy efficiency: the Model National Energy Code of Canada for Buildings (MNECB) and the Model National Energy Code of Canada for Houses (MNECH). These codes were based largely on ASHRAE 90.1-1989, and are due for an update in 2012. Stricter codes, however, are in effect at the provincial/territorial level. Some provinces, including Newfoundland, Labrador, and Prince Edward Island, leave jurisdiction of building codes up to municipalities. In Ontario, however, municipalities are not authorized to adopt codes other than the Ontario Building Code.

2.5.2.2 Government Funding for Energy Efficiency

In the past, the Canadian government has offered few tax-based incentives to stimulate green buildings and energy efficiency, though these are becoming somewhat more common. Rebates and grants are more typical financial mechanisms for promoting green building in Canada. Hundreds of millions of dollars are aimed at energy efficiency retrofits in all sectors, including residential, commercial, and industrial. The Commercial Building Incentive Program (CBIP) has dispensed $40 million in incentives to more than 900 buildings in Canada, and was in use in 18% of new commercial and institutional floor space in 2005.

2.5.2.3 Green Building Certification

The USGBC version of LEED has been available in Canada since 2002. In 2004, the Canada Green Building Council launched LEED Canada, with slight modifications to adapt LEED to the Canadian market. Six certification programs are available, similar to the offerings in the United States: LEED Canada for New Construction (NC), Commercial Interiors (CI), Core and Shell (CS), Existing Buildings (EB), Homes (H), and Neighbourhood Developments (ND).

In the province of Alberta, both Edmonton and Calgary require publicly funded buildings to achieve LEED Silver certification. In 2007, the federal government of Canada committed to LEED Gold standards for all new buildings. As of January 2011, more than 280 Canadian buildings have registered with LEED and over 100 have achieved certification.

Green Globes, another certification program, emerged from the development of BREEAM Canada, a program that was under development in the 1990s but never implemented. The Building Owners and Managers Association (BOMA) Canada has adopted Green Globes as an approved green building standard under the name BOMA BESt/Go Green. More than 1,100 buildings throughout Canada have been certified under BOMA BESt, primarily office and other commercial buildings.

Toronto developed the Green Building Standard, a type of voluntary guideline/standard program that applies to low-rise non-residential, low-rise residential, and all mid- to high-rise buildings in the city.

2.5.3 Europe (General)

Within Europe's business community, there is a great level of awareness of the need for energy efficiency; commodity prices are rising steadily and the distribution costs for electricity are increasing. However, the general public, and corporate and civic leadership are generally not aware of the capabilities of today's energy efficiency technologies. Despite this, the understanding of sophisticated control systems is better in Europe than in North America. One observer commented that in this regard, most of Europe is like the average of the most progressive U.S. states.

Due to aggressive regulations, carbon counting is much more important in Europe than in North America and most other regions. One project manager for a controls company said that European customers often ask for verified carbon reduction figures while U.S. customers hardly ever ask about anything like that.

Construction practices in Europe also vary from other parts of the world: Buildings in Europe are built to last, and most are made of stone, brick, or stucco; wooden homes are relatively rare. In fact, the brick industry in Germany claims better than an 80% share of new construction. Moreover, some countries like Switzerland have very strict regulations in place for most building projects. These factors limit retrofit options in the region, and it is common in some areas to see wiring on the outside of the walls. Consequently, wireless control systems have a great appeal in Europe. In some cases, no other options exist to retrofit controls into a building, so despite the complexities, some companies are willing to try to make wireless solutions work.

Europe has long had a general preference for open architecture in technology markets. (The success of GSM cellular is a prime example of this.) This is a major reason why systems based on the DALI standard have a strong appeal in this region. However, proprietary systems developed by Lutron and others have also found success in Europe.

One control supplier commented on how common it is for their technical staff in the United States to work directly with designers and complete the design of the lighting control system from end-to-end. Vendor technicians also tend to be much more involved in the installation and commissioning process. He contrasted this to the situation in Europe, where contractors are often more experienced and possess more extensive skills. The products are viewed as puzzle pieces, he said, and the technicians in Europe are better able to put them together to make the whole system work.

2.5.3.1 EU Legislation and Regulation

The European Union (EU) estimates that about three-quarters of the lighting in use in Europe is outdated or inefficient compared to the products readily available today. During the past decade, the EU has passed a number of directives to promote energy efficiency in general and the adoption of more efficient lighting technologies in particular.

2.5.3.1.1. *20-20-20*

In March 2007, the leaders of the EU member states agreed that it was necessary to take an integrated approach to climate and energy policy. Their goals were to increase the EU's energy security, strengthen its business competitiveness, and combat climate change. They established a set of aggressive targets and set a deadline of 2020 to meet them. The targets are:

- A reduction in EU greenhouse gas emissions of at least 20% from 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved through improved energy efficiency

In January 2008, the European Commission proposed legislation to codify what had become known as the "20-20-20" targets. The European Parliament and Council agreed to this 'climate and energy package' in December 2008 and it became law in June 2009. The core of the European Union 20-20-20 legislation package comprises four pieces of complementary legislation:

- A revision and strengthening of the Emissions Trading System (ETS), the EU's key tool for cutting emissions cost-effectively
- An 'Effort Sharing Decision' governing emissions from sectors not covered by the EU ETS, such as transport, housing, agriculture, and waste
- Binding national targets for renewable energy that will collectively lift the average renewable share across the EU to 20% by 2020 (more than double the 2006 level of 9.2%)
- A legal framework to promote the development and safe use of carbon capture and storage (CCS)

The climate and energy package creates pressure to improve energy efficiency but does not address it directly. Instead, this is done through the EU's energy efficiency action plan, which is composed of the following directives and rules, as well as extensions.

2.5.3.1.2. *Buildings*

Directive 2002/91/EC set minimum standards for the energy performance of new buildings and major renovations of existing buildings. It also established systems for the energy certification of buildings. The Energy Performance of Building Directive (EPBD) established a framework and each member state develops its own energy efficiency targets. To comply with the EPBD, office buildings of more than 1,000 square meters must track their energy performance and post an energy efficiency label. The classifications range from A for the most energy efficient building, down to F. In February 2009, a revised version of the EPBD set more aggressive targets. It should be noted that the EPBD does not mandate specific requirements for lighting, so it is still possible to have inefficient lighting systems in buildings. Some countries, however, do have specific regulations for lighting system performance.

Over the last decade, the EPBD has had a significant impact across Europe, resulting in national legislation in France and Germany that supports the use of more energy-efficient lighting through subsidies and other incentives.

Most EU countries have building codes. Some, such as those in Spain, Ireland, and the Czech Republic, are more modern. Others are in serious need of updating.

2.5.3.1.3. *Product Labeling and Design*

The Energy Efficiency Label Directive (98/11/EC) was originally implemented in 1998 to encourage people to purchase products with greater energy efficiency by introducing a system of classification for energy consumption. Labels are required on products and packages, with class A representing the most efficient products and class G the least efficient. For lighting, classes are calculated using lumen output and lamp power input.

The Eco-Design Directive for Energy-Using Products (2005/32/EC) established a framework under which manufacturers of energy-using products are required to design them for increased energy efficiency. The focus is on setting minimum energy efficiency requirements so that products that are unable to meet the requirements will be automatically phased out.

As of September 1, 2009, the European Union had banned many incandescent bulbs; stores are forbidden to buy or import them, though retailers can sell off their remaining stock. Other lighting products that are being phased out include low-efficiency metal halide lamps, low-efficiency high pressure sodium lamps and high pressure mercury lamps.

Over time, the allowed energy classes will become more and more restricted. By September 2012, all clear household lamps on the EU market will have to be at least energy label class C. This will effectively eliminate incandescent lamps from the market, but will still permit some forms of tungsten halogen. In addition, there is a provision for a review of the regulations in 2014, and the intention to enhance the requirement for clear lamps to a minimum of class B in 2016.

2.5.3.1.4. *Ballasts*

Ballast Directive 2000/55/EC established energy efficiency requirements for ballasts for fluorescent lighting. The primary approach was to limit the ballast losses.

2.5.3.1.5. *Energy Services*

The Energy Services Directive (2006/32/EC), first implemented in 2008, eliminates barriers that prevent the efficient end use of energy. Companies that supply energy should promote energy efficiency services, supply information to improve energy efficiency, and must refrain from activity that could hamper energy efficiency.

2.5.3.1.6. *Lighting and Controls*

There are efforts in the EU to bring about harmonized Lighting System Legislation. With lighting still recognized as the low-hanging fruit of energy efficiency opportunities, such legislation represents one of the best ways for the European Commission and member states to achieve their 20% energy savings target by 2020. For the near term, an EU mandate is under development that would require the use of basic lighting controls in commercial and institutional new construction.

2.5.3.2 *EU Funding for Energy Efficiency*

While most of the funding for the EU's energy efficiency initiatives is expected to come from the member states and the private sector, the EU does have its Structural & Cohesion Funds. These are financial resources allocated by the EU to reduce regional differences in income and wealth.

The Structural Funds include the European Regional Development Fund (ERDF) and the European Social Fund (ESF). The budgets of these programs for the six year period from 2007 through 2013 are €201 billion and €76 billion, respectively. The objectives include reinforcing competitiveness, accelerating economic development, and environment protection. Priorities include innovation and the environment.

2.5.3.3 Green Building Certification

The Greenbuilding program is available for buildings in EU member countries. It measures a building's energy consumption in relation to the rest of the country's building stock. It is not used as a design tool, but as a label to certify that the building consumes 25% less energy than the minimum code requirements for a particular country. Like ENERGY STAR, there is only one certification level. Some governments and countries have policies that they will only occupy or rent buildings that have received the Greenbuilding label. Builders that commit to building only to the Greenbuilding standards can apply for certification as an "EU Greenbuilder."

Given the fact that the rating refers to a particular country's regulations, a building that receives the Greenbuilding label in a country with an inefficient building stock may be far more energy-intensive than a Greenbuilding-labeled facility in other countries. Because Greenbuilding labels carry more importance in countries with efficient building stocks, it has been adopted most vigorously in Scandinavia. Many buildings receive both LEED and Greenbuilding certifications. Still, overall adoption of Greenbuilding has been relatively low throughout Europe.

2.5.3.4 Lighting and Lighting Controls

Within the EU, lighting accounts for 26% of the electricity consumption in non–residential buildings. The Caltech Lighting Center, part of the California Institute of Technology, is managing a program to help advance the use of energy-efficient lighting technologies in Europe. Much of this program is focused on increasing the adoption of existing, mature technologies. For example, to date there is relatively little use of daylight harvesting, and estimates state that a minimum of 30% of the energy consumed by non-residential lighting can be saved by using existing occupancy-sensing technology to automatically turn off the lights when a space is unoccupied. Additionally, 60% of installed ballasts in Europe are magnetic, and these are much less efficient than the newer electronic ballasts.

However, the transition to basic controls is progressing more rapidly in Europe than the transition to energy-efficient lighting. Simple measures such as timers and the use of some independent occupancy sensors are already becoming prevalent in new construction.

2.5.4 Germany

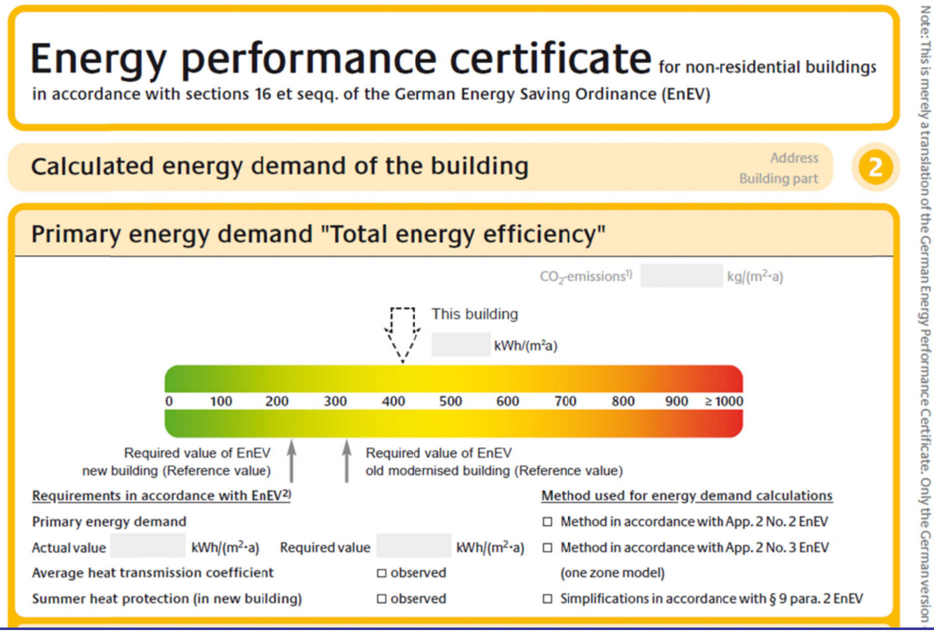
In 2000, Germany launched an environmental sustainability program as part of its commitment to the Kyoto Protocol. Through government initiatives, tax incentives, and loans, the government has encouraged renewable energy use, higher energy efficiency, and the reduction of carbon dioxide emissions. Under the Kyoto Protocol, Germany has been targeting a 21% reduction from 1990 consumption levels by 2012, and a 40% reduction by 2020.

2.5.4.1 Legislation and Regulation

2.5.4.1.1. Energy Conservation Regulations

The Energieeinsparverordnung (EnEV), or Energy Conservation Regulations, is Germany's energy efficiency building code. Considered to be one of the most stringent codes in the world, it establishes standards for insulation, fenestration, building envelope, and HVAC systems. The code was originally passed in 2002 and updated in 2009. Since all residential and commercial buildings must receive an energy performance certificate, the EnEV regulations meet the requirements for the EU EPBD. The energy performance certificate is also required when a building is rented or sold. EnEV is scheduled to be revised in 2012 with new, more stringent efficiency standards.

Figure 2.8 German EnEV Certificate



(Source: EnEV Germany)

While EnEV does not require lighting controls, the energy use of the building being rated is compared against the energy that would be used by a "reference building." The assumptions for the reference building do include the use of occupancy sensors in certain lighting zones.

2.5.4.1.2. National Energy Efficiency Action Plan

The National Energy Efficiency Action Plan (EEAP) of the Federal Republic of Germany was developed to satisfy the requirements of the EU Directive on "energy end-use efficiency and energy services" (2006/32/EC).

One of the provisions for end-use energy savings directly implies the use of lighting control systems, at least at a basic level. "The hours when [electricity, heat and water] are supplied for operating purposes shall be aligned with the hours when these resources are actually required by users to carry out their tasks. This especially applies to ventilation systems and air conditioning equipment, as well as lighting equipment and large-scale consumers. If required, technical aids (building automation, timer switches, motion detectors, etc.) shall be used."

2.5.4.2 Government Funding for Energy Efficiency

The German government has established incentive programs, including low-interest loans and direct subsidies, for residential contractors. Many of these specifically target carbon emissions-reducing programs. Governmental financial incentive programs in Germany focus on the residential sector. The 2007 Energy Saving Ordinance, for example, established incentives for passive and zero-energy houses and created the "Blue Angel" certification for sustainable building products.

2.5.5 United Kingdom

The United Kingdom is a leader in Europe with regard to energy efficiency and carbon emissions reduction. It has a comprehensive set of regulations that follow EU directives.

In the past, the United Kingdom tended to rely more on mandates than on incentives, such as the way it implemented the phase-out of the incandescent light bulb. The downside of this approach is the lack of education to the public regarding the need for and benefits of energy efficiency. The result can be seen in the strong resentment of being forced to use CFLs and the complaints about poor color quality and mercury content. With LEDs not yet a viable alternative due to their high price, consumers are left with no options.

The United Kingdom appears to be changing its ways, somewhat, with the introduction of the more recent carbon legislation. The Carbon Trust was established to provide a wide range of support services, education, and financing to businesses of all sizes and the public sector. However, the country still has work to do on the consumer side.

2.5.5.1 Legislation and Regulation

The United Kingdom has extensive legislation that deals with energy efficiency and climate change. While building codes do not yet require lighting controls, the technology is recognized as a way to increase the energy savings provided by lighting system upgrades and is being installed in commercial spaces.

2.5.5.1.1. Buildings Policy

Energy certificates allow a building's energy performance to be measured consistently and objectively. Certificates grade a building's energy performance on a scale from A to G. There are two types of certificates for commercial buildings:

- **Asset certificates** (Energy Performance Certificates, EPCs) measure the *expected* energy performance of the building *based on its design*. EPCs need to be renewed every 10 years. They must be available at the time of sale of the building, or at the time of leasing and lease renewal.
- **Operating certificates** (Display Energy Certificates, DECs) are based on *metered energy* usage, so they represent the building's *actual performance*. DECs are required for public sector buildings with a usable floor area greater than 1000m². They must be displayed publicly and need to be renewed annually.

2.5.5.1.2. Building Regulations

U.K. building regulations were revised in 2006 to comply with the EU directive on the energy performance of buildings (EPBD). Consequently, Part L, which applies to new construction and to the renovation of existing buildings that exceed 1,000 m², was revised to establish maximum carbon dioxide emissions for whole buildings. For new construction, Part L reduced carbon emissions by 25% from 2002 standards (which had reduced emissions by 15% at the time). The current version of Part L is less prescriptive than previous versions, providing building designers with a degree of flexibility in their approach toward achieving the emissions target.

In December 2006, the U.K. government announced that all new homes and schools would be net-zero carbon by 2016, government buildings by 2018, and all other commercial buildings by 2019.

2.5.5.1.3. *Climate Change Act and The Carbon Trust*

In November 2008, the United Kingdom adopted the Climate Change Act. The Act set a carbon reduction target for an 80% reduction in carbon emissions from 1990 levels by 2050. An interim target of a 34% reduction by 2020 was also established. In addition, the Act defined carbon budgets.

At the same time, the U.K. government established The Carbon Trust to help businesses and public entities reduce their emissions. "The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to help business and the public sector cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key U.K. goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs."

2.5.5.1.4. Carbon Reduction Commitment Energy Efficiency Scheme

The Carbon Reduction Commitment Energy Efficiency Scheme (CRC) is a carbon emissions reporting and pricing scheme that is mandatory for all organizations that use more than 6,000 MWh of electricity annually. The CRC was initiated in April 2010 to reduce carbon emissions from sources that are not covered by other U.K. legislation. Its focus is on sectors in the U.K. economy other than the major energy-intensive industries.

Organizations participating in the CRC will be required to measure and report their carbon emissions on an annual basis. The first annual report will be due in July 2011. Starting in 2012 and ensuing years, participants will buy allowances from the U.K. government to cover their emissions in the previous year.

Participating organizations will be in public competition with one another. Taking a cue from the sporting world, a CRC "performance league table" will display each participant's performance in comparison to other organizations. The thinking is that a high ranking in the league table will "give a significant boost to your organisation's reputation, demonstrating its success in cutting emissions."

2.5.5.1.5. Climate Change Levy and Agreements

The Climate Change Levy (CCL) was introduced to encourage energy efficiency. CCL is a charge placed on energy usage by business and the public sector. Climate Change Agreements (CCAs) provide discounts on the levy to energy-intensive organizations of 80%, if they are able to achieve established energy efficiency targets and carbon dioxide emissions reduction targets.

2.5.5.2 Financial and Other Support

The Carbon Trust provides financial support to small and midsized businesses, such as 0% business loans of £3,000 to £100,000 to help companies invest in energy-saving projects. In addition, The Carbon Trust Entrepreneurs Fast Track was established to support early-stage low-carbon, cleantech companies. The program provides expert advice in the form of consulting services, for which The Carbon Trust will fund up to £70,000. It also makes grants of £20,000 to £500,000 to cover a share of research and development costs, as long as the recipient can show where the remaining funds will come from.

The London Green Fund is setting up a £50 million energy efficiency Urban Development Fund (UDF). This UDF can make loans for energy efficiency retrofits for public and voluntary sector (nonprofit) buildings and social housing.

The U.K. government also has an Enhanced Capital Allowances program that provides a 100% first-year tax relief on the purchase of energy-saving equipment.

The Better Buildings Partnership (BBP) was created in 2007, and is a partnership between London's leading commercial property owners and organizations such as Transport for London and the London Development Agency. The BBP's goal is to help improve the sustainability and energy efficiency of London's existing building stock. It has a green lease program, provides guidance for the financing of retrofits, and offers a Green Building Management Toolkit.

2.5.5.3 Green Building Certification

The first widely recognized green building certification program originated in the United Kingdom. It was developed by the Building Research Establishment (BRE), a private-sector organization that addresses not only green buildings but also other aspects of building performance and quality. The Building Research Establishment Environmental Assessment Method (BREEAM), which dates back to 1995, has influenced many green building certification programs around the world, including the more internationally recognized LEED. Like many of the programs that have used it as a blueprint, BREEAM assigns points to certain green building measures and tallies them up to certify that a building has achieved a recognizable, measurable level of efficiency. Variations of BREEAM have been adopted by countries throughout Europe and in other parts of the world.

BREEAM subdivides its certification into a wide range of commercial and residential applications, including Offices, Industrial, Healthcare, Multi-Residential, and Retail. It offers five levels of certification: Pass, Good, Very Good, Excellent, and Outstanding. BREEAM does not have criteria that specifically require intelligent lighting controls. Health & Wellness (HEA) 6 credit, Lighting Zones and Controls, requires that "Lighting is zoned to allow separate occupant control" of specified areas. The emphasis is on zoning, and standard switches qualify as control.

Lighting controls, to the extent that they reduce energy consumption, would primarily come into play in the Energy (ENE) 1 – Reduction of CO_2 Emissions section, which is worth up to 15 credits.

2.5.6 Other European Countries

The Scandinavian countries, and Sweden in particular, are strong supporters and implementers of energy efficiency. In fact, there have been comments that LEED would not be relevant in Sweden since LEED Platinum is pretty much the baseline for all building in the country.

For its part, France has passed legislation requiring energy efficiency upgrades, especially in the public sector, and a number of competing green building certification programs have been developed in the country. However, adoption of energy efficiency is still slow, largely because the price of electricity is much lower than in Germany and other European countries. (France derives more of its electricity from nuclear power than any other country.) In addition, France's building codes are not up to modern standards.

Spain falls within the average ranks in the EU as far as promotion and support of energy efficiency. The country established a Lighting Center in Barcelona, and lighting controls is one of four thrust areas. The Center recognizes that basic controls are inexpensive, easy to implement, readily available, and provide good financial payback. However, government and industry efforts to expand the use of lighting controls are not sophisticated enough, and more could be done.

Lighting controls are in use throughout Europe, including in Eastern Europe. One engineer in Poland confirmed that DALI digital controls are working in a number of buildings there. There is also high interest in implementing energy-saving technologies, and business people, at least, recognize that lighting controls can play a role.

Unfortunately, many European countries, especially those in Eastern Europe, are not yet able to mount efforts in support of energy efficiency that are as well organized as some of the leading EU member states. In a recent interview, the chairman of the Bulgarian National Committee for Industrial Energy, a nongovernmental industry organization, was quite critical of the country's new energy efficiency laws. The problems his comments describe are likely typical of nations in similar stages of economic development not only in Europe, but also other parts of the world.

- "Laws are being developed and voted on without the presence of a national energy efficiency strategy."
- "We have legislation with very strong administrative, bureaucratic and sanctioning character, but there are no incentives. This is contradictory to European practice in this field."
- "It is a mistake that there is nothing about energy efficiency standards in this variant of the law. They are widely used in European practice as an efficient measure for effecting and managing energy efficiency."
- "The law stresses programs, plans and reports of economic measures, but there is nothing about energy efficiency management or about management of energy consumption."
- "In the whole text there is still no word about credit lines for financing energy efficiency, which are very important for the implementation of these activities."

2.5.7 Asia Pacific (General)

Governments within the Asia Pacific region are making progress at driving the energy efficiency market with green building design guidelines, the introduction of new energy efficiency technology, and funding schemes to assist retrofit projects. Within the majority of the region, however, controls focus far more on HVAC systems than lighting.

In general, there is not much demand for higher-end commercial control systems and there is not as much concern for the aesthetics of control schemes as in some more developed regions. In all but the very highest profile buildings, using the most basic functionality needed to achieve cost savings is the overriding objective. While demand for lighting controls has been on the rise, most of the business goes toward less sophisticated systems that use open protocols and simple, less expensive control schemes. Where dimming is used, 0-10VDC analog ballasts dominate.

2.5.8 Japan

By far the most mature economy in the region, Japan is the glaring exception to the preceding comments. Some Japanese companies are among the leaders in providing control systems, and the rate of control deployment is very high. Moreover, buildings in the country tend to have a shorter lifespan than buildings in other countries. As a result, new construction plays a more prominent role in the Japanese construction industry than in other developed countries and creates a favorable environment for green building.

There is also a strong energy retrofit industry in Japan. A number of ESCOs have been in operation for many years, and the industry makes good use of Energy Savings Performance Contracts. The newer financial model of shared savings agreements is also catching on.

Within the commercial sector, hospitals, hotels, and supermarkets represent major energy consumers and are therefore promising opportunities for energy retrofits, as are major retailers. Almost all Japanese department stores have faced a severe slowdown in business due to the country's economic stagnation. In fact, approximately 90% of Japanese department stores have recorded losses over the last 10 years. This market situation has been driving corporate management to implement comprehensive retrofits for energy conservation.

2.5.8.1 Legislation and Regulation

Regulations concerning energy use in buildings are becoming progressively more stringent. Most of Japan's regulation with respect to energy efficiency focuses on prescription rather than incentives. Industry sources cite a shortage of subsidies for green building measures as a barrier to the growth of sustainable building in Japan, though some incentive programs do exist. For example, some municipalities allow additional floor space (beyond what zoning laws might permit) for buildings that achieve a high Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) rating. Still, many landlords and tenants in Japan face strict energy efficiency requirements without much government assistance.

Japan's Energy Conservation Law came into effect in 2003. The law established stringent requirements for energy efficiency and control systems in commercial buildings. It was updated in 2006 with further regulations, including a requirement that commercial buildings with a total floor space of greater than 2,000 m^2 provide a record of conservation measures taken in the building.

As of April 2010, the Japanese government required owners of certain types of commercial and residential buildings measuring over 2,000 m^2 to meet energy efficiency baselines during new construction and major renovation projects. The building owner risks a fine if documentation fails to show compliance with these minimum requirements.

2.5.8.2 Green Building Certification

In 2001, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) initiated a project to create a certification system to evaluate the environmental performance of buildings based on Japanese environmental factors. A diverse set of organizations, including the Japanese government, industrial companies, and academia, worked together to develop the CASBEE. CASBEE was first launched in July 2003 through the Japan Sustainable Building Consortium (JSBC).

The CASBEE system provides third-party-verified certifications for buildings that are environmentally responsible. There are currently 12 CASBEE tools for different building types and lifecycle stages. The tools include CASBEE-NC for New Construction, CASBEE-EB for Existing Buildings, and CASBEE-RN for Renovations. As of January 2011, 119 commercial buildings have been certified under CASBEE-NC, EB or RN.

2.5.8.3 Financial Support for Energy Efficiency

The Japanese government supports small and medium enterprises (SMEs) through favorable financing conditions that provide access to special funds for the initial cost of the retrofit, energy efficiency engineering, and the purchase of measuring equipment. In addition, the Development of Bank of Japan and Japan Finance Corp., a public corporation wholly owned by the government, help Japanese clients find lenders for building efficiency retrofits and ESCO projects.

In Japan, the cost of energy efficiency equipment and energy management systems can be used toward a partial tax deduction or depreciated under a special accelerated schedule.

2.5.9 India

Lighting consumes about 22% to 25% of the electricity in commercial buildings in India, about the same as in most developed nations. Green building in the country, particularly with regard to energy efficiency, is driven by the new construction market. With the exception of historic buildings, it is normally assumed that older buildings will not be around long enough to make extensive retrofits pay off.

A lack of high-quality contractors in the country, especially ones qualified to work on more complex systems like lighting controls, is a common issue, but is not unique to green building projects compared with the overall construction industry.

While the ESCO industry has been operating in India for a number of years, it is now beginning to grow rapidly. Pike Research projects that ESCO revenue in India will grow at a CAGR of 52.8% from 2009 to 2015, making it the fastest-growing ESCO market in Asia Pacific. ESCO revenue was approximately $50 million in 2010.

2.5.9.1 Legislation and Regulation

In India, the Bureau of Energy Efficiency (BEE) is the primary organization that handles national energy efficiency policies and issues, including those related to building spaces. BEE promotes energy efficiency measures in accordance with the Energy Conservation Act of 2001, the legislation that created the organization.

The first code, the National Building Code of India (NBC 2005), minimally addressed energy. The Ministry of Power and the BEE established the Energy Conservation Building Code (ECBC) in 2007. Although voluntary, it is likely to become mandatory at the state level in parts of India. It operates in much the same way as the most advanced U.S. code (ASHRAE 90.1-2007), though it is slightly more stringent in terms of the building envelope. A number of elements in the ECBC directly address lighting and lighting control. For example, the following sections are part of the mandatory requirements for compliance with the code. Section 7.2.1 deals with lighting control. (Since this information is included as an example and not a reference, the text is edited for brevity.)

Automatic Lighting Shutoff: Interior lighting systems in buildings larger than 500 m^2 shall be equipped with an automatic control device. Within these buildings, all office areas less than 30 m^2 enclosed by walls or ceiling-height partitions, all meeting and conference rooms, all school classrooms, and all storage spaces shall be equipped with occupancy sensors. For other spaces, this automatic control device shall function on either a scheduled basis at specific programmed times or via occupancy sensors that turn off the lighting within 30 minutes of an occupant leaving the space.

Control in Daylighted Areas: Luminaires in daylighted areas greater than 25 m^2 shall be equipped with either a manual or automatic control device that is capable of reducing the light output of the luminaires in the daylighted areas by at least 50% and controls only the luminaires located entirely within the daylighted area.

Additional Control: The following lighting applications shall be equipped with a control device to control such lighting independently of general lighting:

- Display/accent lighting
- Display case lighting
- Hotel and motel guest rooms and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles
- Supplemental task lighting
- Lighting for non-visual applications, such as plant growth and food-warming

The Bachat Lamp Yojana PoA was developed by BEE to promote energy-efficient lighting in India. The program was announced in May 2007 and launched in February 2009. There are no mandates in India requiring the use of energy-efficient lighting, but voluntarily participation levels appear to be good so far. The program is a part of the United Nations Framework Convention on Climate Change (UNFCC) Clean Development Mechanism (CDM), which supports emissions-reduction efforts in developing countries.

2.5.9.2 Green Building Certification

For a developing country, India's green building movement has gained quite a bit of momentum.

The Indian Green Building Council (IGBC) certifies green construction in India. S. Srinivas, principal counselor at IGBC recently said, "About 2% to 3% of all construction in India is green, as good as [in] the United States. In the next two or three years, we want to bring it up to 10%, which will put us on top." As of January 2011, the IGBC has more than 830 registered buildings and more than 134 certified buildings with over 530 million ft^2 of green building space.

LEED has also gained a strong foothold in India. As of January 2011, there are more than 200 projects registered with LEED and at least 66 LEED certified buildings.

2.5.10 Australia

The largest demand potential in the property industry is in the renovation and retrofitting of existing buildings. Roughly 2% of building stock is substantially refurbished every year.

Market attention in the building energy efficiency markets has been focused on green building certification in Australia. However, the country will pay more attention to retrofits and efficiency measures provided by ESCOs for existing building spaces over time. The Australian ESCO industry is healthy, and growing at a moderate pace. For 2010, ESCO revenue in Australia was approximately $90 million.

2.5.10.1 *Legislation and Regulation*

Australia has robust and systematic government policies and national programs to enhance energy efficiency in the country's buildings. The National Strategy for Energy Efficiency, for example, aims to improve minimum standards for energy efficiency, accelerate the introduction of new technologies through regulatory incentives, and address identified barriers to improved energy efficiency. Moreover, all levels of government will increasingly mandate Green Star standards and government agencies will demonstrate green leadership by operating from Green Star-certified buildings and tenancies.

Presently, Australia has a range of national and state energy efficiency policies. These policies involve many different initiatives, from the provision of information to consumers and regulation of minimum standards, rebates, and grants to the use of state-based targets.

Australia's Building Energy Efficiency Disclosure Act 2010 required that as of November 1, 2010, most sellers or lessors of office space of 2,000 m^2 or more are required to obtain and disclose an up-to-date energy efficiency rating at the point of sale, lease, or sublease. The most common rating is NABERS, a government-run benchmarking tool that evaluates a building's energy, water, indoor environment, and waste characteristics. Owners also obtain a Building Energy Efficiency Certificate (BEEC), which provides a detailed energy profile.

Pending legislation could also drive significant demand for energy efficiency in buildings on a national scale, including the probable Australian Carbon Trading Scheme.

Section J of the Australian Building Code has several requirements concerning lighting and controls that must be followed, but there is room for the electrical engineer to interpret these requirements.

2.5.10.2 *Green Building Certification*

A number of drivers are responsible for Australia's growing interest in green building:

- Energy costs in Australia are generally rising and a national carbon trading scheme, which would put upward pressure on energy prices, is likely in the near future.
- Many building owners, especially those with large holdings, understand that green standards are going to become increasingly stringent.
- Large Australian and multinational firms are already setting voluntary greenhouse gas reduction targets. A company's real estate portfolio is a major component of its greenhouse gas production.

Developed by the Australian government, Green Star is a comprehensive, national, voluntary environmental rating scheme that evaluates the environmental design and achievements of buildings. Green Star has established individual environmental measurement criteria with particular relevance to the Australian marketplace and environment, and is promoted by the Green Building Council of Australia. As of January 2011, there are more than 250 Green Star-certified projects and at least an additional 125 projects registered.

The most predominant green building-related program in Australia, NABERS, was formerly known as the Australian Building Greenhouse Rating System. It is a government-run benchmarking tool that evaluates an existing building's energy, water, indoor environment, and waste characteristics. Buildings are rated on a scale of 1 to 5, with 5 representing the most efficient buildings.

The average NABERS rating increased from 2.5 in 2005 to between 3 and 3.5 today as better-constructed and upgraded buildings participated in the voluntary phase of the program; however, now that the program has reached a mandatory phase, the average rating is likely to decrease. In the long run, Pike Research expects to see the average move higher once again as older buildings are renovated and better-performing new buildings are constructed. In fact, it is believed that properties in Australia are becoming so much more efficient that it may be necessary to either recalibrate the 5-point NABERS scale or introduce a sixth and possibly a seventh star in the near future.

2.5.10.3 Financial Support for Energy Efficiency

Australia has numerous energy efficiency rebate programs. One example is the Energy Efficiency Trust, which is managed by the Australian Carbon Trust. This initiative supports investments in energy efficiency measures in commercial buildings and other business operations, including efficient lighting, ventilation, heat, and air conditioning; efficient computer systems and other office machines; and transport logistics. The Energy Efficiency Trust covers the up-front capital costs and the business repays the capital costs at a commercial rate. Also of note, the recent Australian stimulus package included an AU$19 million fund that covered up to one-half the cost of green building upgrades.

2.5.10.4 Lighting Controls

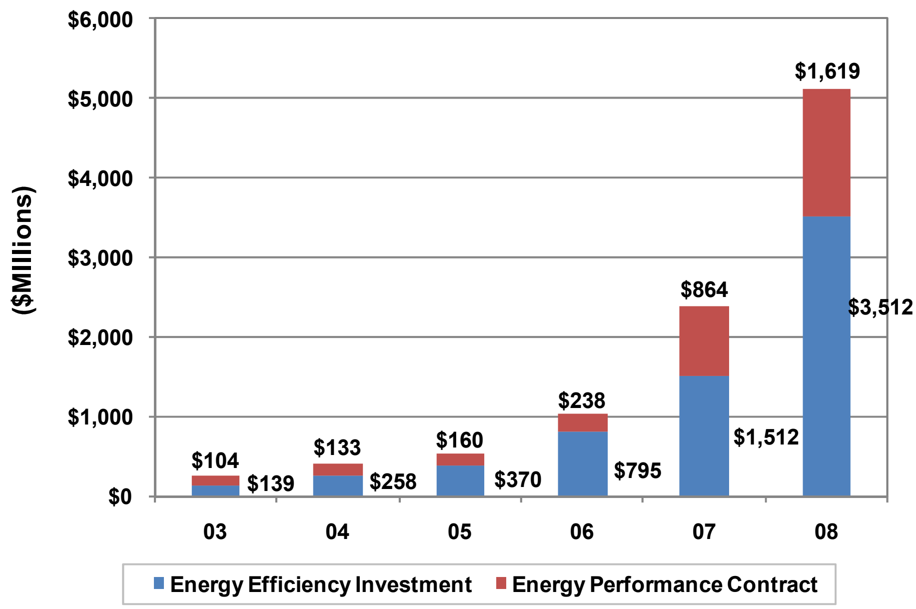
When it comes to the installation of lighting controls in Australia, cost is generally the driving factor for most new construction projects. If the client is prepared to pay for a truly functional system and the consultant has the design intent, the system can be extremely effective. The norm, however, is a compromise that is compliant to the code but in reality nothing more than a sophisticated scheduled system with some more advanced control features for conference rooms and other special spaces.

Government offices have strict energy management requirements and many government buildings, especially in Canberra, the nation's capital, normally have full DALI installations. DALI is extremely popular in Canberra and is slowly being accepted within other states and territories.

2.5.11 China

From the perspective of energy consumption, extensive retrofits are needed in most existing buildings in China. Currently, the government classifies 95% of the country's buildings as "high-consuming." Moreover, Chinese buildings are consuming two to three times more energy per square foot than North American and European buildings. As can be seen in Chart 2.3, Chinese investment in energy efficiency is growing very rapidly.

Chart 2.3 Energy Efficiency Investment and ESCO Revenue, China: 2003-2008



(Source: EMCA)

The construction supply chain in China is not well-adapted to green building. As a result, green building certification, or even building to green building standards remains relatively expensive. Thus, many construction projects require contributions from foreign professionals, marking a costly addition. To address some of these barriers, the governments of China and the United States signed a memorandum of understanding in July 2009 to facilitate informational and technological exchange, including HVAC, insulation, lighting, and on-site renewables.

2.5.11.1 Legislation and Regulation

Green building was selected as one of China's major priority areas in its eleventh Five-Year Plan, as were other energy- and climate change-related issues. According to industry sources, the Chinese government's main interest in green building relates more to energy efficiency than to other green building topics such as materials and indoor environmental quality. The government is targeting a reduction in energy consumption in cities of 65% from 1980 levels by 2020. Comprehensive energy codes aim to control energy consumption in buildings, but compliance and enforcement varies by city and by region since implementation resides with local authorities and measurement tools are not universally available.

In 1986, the Chinese Ministry of Construction (MoC) established an energy code for cold and severe climates. Today, the Chinese National Development and Reform Commission

(NDRC) has established aggressive energy conservation targets for all Chinese buildings. These codes include standards for residential buildings in different parts of China and one standard for public buildings. Although MOHURD (the Ministry of Housing and Urban-Rural Development, which is the current name for the MoC) coordinates and develops China's building codes, day-to-day enforcement occurs at a local level. Consequently, compliance is variable, but is generally better in Shanghai and Beijing, according to a report by Pacific Northwest National Laboratory.

The National Energy Efficient Design Standard for Public Buildings is China's commercial code, implemented on a national level. The objective of the code is to improve indoor air quality and reduce energy use by 50% from 1980s levels. The code focuses mainly on HVAC and the building envelope, however, with little emphasis on lighting. There are also regulations surrounding civil buildings, such as the Regulations on Energy Conservation in Civil Buildings, which was issued in 2008.

2.5.11.2 Green Building Certification

Officially launched in 2007 by MOHURD, the Green Building Design label certifies buildings based on their preliminary design, while the Green Building Evaluation label certifies the building based on its actual performance. These labels consider land use, energy, water, and materials, as well as indoor air quality and performance. As of June 2009, approximately 10 designs had received the Green Building Design label. Since then, however, the Chinese government has certified hundreds of buildings with that label. Given that the program was developed by the Chinese government, it is likely to be the certification of choice for the majority of green buildings in China in the long term. Some international real estate developers have also begun to adopt the Green Building Design label. The program is now more commonly known as the Three Star system, since buildings can be awarded one, two or three stars for different levels of performance.

The Chinese national government is currently in the process of piloting 80 green building projects, each representing one or more Three Star-certified properties. In addition, 17 local government projects have kicked off that will need to achieve either a one or two star rating and a large number of local incentives are also available for green development.

In the future, the Three Star system will follow in the footsteps of LEED, achieving higher levels of rigor – particularly with regard to energy. While the Three Star label requires buildings to achieve energy savings of 65% better than average today, that requirement may jump to 75% in the next iteration. This rising baseline will form a central part of the Chinese government's overall energy targets.

The Three Star system does include a couple of items related to lighting control. (General items are the primary scoring. Preference items are additional and are required for the 2-star and 3-star ratings. Control items are prerequisites.)

- Residential Building General Item 4.2.7 states: For the illumination of a public space, highly efficient light sources and lighting fixtures, and such accessories as low-loss ballasts shall be used, and other energy-saving measures shall be taken. An area with natural lighting shall be equipped with timing or photoelectric control.
- Public Building General Item 5.6.9 states: The automatic monitoring system for ventilation, air-conditioning, lighting, etc. in a building shall have reasonable techniques and efficient operation.

Although not very strict or specific, these represent a start.

Multinational corporations are establishing a stronger presence in Chinese cities, driving demand for LEED certified commercial building space. The majority of LEED certified buildings in China are internationally owned and occupied office buildings. The first LEED certified building was the Century Prosper Center, which was certified under LEED for Core & Shell in 2003. As of January 2011, more than 100 buildings have been LEED certified in China. There are over 500 LEED registered projects in total.

Among property owners, product differentiation is a major driver of green building certification in China, as opposed to environmental concerns or operating cost savings, according to EMSI, a leading green building consultancy in China. Green building certification is being used to reduce building vacancies and increase rent amounts.

2.5.11.3 Lighting Controls

There are no mandatory laws or regulations regarding the use of lighting controls in China, though some people there believe that such rules will eventually be adopted.

Lighting controls are in use in some high-end hotels and office buildings, especially in meeting rooms and similar spaces. And there are very occasional instances of lighting controls installed in warehouses and a few of the largest retail locations.

2.5.12 Other Asian Countries

2.5.12.1 Korea

The Korean government has become increasingly aggressive on the issue of energy efficiency in the past decade. In 2001, the government released its first building energy codes, known as the Building Design Criteria for Energy Saving (BDCES). These codes place caps on energy consumption for certain traditionally energy-intensive building types. Although determined at the national level, the codes are to be enforced by local governments via the permitting process.

Among the provisions of the codes is an incentive known as the “Relaxed Zoning Restrictions on Building Size.” This measure allows buildings that surpass the energy efficiency requirements of the BDCES to exceed the size that the local zoning ordinances would typically allow. The Korean government also offers other incentives, such as low-interest loans, for a wide variety of projects that target increased energy efficiency in buildings and renewable energy installations.

In Korea, private banks are providing special interest rates to help ESCO projects. The loan program covers as much as 80% of the total project cost for conglomerates and large companies, and up to 100% for SMEs.

2.5.12.2 Association of Southeast Asian Nations

ASEAN member countries include Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. As of now, ASEAN countries face one of the highest levels of vulnerability to climate change, in part due to rapid economic growth and urbanization. Thus, ASEAN market participants are paying attention to building spaces, which have the greatest potential for producing greenhouse gas emissions. Due to awareness of the serious threat to their national economies, each country in ASEAN has been embracing comprehensive and actionable measures, such as more sustainable design and energy efficiency retrofits, and preparing for greener building programs.

Overall market development for building energy efficiency is in the nascent stage within the ASEAN countries, especially in the developing countries. However, recent market perception toward ESCOs and retrofit services has become favorable.

In general, there are no mandatory energy codes in ASEAN. For example, Indonesia adopted voluntary commercial energy codes in 1992. The code applies to the building envelope, lighting, and HVAC. Unfortunately, it is believed that the codes are not understood or adhered to by builders and designers in Indonesia.

2.5.13 Middle East

2.5.13.1 Construction Activity

Until just a couple of years ago, before the global recession, the trend in many of the major cities in the Middle East was “conspicuous construction.” No project could be too large or too extravagant, it seemed. This was especially true in the United Arab Emirates (UAE) and Dubai, as well as the largest cities in Saudi Arabia. One local commented that there seemed to be an attempt to turn the oil money into facilities that would attract tourists after the oil money dried up. There was an interest in being green, as much as that is possible in the context of such extravagance, but there also seemed to be an underlying assumption that there would always be plenty of energy to run the buildings. While construction slowed along with the economy, some projects continued; these are still grand, but in a “more conservative” way.

The construction industry in the UAE was hit especially hard in recent years. Office buildings had been one of the key business sectors for green building, and this part of the industry faced a severe drop in activity. More recently, UAE construction activity has been focused on large government projects in the areas of infrastructure and transportation. Beyond this, hotels represent the strongest construction sector in the Middle East, especially around the Persian Gulf. A recent survey by tophotelprojects.com revealed that more than 110 first class and luxury hotels have opened in the Middle East within the past two years alone. In 2011, 286 hotels are expected to open their doors, representing a total room count of 84,100. In addition, there are currently about 200 other hotel projects under construction or development. This activity will likely continue for some time in anticipation of the 2022 FIFA Football World Cup in Qatar.

Building owners in the region have been facing increased vacancy rates. With that kind of financial stress, capital for new building initiatives will be harder to find, putting a damper on demand for energy efficiency technologies.

2.5.13.2 Saudi Arabia

The Saudi Arabian government has been the primary force behind the green building movement in that country. However, Saudi Arabia lacks significant regulations and incentives for green building. Building standards are designed without consideration of sustainability, prompting little activity outside of government projects.

The government recently drafted a preliminary green building guide and is in the process of developing green building standards. Since the government is responsible for most major construction projects in Saudi Arabia, these standards are likely to lead to a boom in green projects. Additionally, the government has announced that it intends to invest $135 billion in development, infrastructure, water, and electricity over the next 6 years, much of which may involve green building projects.

2.5.13.3 *Green Building Certification*

Until recently, BREEAM and LEED were the predominant options for builders pursuing a green building certification. In addition to the recently launched BREEAM Gulf Scheme, about 15 to 20 buildings have received LEED certification to date, most of them large office buildings.

Awareness of and demand for green building has grown in the UAE. In some sectors, such as high-end office buildings, green building certification is considered standard. Additionally, the UAE's international focus and the presence of multinational corporations have driven demand for green-certified office space.

However, Abu Dhabi has also been developing a unique green building program for its market. Known as Estidama (which means "sustainability" in Arabic), the program is targeting resorts and hospitality buildings, commercial interiors, and single-family residences, covering both new and existing buildings. The centerpiece of the program is the Pearl Rating System, which has been under development since 2007. While many certification programs focus on energy and allot many points to it, Estidama offers more points for water efficiency (30% of the total) than for any other category. In addition, materials and site selection play a less important role in Estidama than in LEED.

2.5.13.4 *Lighting Controls*

The cost of energy in the region has historically been low, but has been on the rise recently. The progressive governments in the region are actively seeking ways to reduce energy consumption, as the prospect of having to build more power plants is not appealing.

In the major cities, the growth of lighting controls has tracked the construction of new buildings. Growth was strong for a while, less so currently, but is expected to pick up again in the near future.

2.5.14 Latin America

In general, there is not as much demand in Latin America for higher-end commercial systems for HVAC, lighting, etc. Basic control functionality, when available, meets most requirements and desires. Along this line, there has been relatively little use of advanced lighting controls to date.

In contrast to the rest of Latin America, Mexican building owners have access to nearly the same array of products from established vendors as is available in the United States. There is almost certainly more use of lighting controls in Mexico than in the rest of Latin America, though implementation rates are also far lower than in the United States and Canada.

Although there has been some interest in energy efficiency retrofits for existing buildings, the majority of green building development in Latin America has been, and will continue to be, in new construction.

There has been some retrofit activity, such as in Argentina, which houses the region's majority of LEED for Existing Buildings-certified projects. Brazil has a very large existing building stock that may offer considerable retrofit opportunities, and its large number of government buildings would be prime candidates. However, many of the office buildings in Brazil's major cities are aging, which may lead to reluctance to invest in energy efficiency upgrades.

2.5.14.1 *Green Building Certification*

LEED is the only major green building certification option in most of Latin America. Brazil has a national program, AQUA, that is based on the French program HQE; however, AQUA is still less popular than LEED within the country.

Achieving green building certification poses challenges throughout Latin America due to the difficulty of maintaining an integrated design team. Architects and engineers in the region are not accustomed to working in collaborative design teams. In conventional building projects, many aspects of the engineering, such as HVAC, controls, lighting, and water systems, are subcontracted. As a result, control over building systems designs is highly decentralized. The property owners and developers also face the risk that, through this fragmented process, the contractor and subcontractors will make mistakes that limit the number of points awarded or add unforeseen costs. Such mistakes could cause the project to fail to meet its target certification. These same factors inhibit the expansion of other, more complex energy efficiency systems such as lighting controls, regardless of attempts at certification.

2.5.14.2 *Mexico's Lighting Initiative*

During 2008, the Mexican Congress passed the law on Sustainable Use of Energy, which resulted in the National Program for the Sustainable Use of Energy in 2009. The legislation had identified seven priority areas for energy efficiency improvement, the most important of which was lighting.

The primary objective of the Program is to transform the market through regulation and sponsored projects in order to improve the use of energy for lighting.

- A mandatory standard (Norma Official Mexicana) is being developed to establish minimum requirements for lighting efficiency in the residential, commercial, services, industrial, and public sectors.
- A residential sector project has the objective of distributing 45.8 million CFLs into low- and middle-income households by 2012 through exchanges for incandescent bulbs.
- In another project, BANOBRAS, a Mexican development bank, will provide credit to municipalities to finance the replacement of inefficient public lighting technologies. The upgrade costs are expected to be offset by the energy savings.

2.5.15 Africa

In general, there is very little incentive to implement lighting control systems in most of Africa. Energy codes there are rare and electricity costs are held artificially low in many of the countries. Moreover, only a handful of green buildings have been built in countries other than South Africa. Examples include the British Embassy in Algeria; a building on the island of Mauritius, off the coast of Madagascar, which received BREEAM certification; and one LEED-certified building in Johannesburg, South Africa.

2.5.15.1 *South Africa*

The South African National Standards (SANS) 204 is a series of standards that address energy efficiency in commercial buildings. Although some admit that SANS 204 is far from perfect, as a voluntary standard it is credited with helping to mitigate the country's 2008 energy crunch. Industry sources believe it will become mandatory for all new buildings in 2011 or 2012.

There has already been some significant lighting control activity in South Africa. One engineer interviewed for this report noted that his first lighting control project occurred back in 1995. He also reported having recently completed work on a large DALI system for a convention center, and mentioned that there are many DALI systems in the country.

Green buildings in South Africa are apt to use the Green Star SA program, which was adapted from Australia. Green Star SA is managed by the Green Building Council of South Africa (GBCSA). Early adopters will likely include large multinational and South African corporations, as well as the South African government. Currently, Green Star SA only offers full-fledged certification tools for office buildings and for retail; however, a pilot program is underway for multi-unit residential buildings, and certifications for education, healthcare, and other types of buildings are likely in the next few years.

The Green Star SA rating system does have sections that encourage "lighting design practices that offer greater flexibility for light switching, making it easier to light only occupied areas." More specifically, for the Office rating tool, one point is awarded when all the following criteria are met:

- All individual or enclosed spaces are individually switched
- The size of individually switched lighting zones does not exceed 100 m^2 for 95% of the area
- Switching is clearly labeled and easily accessed by building occupants

An additional point is awarded when the first point is achieved and it is demonstrated that an individually addressable lighting system is provided for 90% of the area.

Although very few buildings have been certified under LEED or the Green Star SA program, awareness of green buildings is on the rise due to intermittent and unreliable electricity, water shortage risks, climate change concerns, and international demand for green building. Third-party certification already carries value due to broad awareness of green building in South African cities.

Section 3

TECHNOLOGY ISSUES

3.1 Introduction to Lighting Control

3.1.1 Lighting Control Strategies

As mentioned in Section 1, there are as many as eight basic lighting control strategies. These strategies determine the triggering condition for changing the lighting at any particular time and the rationale for making the change. These strategies are:

- Scheduling: A change in lighting based on a schedule
- Occupancy: A change in lighting based on presence or lack of people
- Daylight harvesting: A change in lighting in response to the amount of available natural light
- Task tuning or adaptive compensation: Light levels that people need and prefer differ depending on the task at hand and time of day
- Load shedding: A change in lighting to reduce energy consumption during a particular time period, either in response to a signal from the utility (demand response) or for some internal purpose such as controlling a facility's peak demand
- Personal controls: An individual can change light levels according to personal preference.
- Lumen maintenance: Adjusting the level of power delivered to light sources to compensate for the fact that light output declines over the life of the source
- Interface with temperature control: Through a connection with an HVAC system, adjust lighting to reduce the load on the building's cooling system

In some cases, the strategy determines some or all of the technologies that need to be used. However, there are interrelationships among the strategies and technologies that are not exclusive. The particular situation and project objectives will determine the specific technologies that should be deployed.

3.1.2 Lighting Control Zones

A lighting control zone is a group of luminaires that are subject to the same management from either a switch or an automated system. If a switch turns on multiple lights in a room, those lights have been defined as a zone.

Multiple layers of lighting zones can be defined in one building. The smallest zone could be an individual fixture; the largest may be all of the lights in the building. Emergency lights, though, are usually not subject to the same control as the rest of the lights, so there may be a minimum of two lighting zones in a building: the general lighting and the emergency lighting.

3.1.3 Override Capability

Many lighting control systems include override capabilities. This most often means that it is possible for someone to temporarily turn lights on that are scheduled to be off, or to temporarily prevent lights from being turned off by an automated controller. Override capabilities are usually defined for specific zones within a building.

A manual change to the control system that is not temporary is more than just an override. This is sometimes referred to as "decommissioning" or "defeating" the system. If someone makes a change to the lighting system – at a physical circuit or via a software command – that does not leave the automated controller with the ability to eventually turn off the lights again, this is decommissioning. One approach that occupants have historically taken to defeat a system is to cover a photosensor with tape to prevent it from detecting light.

3.1.4 Switching versus Dimming

Each lighting control strategy may involve switching (i.e., turning the lighting on and off) and/or dimming (adjusting the light to an intermediate level between totally off and full power on). Table 3.1 shows some of the reasoning that can help a designer decide between the use of switching and dimming.

Table 3.1 Function and Benefits of Switching and Dimming

	Switching	Dimming
Primary Use	Energy management	Visual needs
Basic Function	Turn lights on or off	Change light output with smooth transitions between light levels
Benefits	Utility cost savings	Occupant satisfaction, flexibility, utility cost savings
Advantages	Relatively inexpensive and simple to commission	Can set light output at any level within available range; greater user acceptance due to smooth transitions between light levels
Disadvantages	Lower user acceptance in occupied spaces with stationary tasks due to abrupt, noticeable changes in light level	Higher installed cost; can require more sophisticated commissioning

(Source: Lighting Controls Association)

3.1.5 Localized versus Centralized Control

Another factor in planning a lighting control scheme is determining how much of the lighting should be controlled independently as compared to through the use of more centralized control. The control scheme can be designed with local systems and a centralized system working together as layers. Both local and centralized systems can be integrated into building automation systems for control of lighting and HVAC.

The Lighting Controls Association summarizes the key aspects of Localized and Centralized approaches as follows: The building is divided into a series of control zones. Each zone constitutes a lighting load controlled by a single controller.

- Localized Control
  - Each zone operated by its own point of control independently of other zones
  - Lower cost, less sophisticated commissioning
- Centralized Control
  - All zones operated by single point of control
  - Greater capabilities, flexibility, potential cost savings

3.1.6 Basic and Advanced Intelligent Controls

Though there is no official definition for what constitutes "basic" or "advanced" when it comes to control techniques and technologies, the following is the categorization that Pike Research has used to develop the forecasts in this report. This grouping provides some perspective on the relative cost and complexity of the approaches.

Table 3.2 Categories of Control Technologies

	Intelligent Controls	
Simple Controls	**Basic**	**Advanced**
On/Off controls	Occupancy sensors	Daylight harvesting
Manual dimming controls	Light-level sensors with high/low dimming	Dimming capabilities
Scheduling (clock/timer) controls		Networked controls
Lighting sweeps		

(Source: Pike Research)

3.2 Introduction to Control Technologies

When trying to determine the appropriate lighting control technologies to apply, the most important thing is to understand the available options and their advantages and disadvantages. If these are lined up against a thorough understanding of the goals for the project, the course of action should be pretty clear.

The remainder of this section focuses on the application of these technologies; more detailed technical information on sensors and control signaling appears in Section 3.3, Control System Components.

3.2.1 On/Off Controls

An On/Off control is a simple switch that controls one or more luminaires. A specific switch always controls the same luminaires, and there are no intermediate positions or settings. The switch position is changed by a person; no automated options are available.

3.2.2 Manual Dimming Controls

A manual dimmer is a slide or dial that controls the brightness of one or more luminaires. The dimmer may include an "off" position at the low end, or an on/off switch may be connected to the dimming device. A specific switch always controls the same luminaires. The dimmer position is changed by a person; no automated options are available.

Manual dimming is usually used to create an ambiance, such as in a restaurant, or to emphasize another light source such as in a theater or a conference room with a projector. Though it is possible that manual dimming will lead to energy savings, it is not a good approach for maximizing savings.

The ability for a light source to dim depends on the type of lighting technology. Fluorescent and HID lamps need ballasts that are capable of dimming. Incandescent lamps do not require ballasts.

3.2.3 Bi-Level or Stepped Switching

Before the introduction of dimming ballasts to the broader market, light level reductions were often achieved through the use of bi-level or multi-level switching approaches. (The term “bi-level switching” often refers to both bi-level and multi-level switching. Stepped switching is another term that is sometimes used.) In fact, the IECC recognizes four methods of light level reduction control. The latter two are considered bi-level switching.

- Switching each fixture or each lamp
- Controlling all lamps or fixtures; for example, dimming or light level switching (dimming is discussed in Section 3.2.7 of this report)
- Dual switching alternate rows, fixtures or lamps
- Switching the middle lamp independent of outer lamps (3-lamp fixtures), or one of the lamps in a 2-lamp fixture.

Bi-level switching is primarily used with multi-lamp fluorescent luminaires. With 3-lamp fixtures, for example, two separate ballasts can be used. One drives the two outer lamps and the other drives the middle lamp. Normally, the middle lamp is turned off to reduce light levels, though 100%, 66% and 33% levels can all be achieved. These adjustments can occur manually (i.e., according to occupant desires), or automatically (to save energy), usually as the result of input from photosensors.

A primary benefit of bi-level switching is that occupants can choose light levels. They then have the ability to make adjustments based on their personal preferences for the task at hand or for ambient light levels.

At this time, energy codes that require light level adjustments can generally be satisfied by a stepped switching configuration. For example, the IECC requires that occupants must be able to reduce the lighting load in a reasonably uniform pattern by at least 50% in each indoor enclosed space. Future codes, though, are expected to require stepped dimming or continuous dimming systems, which are discussed in Section 3.2.7.

3.2.4 Scheduling and Lighting Sweeps

Time clocks were the first lighting controls. Scheduling uses a timer to automatically turn on and turn off one or more luminaires at pre-set times. Lights in a section of a building can be controlled together as a lighting zone, and different zones can be subject to different schedules.

Scheduling is appropriate when there are large, open spaces in a building that have predictable hours of use. Lights can be turned on just before the start of normal operations and turned off after the normal operation end time. The schedule can vary for different days. If there are no weekend operations, the lights do not need to come on at all.

With a scheduled system, it is important to give occupants the ability to override the timer to keep lights on. However, many current energy codes limit this override to a maximum of two or four hours at a time.

A lighting sweep refers to an operation that is initiated at the end of normal operating hours to turn off all lights in the building (except emergency or other special purpose lights). A sweep might be performed every two hours, for example, to turn off any lights that are on at the time. People who are working later than the normal time would then need to use an override capability to turn the lights back on.

3.2.5 Occupancy Sensors

Occupancy sensors, sometimes referred to as motion detectors, have been around for more than 30 years. They are best used in spaces that are often unoccupied, including conference rooms, storage rooms, restrooms, warehouses, and private offices. Open office areas and other spaces that are occupied for most of the work day are generally not as well suited to occupancy sensors.

Occupancy sensors are credited with energy savings because of the assumption that the last person to leave a space would not necessarily turn off the lights. In some countries, especially in less developed economies, lighting vendors and building managers often state that people are more attuned to the cost of energy and do simply turn off the lights when a space is not in use.

Due to their relative simplicity and the fact that energy codes are now requiring automatic light shut-off in certain types of spaces, occupancy sensors are becoming increasingly common in new construction and in lighting or other energy retrofits.

3.2.5.1 Savings due to Occupancy Sensors

Occupancy sensors are thought to save at least 20% of lighting energy, though this figure will vary widely depending on the type of space and how often it is used. The less frequently a space is used during normal operating hours, the greater the potential savings. Savings will also depend on the time-out settings (i.e., the amount of time after the last detection of an occupant until the sensor sends the OFF signal to the luminaires).

Table 3.3 Savings due to Occupancy Sensors in Different Types of Spaces

Occupancy area	Energy Savings
Private office	13-50%
Classroom	40-46%
Conference room	22-65%
Restrooms	30-90%
Corridors	30-80%
Storage areas	45-80%

(Source: Lighting Controls Association)

The actual savings due to occupancy sensors will, of course, depend on the rules that are established for how the occupants interact with the controls and what the controls do in various situations. For example, a bi-level switching occupancy sensor can be configured in the following ways. The savings figures are from a study that focused specifically on these options.

- Auto-ON to 50%: When someone enters the space, the sensor signals to automatically turn one-half of the lamps to ON, providing a 50% light level. The occupant has the option to use a switch to either increase the light level to 100% or turn the lights to OFF. When the occupant leaves the office, the sensor automatically turns the lights OFF after a pre-established time delay. In the study, this configuration saved 52% of the lighting energy compared to the baseline.
- Manual-ON to 50% or 100%: When someone enters the space, the sensor does not turn the lights ON. Rather, the person could turn the lights ON to the 50% or the 100% light level, or leave the lights OFF. When the occupant leaves the office, the sensor

automatically turns the lights OFF after a pre-established time delay. In the study, this configuration saved 46% of the lighting energy compared to the baseline. Since this configuration requires people to turn the lights on manually, it is likely that the 100% light level is more frequently chosen than in the Auto-ON to 50% configuration, resulting in a slightly lesser energy savings.

- Auto-ON to 100%: When someone enters the space, the sensor signals to automatically turn all the lamps to ON, providing a 100% light level. The occupant has the option to use a switch to either decrease the light level to 50% or turn the lights to OFF. When the occupant leaves the office, the sensor automatically turns the lights OFF after a pre-established time delay. This third option was not included in this particular study. However, it can be assumed that some people who would sometimes be satisfied with a 50% light level, or even having the lights off, would not take any action and would leave the lights at 100%. This option, then, would produce less savings than either of the other two.

Since occupancy sensors in most types of spaces tend to have the least impact during peak operating times, their impact on peak electricity demand is usually minimal. The reduction of peak demand would be greater in warehouses that are lightly accessed and other infrequently occupied spaces.

3.2.5.2 *Vacancy Sensors*

Some occupancy sensors are called “vacancy” sensors. These must be turned on manually by someone entering a space. They will turn off the lights if no activity is detected during a set period of time.

Vacancy sensors are best in smaller rooms where they can be accessible to people entering, similar to a standard light switch.

3.2.6 Photosensors

Photosensors detect the lighting level in an environment, both natural and artificial. They are used to turn off or dim artificial light sources when there is sufficient natural light, or to provide feedback to an intelligent system that adjusts light levels for some other reason. Photosensors were first used in outdoor lighting applications in place of astronomical time clocks to turn lights on and off.

When photosensors were first applied to indoor applications, the resulting on/off switching or step-switching proved to be very distracting to occupants. Indoor photosensors are now most frequently used with dimming systems.

The primary uses of photosensors are in open office areas, classrooms, and atriums. They are also used where skylights are present in big-box stores and warehouses.

3.2.6.1 *Daylight Harvesting*

The lighting control strategy known as “daylight harvesting” refers to the practice of measuring the natural light level in a space through the use of a photosensor and then adjusting the level of artificial light to provide the total desired illumination. Higher levels of natural light are treated as a resource and are “harvested” in place of consuming electricity.

3.2.6.2 *Lumen Maintenance*

The lighting control strategy known as "lumen maintenance" is used to ensure that the required amount of light is available over time. Light output declines over time due to dirt that collects on lamps and fixtures, and due to lumen depreciation, which refers to the reductions in lumen output that most sources, including fluorescent and HID, experience over their lives. Therefore, it is often necessary to overdesign the lighting for a space so that, in total, the lamps provide sufficient light levels even as they reach the end of their economic lives. A typical figure for this is 70% of initial output. If all the lamps in a space are run at full power when new, the space would be 30% overlit. Photosensors can be used in such an instance to dim the artificial lights to the desired level of light.

The Heschong Mahone Group, a building energy efficiency consultancy, has estimated that the use of dimming for lumen maintenance can save 5% to 10% of the energy that would otherwise have been consumed over the lifetime of the lamps.

3.2.6.3 *Open-Loop and Closed-Loop Systems*

Photosensors can be part of either open- or closed-loop systems. In a closed-loop system, the photosensor is placed so that it reads and responds to the combined daylight and artificial light levels that fall on the primary work surface. This is considered a closed loop because the sensor is reacting to the results of its own feedback – the change in artificial light. Closed-loop systems are usually considered more accurate since they measure the actual light levels at the work surface.

In an open-loop system, the photosensor is placed so that it responds only to the daylight levels coming into the space. In fact, it is usually mounted either outside of the building or in an inside position facing away from the lighting it controls. The control system then determines the amount of artificial light to supply so that the total desired light levels are achieved. The open-loop system is less precise since the controller must "assume" it knows how to control the artificial light properly, without the feedback of the actual result. In addition, this type of system may not entirely account for such variables as lamp lumen depreciation. An open-loop system can also be "confused" by an action as simple as an occupant drawing a shade to block sunlight that is too bright, since the sensor has no way of knowing that the sunlight is not reaching the work area. Open-loop systems are best for spaces where lighting-level precision is not as important, such as hallways and atriums.

The California Lighting Technology Center has been working with WattStopper and some utilities to develop dual-loop photosensor technology to improve the reliability of photosensors under changing light conditions. Dual-loop is a combination of open-loop and closed-loop photodiodes looking in different directions. WattStopper recently announced a prototype of a dual-loop photosensor.

3.2.6.4 *Sidelighting and Toplighting*

Daylight enters a space in one or two main ways. Sidelighting occurs when daylight enters through vertical surfaces such as windows, whereas toplighting occurs through the ceiling of the space (i.e., through skylights or light tubes). Sidelighting is generally limited to the floor space that is in close proximity to the windows. In fact, a report by the Lighting Research Center suggests that windows can effectively provide daylight to approximately 15% to 20% of the floor space in commercial buildings. (There are advanced lighting techniques, such as "light shelves," that bring sidelight farther into a space, but those will not be discussed here.)

In contrast, toplighting could, in theory, provide daylight to just about all of a single story building or the entire top floor of a multi-story building, accounting for as much as 60% of all commercial space. In practice, though, only a small percentage of buildings have skylights. There are a number of reasons for this, including the fact that skylights in buildings with suspended ceilings require a light well for each skylight, increasing the cost beyond what could be justified by savings in lighting energy. In addition, there is a high perceived risk of leaks from skylights.

Energy codes have generally discouraged the use of skylights. There have been concerns that skylights increase energy consumption due to high solar gain in the cooling season and low thermal resistance during the heating season. The 2006 IECC includes a limit on skylights to only 3% of the roof area. More detailed analysis, however, shows that the energy savings from using skylights with lighting controls dominates any amount of energy required to make up for thermal problems.

The regulatory environment is changing, though, as evidenced by the newest version of California's Title 24, which requires skylights in big-box stores that are greater than 25,000 ft^2 and have ceilings higher than 15 feet. These skylights need to diffuse the light and incorporate controls that will turn off the lights when daylight is available. At least one-half of the floor area must be daylit using skylights.

A 2008 report on toplighting prepared for the U.S. DOE estimates that skylights have the potential to reduce energy consumption for lighting by 35% to 55% in certain building types. Simple payback in big-box stores could be as fast as four to six years, depending on climate zone.

3.2.6.5 Installation Issues

A control system that responds to daylight should include a way to avoid constant changes due to rapidly changing sky conditions, such as clouds passing overhead. A delay on the order of five minutes is often recommended. Also advisable is the use of a fade-in and fade-out time of a minute or more when changes are made to the artificial light levels. Rapid changes to the lighting can be very distracting to the building occupants.

As much as any system in a building, calibration of lighting controls is critical to achieving the potential benefits of the system. Lighting with controls is one of the primary systems in a new building that should be commissioned, and that can usually benefit from re-commissioning on a regular basis. Lighting controls should be calibrated with all furniture in place, but without occupants in the space.

3.2.6.6 Savings due to Photosensors

A report by the U.S. EPA estimated that offices with daylighting can recognize up to a 35% to 40% savings in lighting energy when photosensors are used to dim lights. Other types of spaces, such as classrooms and retailers, can achieve 40% to 60% savings. The New Buildings Institute also estimated that daylighting can reduce energy consumption for lighting by as much as 40% to 60%.

In contrast to occupancy sensors, which are most effective at saving energy during off-peak hours, daylight is usually at its peak at the same time of the day that a building's electricity use would be expected to peak. Therefore, using photosensors to reduce artificial lighting levels can result in a significant reduction in peak electric demand without inconvenience to the occupants.

3.2.6.7 *Low Penetration*

Despite the significant benefits that photosensors can provide, penetration of this technology in commercial markets is still pretty low. Probably only a couple percent of all commercial property, even in the most developed countries, make use of photosensing. Not only does the added cost of the photosensors pose a barrier to adoption, but also the cost of the dimming ballasts that enable a control system to take full advantage of the light sensing capability. In addition, labor costs for installation can be high, and properly commissioning a daylight system can be complex.

Since photosensors are still viewed as a newer technology, any of the parties – owners, lighting designers, electrical contractors, etc. – may view them as bringing a higher-than-tolerable level of risk to a project. In addition, there is a pervasive belief that automatic dimming controls that work with photosensors are unreliable. Undoubtedly, there have been many projects that were improperly designed or commissioned, permitting such a belief to live on. For this reason, an increased emphasis is being placed on producing case studies of successful dimming projects across a range of applications. Finally, many owners and even some design professionals believe that building occupants do not like automatic lighting control.

3.2.7 Dimming

Dimming refers to the partial reduction of light output from a source. Several types of dimming were previously discussed, including manual dimming and bi-level or stepped switching.

3.2.7.1 *Stepped Dimming*

Stepped dimming can be based either on a schedule or on feedback from photosensors. The difference from stepped switching is that the light can be reduced gradually, rather than in major jumps of 25% to 50%. Lighting that changes gradually is less disconcerting to the occupants of the space.

Stepped dimming is sometimes called “bi-level dimming” because the light is sometimes targeted at just two levels: 100% and 50%. However, it can also be implemented with three levels, if necessary. Stepped dimming is often used with HID lighting because HID lamps are subject to a restrike time (the time before a lamp can re-light after it is turned off). If the HID lamp is only dimmed to 50%, it can be brought back to full power quickly.

3.2.7.2 *Continuous Dimming*

Continuous dimming can also be based either on a schedule or on feedback from photosensors. The difference from stepped dimming is that the light can be gradually dimmed to any level over the full range of which the lamp is capable. This would be from 100% down to as low as 1% for fluorescent lamps and 100% down to 50% for HID lamps.

Continuous dimming has some important advantages over stepped dimming. If it occurs in response to changes in daylight, it is far less noticeable. The relative precision of this technique also maximizes energy savings. In addition, continuous dimming, when implemented with multiple zones within a large space, can lead to more uniform lighting across the space since the artificial light is adjusted, as needed, within each zone to achieve the target established for the entire space. Another advantage is that lights can be turned down very low, but not totally off, which can preserve the longevity of the lamps. (Excessive on/off switching can reduce the life of fluorescent and HID lamps.)

Continuous dimming ballasts have long been much more expensive than fixed output ballasts, limiting their adoption. However, the cost has been coming down steadily, making an upgrade to a dimming system a viable option for many retrofit projects.

Continuous dimming is the technique that is most closely associated with the term "dimming." In the rest of this report, "dimming" refers to continuous dimming unless a different technique is specified.

3.2.7.3 *Perception of Light Level Reduction*

It is said that the more aware occupants are of the behavior of lights under lighting controls, the less successful the system will be due to the distraction this causes. Therefore, determining the changes in lighting level that will be noticeable to occupants is very important. The Lighting Research Center has studied people's abilities to detect gradual reductions in light levels. The results are as follows:

- More than 90% of the population would not notice a 10% reduction in lumens
- About 75% would not notice a 15% reduction in lumens
- About 55% would not notice a 20% reduction in lumens

Another study performed by National Research Council Canada – Institute for Research in Construction (NRC-IRC) found that lighting levels could be reduced by 14% to 23% without the occupants complaining.

The figures from these studies can be considered a worst case, since the people in the experiments were aware that the light levels would be changing. Under normal circumstances, occupants of a space would not be waiting to detect dimming.

Perceptions of light change are also impacted by the speed at which the change occurs. Even for a large adjustment that will be noticed regardless, such as 50% or more, it is important for the change to be at least somewhat gradual. A period of 10 seconds is usually the minimum amount of time over which any significant change should be made.

3.2.7.4 *Dimming Ballasts*

The primary downside of dimming is the additional cost associated with the ballasts. For example, a standard (non-dimming) fluorescent ballast can cost as little as $15, while even a non-proprietary dimming ballast will cost $30 to $50, depending on the lamp types and wattage to be supported. Although the price premium has been dropping, this can still represent a significant additional cost, especially for a large project with hundreds or thousands of luminaires. In addition, the control circuitry and software to take full advantage of the dimming capability can cost thousands of dollars for a large system.

3.2.8 Technologies Applied to Load Shedding

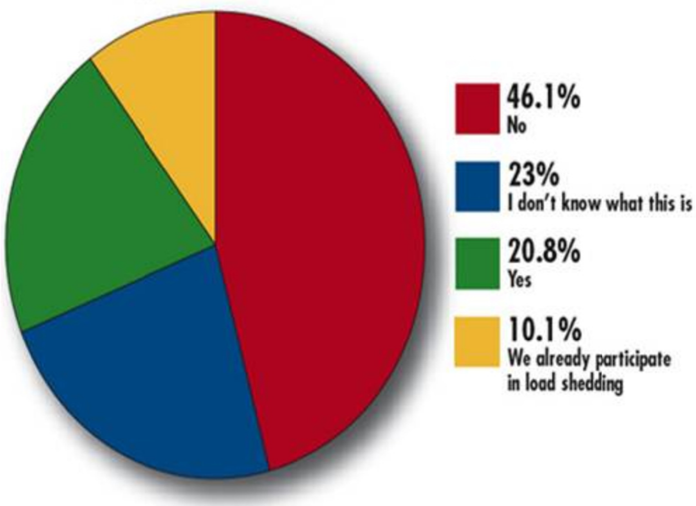
Load shedding is one of the eight basic lighting control strategies. As applied to lighting systems, load shedding involves lowering light levels to reduce energy consumption at a particular time – either in response to a signal from the utility (demand response) or for some internal purpose such as controlling a facility's peak demand. Load shedding for demand response in commercial buildings has tended to focus on HVAC systems, since the energy use is concentrated in relatively few devices. Meanwhile, lighting systems were not often considered due to the requirement for dimmable ballasts and the relatively limited number of them in use. Moreover, the widespread distribution of lighting devices across a facility also posed a complicating factor.

Given the requirement of dimming ballasts for load shedding, it is also virtually required that lighting systems be networked to a central controller to implement the load shedding. The most effective way of shedding electrical load is to reduce lighting most drastically in areas not in use, and reduce levels only moderately in spaces where it would have a detrimental impact on productivity or safety. In addition, the spaces that fit these categories can vary depending on the day or time of day. This is the kind of information that is usually stored and managed in a central application.

If photosensors are in use, the information they provide could be taken into account in shedding decisions. Artificial light could be cut even more drastically in zones that have enough available daylight.

A 2009 NEMA survey indicated that many facility managers are still not convinced that load shedding for lighting systems is worth the trouble, and that many do not really know what it entails.

Figure 3.1 Are You Considering Load Shedding as a Way to Control Lighting Energy Consumption and Costs?



(Source: NEMA)

To make more of the power that is used for lighting available to demand response programs, NYSERDA even provided a simple definition of a "load-shedding ballast" in some marketing materials it prepared in 2006, before the more recent decline in the price of continuous dimming ballasts. The objective was to make it sound as simple as possible, and not to have it viewed as a new kind of technology.

> "A load-shedding ballast is a highly-efficient instant-start ballast with bi-level dimming and a built-in power line carrier signal received for automated dimming response. Appearance, installation and wiring are identical to standard instant-start ballasts. Until now controlling fluorescent lighting loads required customized solutions with expensive hardware and installation. The load-shedding ballast avoids the cost and complexity associated with traditional dimming methods. These new components are specifically designed for load management and energy efficiency."

3.2.9 Technologies Applied to Personal Controls

Personal controls represent one of the eight basic lighting control strategies, and there are a number of ways to provide such controls.

3.2.9.1 Personal Dimming

Personal dimming is especially well suited to private offices. It provides occupants the ability to adjust light levels exactly to their preferences, and the smooth transitions between levels are generally preferred over larger step changes. Personal dimming requires a dimming ballast to control the luminaires in the office and a dimming control device; consequently, the initial product cost and commissioning cost will be relatively high.

Personal dimming control of overhead luminaires can also be a workable solution within an open office; to be practical, however, the overhead fixtures should line up with each individual work space. That way, each occupant has control over personal light levels without significantly impacting surrounding workers. Yet, this could negate a primary benefit of open office set-ups, namely the ability to move workstations around as needed.

Personal dimming can also be used in an office where the luminaires have both direct and indirect lighting components. To make this work, the lamps and ballasts providing the uplighting would need to be electrically separated from the components that produce the downlight. Each downlight could be zoned as an individual fixture and controlled by each occupant sitting below it. The uplights could be zoned and dimmed as a group in response to, for example, a signal from a photosensor.

The user can control dimming with either a physical switch, such as an infrared remote, or an application on the person's computer. The "slider" in Figure 3.2 is an example from the Philips Ledalite Ergolight desktop application. A computer application would require that the dimming ballast in the office is connected to a central controller, probably using a digital control scheme. Digital is not mandatory, but the wiring for individual ballast controls of this sort can otherwise become very cumbersome.

Figure 3.2 Philips Ledalite Ergolight Personal Dimming Desktop Application

(Source: Philips)

Encelium, a vendor of lighting control systems, uses the touchscreen display on each occupant's Cisco IP telephone to control light levels in their workspace. It also allows users to save preset lighting scenes and recall those presets, which can be easily renamed, reorganized, and deleted. This type of functionality is enabled by an Ethernet connection between the Encelium lighting control network and the Cisco phone system.

Personal control works well in spaces with windows. The availability of daylight will lead to higher energy savings as occupants dim electric lights. Since daylight can cause glare, however, window blinds should be considered as part of the personal control strategy. While the availability of blinds may impact the amount of energy savings due to available daylight, occupant satisfaction will be higher.

3.2.9.2 Other Options for Personal Control

Task lighting is a simple way to provide personal control over lighting, and can include on/off, multi-level, or dimmable options. Undercabinet fixtures are a common design approach for this application. However, a wall-box dimmer can also be used to dim all the general light fixtures in a space. These dimmers can be used for private offices or open spaces with a number of occupants and replace the wall switch between the ballast and the power supply.

In private offices and some group spaces, wall switches can be used to allow for bi-level or multi-level switching. With bi-level switching, alternate lamps, fixtures or rows are zoned and switched separately to enable 50% light level reductions. Multi-level switching can provide even more flexibility. In 3-lamp fixtures, 33% and 66% light level reductions can be achieved.

3.2.10 Technologies Applied to Task Tuning

Task tuning is one of the eight basic lighting control strategies. The Building Intelligence Group's Intelligent Building Dictionary defines task tuning as "setting light levels and other environment parameters to suit the particular task or other use of a workspace."

A number of studies have suggested that lighting is often oversized for the tasks performed in a given space, which could be due to the space being used for a purpose other than that for which it was designed, or being used for multiple purposes. Regardless, task tuning provides the building manager or other appropriate party with the ability to control the maximum light and prevent over-lighting. Various lighting "scenes" can be designed to limit or customize the output of the various light sources in the space. Any of these settings can then be initiated as needed for the activity in the space at a particular time.

The basic technologies to enable task tuning are similar to those that provide personal controls. The key is to be able to provide dimming in a particular space, either a private office or an open area. Step dimming may be sufficient, but continuous dimming provides increased flexibility.

3.3 Control System Components

3.3.1 Sensors

As important as dimming ballasts and controllers are, some in the industry say that good sensor technology can be more of a competitive advantage to a vendor than its controllers. For one thing, the demand for sensors is growing faster than demand for other parts of lighting control systems.

Costs vary greatly depending on a sensor's technology, range, durability and method of being powered. The mounting configuration can also impact a sensor's cost. Ceiling mount sensors tend to be the most expensive but also cover the largest area.

3.3.1.1 Occupancy Sensor Technologies

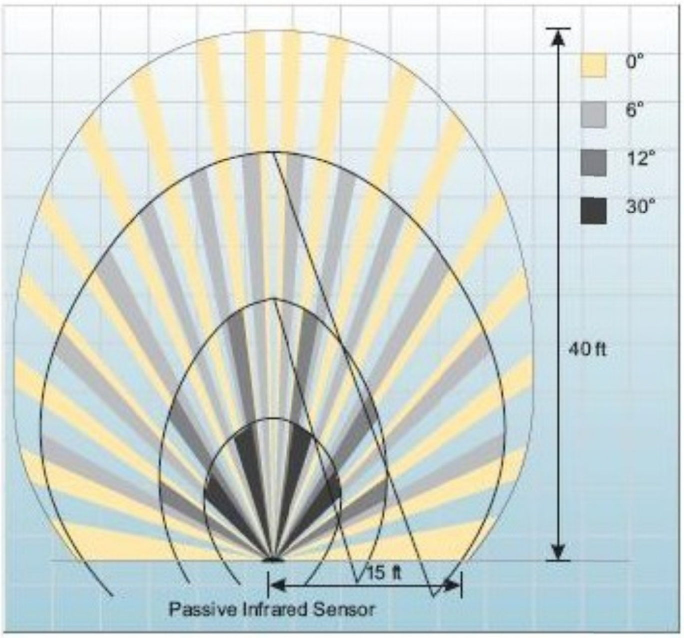
Most occupancy sensors operate with either infrared or ultrasonic technology. Neither technology is inherently better than the other; each may be better for certain types of applications and not for others.

3.3.1.1.1. *Passive Infrared*

Passive infrared (PIR) sensors monitor the difference between the heat from a moving person and the heat of the background space. A person moving across the sensor's field of view causes the heat pattern to change. PIR sensors are best at detecting movement across their field of view, since the pattern changes more significantly than if the movement is toward or away from the sensor.

The PIR sensor is covered by a lens that creates a set of fan-shaped zones that define the coverage area. At farther distances from the sensor, the gaps between the zones become larger; consequently, PIR sensors are not very good at detecting minor motion at farther distances. For example, most PIR sensors can detect a person moving at up to approximately 40 feet away, but may only detect a hand moving at 15 feet or less. In addition, these sensors require a direct line of sight to the moving body: they cannot "see" through objects or around corners.

Figure 3.3 Coverage Zones of an Infrared Occupancy Sensor



(Sources: Watt/Stopper and Lighting Controls Association)

PIR sensors are commonly used in private offices and smaller conference rooms where line of sight is pretty much assured. They are also used in high bay applications, such as in warehouses. Here, the moving objects are large (e.g., people in smaller warehouses; forklifts in larger ones) and move through open spaces that provide the line of sight these sensors require. In high bay applications, the sensor may be fitted with either a lens that provides 360 degree coverage for open areas or one that is configured for narrower coverage down warehouse aisles.

3.3.1.1.2. *Ultrasonic*

Ultrasonic (US) sensors are active, not passive, since they emit a high-frequency signal into the space and then read the frequency of the reflected signal. A difference between the outward and received signal frequencies is interpreted as the result of a moving object. They are more sensitive than PIR sensors and can, for example, detect hand movement up to about 25 feet away. U.S. sensors are most sensitive to movement toward and away from the sensor (as opposed to across a field of view).

Unlike PIR sensors, U.S. sensors do not require a direct line of sight. They are capable of detecting motion around corners and objects. Ultrasonic sensors do, however, have difficulty in spaces with fabric-covered walls such as those commonly used for cubicle partitions. In the presence of such dividers, the sensors may require a direct line of sight.

3.3.1.1.3. Acoustic

Acoustic sensors detect noise. While this includes sounds produced by people, such as speech and keyboard tapping, these sensors will also respond to any other noise that enters the space, even from outside of the building. Therefore, they usually require a higher level of sound than is typically present in an office. Few sensor products use only acoustic sensing.

3.3.1.1.4. Dual-technology

Dual-technology (or hybrid) sensors include two sensing technologies, and the most common combines PIR and U.S. components. Both sensors must detect a presence for the lights to be turned on, nearly eliminating the possibility of a “false on” situation. Moreover, as long as either sensor continues to detect a presence the lights will not turn off, so the occurrence of a “false off” signal is also minimized. Some dual-technology sensors add acoustic technology to PIR technology to increase sensor reliability.

3.3.1.1.5. Calibration

Occupancy sensors have two parameters that can be adjusted: The “sensitivity level,” which determines the level of movement that will result in a signal to turn on the lights, and the “time delay,” which determines the amount of time after motion is last detected until an “off” signal is sent.

Reports of occupancy sensors not working are due mainly to parameters that are set incorrectly based on the activity in the space and/or the preferences of the occupants. A shorter time delay will increase energy savings. However, when surveyed, technicians who install occupancy sensors reported that setting a time delay of ten minutes or less leads to a much higher rate of callbacks “for repairs” than a time delay of 15 minutes or more.

Shorter time delays can also have a negative impact on lamp life by causing more frequent on/off switching. Note, however, that this does not necessarily mean the lamps would need to be replaced more frequently, since the occupancy sensors may lead to a significant enough increase in off hours to compensate for the shorter rated life.

3.3.1.1.6. New Occupancy Sensor Technologies

Although occupancy sensors developed bad reputations in their earlier days, they have continued to improve. Field technicians who have worked with these products for a while generally acknowledge that manufacturers have made significant improvements in their basic operation and have added valuable functionality.

For instance, self-calibrating or “smart” occupancy sensors are now available. A processor in the sensor monitors activity, or lack of activity, in the space to develop a usage profile. The sensor is then able to adjust its own sensitivity level and time delay for optimal performance. Even if the usage pattern of the space changes, the sensor will adapt to the new situation. This technology greatly simplifies the setup process and will reduce the chance for dissatisfaction if use of the space changes without the controls being recalibrated.

In addition, some PIR sensors now have double-eye sets to minimize blind spots that can result from the wedges of coverage. And some US sensors incorporate boosters that make it possible for a wall mounted sensor to handle very large or oddly shaped rooms.

3.3.1.2 *Photosensor Technologies*

Indoor photosensors are based around a light-sensitive photocell, which is usually made of silicon. This photocell produces an electrical current in proportion to the amount of light that strikes it. The photosensor also includes some type of lens to collect and focus the light and internal electronics to convert the output from the photocell into a control signal.

Some photosensors are fully integrated units that mount on the ceiling or are attached to a luminaire. Other versions have the sensing part for ceiling mounting and separate electronics that can be located in a more convenient place for commissioning access.

Although the components of photosensors are very similar, specific products are designed for use in very different applications. Variables include the size of the space and whether the sensor will be in an office environment, a warehouse, etc.

A photosensor’s “spatial response,” or “angular sensitivity,” defines how it detects light that comes at it from different directions. This is the photosensor’s field of view. A narrower spatial response means that the photosensor will be most responsive to the brightness of the surface at which it is directly pointed. “Spectral response” is the photosensor’s sensitivity to different wavelengths of light. The photocells detect ultraviolet and infrared light, which are outside the normal visual spectrum, so filters can be used to remove these frequencies before they reach the photocell. Different photosensors are also designed for different ranges of light levels (brightness).

3.3.1.3 *False Triggering of Sensors*

A number of conditions can lead to false triggering of sensors. These factors must be accounted for in the design of the product, and then monitored on an ongoing basis to ensure that the lighting control systems are providing their maximum benefit.

- Sensitivity of occupancy sensor or photosensor set too high
- Sensor range (distance) too large for the space
- Passive infrared sensors triggered by non-human heat sources
- Ultrasonic sensors triggered by fans or other environmental noises

3.3.2 Dimming Ballasts

As previously mentioned dimming ballasts must be used in order to dim fluorescent or HID lamps. These ballasts must be able to accept control signals, either low voltage or line voltage. When a dimming ballast receives a signal from a control device, such as a photosensor or a central control system, it responds by changing the current flowing through the lamp. This creates a controlled change in the output of the lamp.

3.3.2.1 *Rapid-Start and Programmed-Start*

As electronic ballasts have continued to evolve, the industry has developed different methods for ballasts to start up (turn on) lamps. “Rapid-start” ballasts use a small voltage to preheat the cathodes in the lamp. As a result, less voltage is needed to start the lamp when the time comes for the ballast to initiate the arc.

"Programmed-start" ballasts, a type of rapid-start ballast, preheat the cathodes more accurately. This minimizes damage to the cathodes during startup, helping to optimize lamp life while maximizing energy savings. Programmed-start ballasts are said to provide as many as 100,000 starts, which is good for spaces with occupancy sensors, for example, where the lamps are frequently switched.

The slight downside to programmed-start ballasts is that they may operate at a reduced efficacy when used for dimming. For example, dimming lamps to 50% of light output may only reduce wattage used by 40%. "Instant-start" ballasts (not the same as rapid-start) would offer proportional reductions in light and wattage, but some manufacturers warn that they may negatively impact lamp life when subject to, for example, five or more on/off cycles per day.

3.3.2.2 High Efficiency Ballasts

During 2008 NEMA launched the Premium Ballast program to identify the most efficient fluorescent fixed-output and dimmable electronic T8 ballasts. The Consortium for Energy Efficiency (CEE) had worked with NEMA to develop a definition of high-efficiency T8 ballasts using a metric called ballast efficacy[1] factor (BEF). This metric was adopted as NEMA Standard BL 2-2007 covering electronic ballasts for use with 4-foot T8 lamps. Ballasts that satisfy BL 2-2007 can be designated as NEMA Premium Ballasts. Dimmable ballasts are now available that are as efficacious as standard instant-start, fixed-output ballasts.

3.3.3 Control Signaling

Lighting control systems depend on communication among sensors and actuators – and in networked systems, the central controllers.

3.3.3.1 Low Voltage and Line Voltage/Power Line Carrier

Traditionally, control signals have been transmitted over dedicated low voltage wiring. A "line voltage" or "power line carrier (PLC)" option has also been available for some time. A third approach using wireless technology is discussed in Section 3.7 – Wireless Control.

For a low voltage setup, control signals are sent along dedicated low voltage wiring. These wires can follow very different paths than the wires that provide power to the ballasts and lamps. Many types of lighting control systems may be based on low voltage signaling, including scheduling and daylighting control. The signals from photosensors, for example, are often carried on the same type of low voltage wiring that is accepted by these ballasts.

Line voltage, also known as "power line," signaling transmits information using a high frequency signal over the same wiring that provides the power to the ballasts and lamps. These include the 120 or 230 volt lines for lighter duty, or the commercial 277 to 480 volt (or other, depending on location) wires that run throughout the building. Line voltage approaches are popular for retrofit projects since there is no need to run all of the

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[1] One of the most important characteristics of a lighting technology, and the one that is most commonly used to compare technologies, is "efficacy." The term efficacy is applied where the input and output units differ. Efficacy is usually stated in lumens per watt (lm/W) – the amount of light output from the lamp per watt of electricity consumed. This is distinct from "efficiency," which is dimensionless and is usually expressed as a percentage.

additional low voltage control wiring. However, line voltage signaling can be subject to interference, and the signal can sometimes be "absorbed" by other equipment in the building, especially capacitive equipment like some electronic ballasts. The signals can then become too weak for the intended receiver, such as a time clock, to "hear."

3.3.3.2 Analog Signaling

In a dimming system, ballasts and controllers must be designed to use the same physical communication method. Using incompatible components can lead to poor dimming performance or damaged equipment. Today, both analog and digital control schemes are available, and while the components of analog systems are usually less expensive, digital systems provide enhanced functionality and flexibility that could be very valuable in some applications.

Analog dimming methods include 0-10VDC, two-wire phase-control, three-wire phase-control, and wireless infrared. Note that these are different methods and not standards; there are no industry standards for analog dimming ballasts. Consequently, components may be compatible in that they will work together, but they may not provide the same performance. For example, one manufacturer's ballast may respond to a 5 volt signal with a 50% dimming level, while a ballast from a different manufacturer may respond to the same signal with 30% dimming. Because of this, it is usually advisable not to mix ballasts from different manufacturers on the same system without knowledge of how they perform across the range of control signaling.

Another possible problem with some analog signaling is that voltage drops are possible along a long signal control wire. If this happens, the lighting change may not match the intent of the controller.

3.3.3.2.1. 0-10VDC

A 0-10VDC system uses a separate, low voltage wire to carry the control signal. When the voltage level is near or above 10VDC, the ballast provides full light output. As the voltage in the control signal is decreased, the ballast reduces the output of the lamps. However, the relationship is not always linear, and responses to the same voltages can vary across manufacturers' products.

The control wiring may either be routed in the same conduit or raceway as the power wires (class 1 wiring) or along a separate path (class 2 wiring). While separate conduit is not always required for the low-voltage wiring, it is recommended for long wire runs. Otherwise, the power wires may induce a voltage in the low-voltage wiring, corrupting the control signal.

For 0-10VDC systems, ballasts that provide 100% to 3% dimming are available for T8 lamps and CFLs. Ballasts for 100% to 1% dimming are available for T5HO lamps.

In a 0-10VDC system, the on/off control can be separated from the dimming control. This allows for the use of distributed dimming equipment with a centralized switching system or a more robust building management system while also allowing local occupants to have control of the lighting. According to the Lighting Controls Association, of the analog dimming options, 0-10VDC systems are required for the majority of applications that use photosensors.

3.3.3.2.2. Two-Wire Phase-Control

Analog two-wire phase-control is also called AC dimming, forward phase control, triac dimming, phase-chop dimming, or two-wire dimming. This is a power line approach, since the signals between the controller and ballasts are sent over the existing power wiring. Two-wire dimming ballasts are wired the same way as conventional non-dimming ballasts. Also, the control signals are less sensitive to interference than those in 0-10VDC analog systems.

For two-wire phase control systems, ballasts for T8 lamps and CFLs are available that provide 100% to 5% dimming. Ballasts for 100% to 1% dimming are available for T5HO lamps

Though it is possible to use two-wire ballasts in building-wide control systems, they are most appropriate for a local dimming application such as in a private office or a conference room. This approach is also suitable for retrofits of existing fluorescent fixtures, and thereby enables low-cost retrofit projects. With the two-wire approach, the dimming is normally controlled by the local occupants of the space.

3.3.3.2.3. Three-Wire Phase-Control

Three-wire phase-control dimming uses a third wire (in addition to the "hot" wire and "neutral" wire) to carry the phase-control signal to the ballast. All three wires are rated class 1 and can be run within the same conduit. Three-wire phase-control can be used in both local dimming applications and centralized systems connected to building management systems.

Three-wire phase-control ballasts can provide a dimming range of 100% down to 1%.

3.3.3.2.4. Wireless Infrared

Wireless infrared dimming uses an infrared transmitter to send the control signals. Therefore, these systems do not require any additional wiring beyond the power wires. The transmitter may be either a specialized handheld remote device or an application on a more sophisticated fixed or portable device that can transmit infrared signals.

A wireless infrared system is good for allowing occupant control over local lighting, but it can also be integrated into a larger lighting control system and a building management system. Since no additional wiring is needed, this system can be good for retrofit situations.

Wireless infrared controls can provide a dimming range of 100% down to 1%.

Table 3.4 Summary of Analog Dimming Methods

Analog Method	Available Dimming Range	Control Line/Low Voltage
0-10VDC	100% to 3% (T8 and CFLs) 100% to 1% (T5HO)	Low Voltage
Two-wire phase-control	100% to 5% (T8 and CFLs) 100% to 1% (T5HO)	Control Line
Three-wire phase-control	100% to 1%	Control Line
Wireless infrared	100% to 1%	Wireless

(Source: Lighting Controls Association)

3.3.3.2.5. Analog Signaling for Actuators

In an analog signaling setup, actuators are usually wired directly to the physical system being controlled, such as a damper in an HVAC system. Each controller must commonly signal to a number of actuators at the same time and is often located at a considerable distance from the actuators. Consequently, low-voltage wiring must be run between every actuator and controller. This task is complex and highly subject to errors. In addition, the labor costs often make this type of system too expensive to implement in existing buildings. For this reason, many building systems began migrating to digital control.

3.3.3.3 *Digital Signaling – Direct Digital Control*

Driven by the need for a workable and economically feasible retrofit solution, the HVAC industry began to work on digital signaling in the early 1980s. The popularity of this approach grew, and virtually the entire market went to digital control by the mid-1990s. While other building systems have also come to be dominated by digital control, this has not been the case for lighting – even despite a near 50% decline the cost of the digital approach during the last decade.

With the number of devices (luminaires) and control zones, lighting control would seem to be an excellent candidate for digital control, and it is. Dimming with digital control offers some clear advantages over analog methods, including:

- Simplified wiring and far less wire: In a digital dimming system, a single set of control wires form a low-voltage control bus. (This is sometimes called a “control loop,” but this is not technically correct.)
- It can be very economical to have a greater number of control zones, since zones are independent of circuit wiring. Each ballast has an address, so zones are defined using remote software. This can be especially valuable if using a combination of control technologies (dimming, switching, daylight sensing, etc.). The more zones, the higher the potential energy savings and the greater the occupant satisfaction.
- A very high degree of control is possible, down to individual luminaires if desired. Control can also be defined in layers, combining groups of devices for different purposes.
- Easy reconfiguring of control zones without rewiring. This can be achieved remotely via software.
- The control comes directly from software rather than a physical signal such as voltage. Centralized control can be managed from a personal computer or building automation system. Local controls such as manual dimmers can also be used.
- Digital signals are more consistent and are not vulnerable to 60 Hz interference.
- Two-way communication becomes possible. Information can be collected from the network, enabling an entirely new set of applications.

The potential applications of this two-way communication are many and building management system vendors are now looking to lighting systems to provide all sorts of valuable information that they can leverage. Examples include:

- Having the ballasts send maintenance information, such as the status of the ballast and lamps. This could improve the efficiency of lighting maintenance.
- Providing energy usage information for benchmarking purposes and to verify savings.
- Taking advantage of energy usage information to bill internal departments or tenants individually for lighting energy consumption.

Since controls can be calibrated remotely, digital systems can be easier to commission. However, if all of the flexibility of the digital system is going to be used, the system will be fairly complex and the commissioning process to get the system, and each luminaire, operating as desired could be lengthy. Commissioning the lighting system should often be viewed as a major subproject of the larger construction or retrofit project and not simply a piece of the lighting project. This way, more attention can be placed on getting a highly qualified party to do this work.

One industry participant pointed out that the construction industry is in desperate need of efficiency improvements. He pointed out that shifting to digital control would greatly improve the efficiency of lighting system installation, and also have a positive impact on the rest of the construction process.

3.3.3.4 Proprietary and Open Standards

The key to having a *system* is that all components must be able to communicate with each other and work together. For a lighting system to be dimmable, the controllers must be able to communicate with the ballasts using a defined language or protocol. Earlier dimming systems were based on proprietary protocols developed by specific manufacturers, and were therefore limited to products from that manufacturer and companies that obtained permission to produce components for the system.

Proprietary systems offer significant advantages. Obtaining a complete control system from a single manufacturer usually means that all components have been tested and verified to work properly together. Moreover, there is a single point of responsibility for the system, rather than a contractor (who may be far from a lighting controls expert) with primary responsibility for integrating different components.

While successful systems can be and have been developed with proprietary technologies, open standards are seen to offer a number of advantages. Generally, open standards result in more vendors providing products for the system, giving customers more choice of suppliers. Some customers do not like being “locked in” to a single supplier. In addition, prices tend to be driven down by the competition associated with open standards.

3.3.3.5 DALI

European markets have tended to favor open standards. Europe’s International Electrotechnical Commission’s (IEC) standard 60929 covers electronic ballasts used in AC systems. Appendix E defines the Digital Addressable Lighting Interface (DALI) protocol. Adopted as NEMA Standard (243-2004) in the United States, DALI is a royalty-free, non-proprietary, two-way, open and interoperable digital protocol. It is important to stress, however, that DALI is a standard for *ballasts*, and not a complete control system.

DALIbyDesign is a collaborative, non-commercial website created to educate lighting practitioners, building owners, and other professions about digital control systems that use DALI (www.dalibydesign.us). The site describes the advantages of DALI in this way:

- Provides true interchangeability across ballasts and controls. Multiple manufacturers can be involved in a system, instead of being tied to a single supplier, using DALI as an open platform. This can result in lower costs, ensures future availability, and enables the system designer to select product functions from one manufacturer and combine them with products from other manufacturers.
- Provides standardized ballast performance. For example, DALI defines light output for all levels of dimming signals. DALI ensures consistent dimming performance across all dimming ballasts regardless of type or manufacturer, which is currently not achievable with analog dimming methods such as 0-10VDC.

A DALI system can include up to 64 DALI devices, each with its own digital address, on a single control bus. Multiple buses can be networked for larger systems. When a DALI ballast is configured, the custom configuration is contained within the ballast itself. DALI ballasts are able to set light levels, fade time, and fade rate, and can dim fluorescent tubes down to 1% and CFLs down to 3%.

Many companies offer DALI ballasts and interfaces to DALI systems, and DALI has not only gained good traction throughout Europe but is also in use in other parts of the world. DALI-AG is an organization within the German ZVEI (German Electrical and Electronic Manufacturers' Association) that is dedicated to promoting the standard throughout Europe and the world. The organization's website has information about projects all over Europe and in Australia, India, China, Brazil, and even Uzbekistan.

There have been some DALI projects in the United States, but these are relatively few in number considering that it has been a NEMA standard since 2004. DALI has a reputation in the United States as being expensive; while the ballasts are more expensive than standard dimming ballasts due to the advantages of a digital approach, the total cost at the system level can be very competitive with other options. Another criticism of DALI is that it is not really "standard." However, this is because some vendors are adding proprietary features on top of the basic DALI standard.

A wide variety of DALI products are available in Europe, but not in the United States. According to Lam Partners, a lighting design firm in Massachusetts, the only DALI ballasts available in the United States as of January 2011 are for 4-foot linear fluorescent lamps (T8, T5, and T5H0), 2-foot T5 lamps, 18/26/32 W quad- and triple-tube compact fluorescent lamps, and 40 W biax lamps. While these lamp types cover the majority of applications, larger systems sometimes require other sizes and configurations for specific situations. It becomes impractical to use DALI only for *most* of a building's lighting.

DALI is a dedicated protocol purely for lighting control. This means that it cannot be used to control other systems such as a BMS. DALI supporters are, however, working to provide interfaces to BACNet and LonWorks, which can then enable DALI lighting control systems to communicate with and be controlled by a larger BMS.

3.3.3.6 NEMA Digital Lighting Controls Open Protocol

As was mentioned, DALI is a standard for ballast configuration and control commands. It does not cover control devices such as occupancy sensors, switches, and photosensors. To address this, NEMA's Joint Sections Committee on DALI partnered with the California Energy Commission to author an expanded DALI protocol to incorporate standard DALI control devices. The NEMA Digital Lighting Controls Open Protocol is expected to receive NEMA approval this year.

The NEMA Digital Lighting Controls Open Protocol standardizes all the necessary control devices needed to build a complete lighting system around DALI electronic ballasts. It provides a single set of control commands and capabilities for all these devices, regardless of manufacturer. Working groups within Europe's IEC are also considering new standards for control devices, and NEMA is participating in this process.

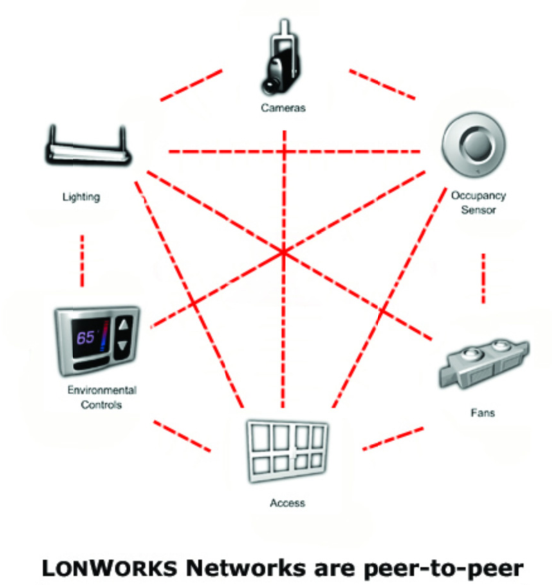
3.3.3.7 LonWorks

LonWorks is set of international standards for building automation, control, and management applications. In January 2009, the protocol underlying the LonWorks platform was ratified as a global standard for building controls. It is now formally known as ISO/IEC 14908-1.

The LonWorks protocol defines a set of operations that allow devices to send and receive messages to and from other network devices – without requiring them to know the network topology or the other devices' names, addresses, or functions. This requires, of course, a degree of intelligence within each device.

LonWorks defines a mesh network architecture in which data can travel from any point on the network to any other point, allowing full peer-to-peer interoperability among components. The mesh approach eliminates the danger of having a single point of failure. The protocol also includes high-level security.

Figure 3.4 The LonWorks Mesh Network



(Source: Echelon)

LonWorks can provide end-to-end acknowledgement of messages, authentication of messages, and priority delivery to provide bounded transaction times. It also includes support for network management services that enable remote network management tools to interact with devices over the network. These tools can perform operations such as configuring network addresses, downloading application programs, and diagnosing network problems.

LonWorks networks can be implemented over any communication medium, including power line, twisted pair, radio frequency, infrared, coaxial cable, and fiber optics.

3.3.3.8 KNX

KNX is a standard for building control, and is approved as an International Standard (ISO/IEC 14543-3) as well as a European Standard (CENELEC EN 50090 and CEN EN 13321-1) and Chinese Standard (GB/Z 20965). The KNX Association website also indicates that it is approved in the United States as ANSI/ASHRAE 135. The KNX Association states that KNX is therefore “the world’s only open standard for the control in both commercial and residential buildings.”

Figure 3.5 KNX Controls Many Building Systems

(Source: KNX Association)

KNX devices are connected along a bus. Devices can be sensors or actuators needed for the control of building management equipment such as: lighting, blinds/shutters, security systems, energy management, heating, ventilation and air-conditioning systems, signaling and monitoring systems, interfaces to service and building control systems, remote control, metering, audio/video control, white goods, etc. The bus can exist over various communication mediums, including twisted pair, radio frequency, power line or IP/Ethernet.

For lighting control, KNX devices can provide:

- Switching & Dimming
- Automatic Lighting
- Constant Light Control
- Timed Control
- Light Scenes
- DALI Gateway

The KNX Association, with over 200 member companies worldwide, offers a product certification process that ensures that different products from different manufacturers operate and communicate with each other. It employs third-party testing to ensure product compliance, and also operates training centers for contractors and building designers. Of note, there is a single, manufacturer-independent design and commissioning tool called Engineering Tool Software (ETS). ETS runs on Windows computers.

According to the KNX Association, several KNX manufacturers offer gateways to other networks – i.e., to other building automation systems, telephone networks, multimedia networks, IP networks, etc. KNX systems can be mapped to BACnet objects (as documented in the international standard ISO 16484-5) or offers the possibility to interface with the DALI technology.

3.3.3.9 DMX512

DMX512-A is an ANSI standard for digital communication networks. It grew out of work done for networks that control stage lighting, and this is still its most frequent application. While originally intended as a standardized method for controlling light dimmers, it soon became the way to also control special effects devices such as fog machines and moving lights.

The bus topology of a DMX512 network has nodes connected in a daisy chain. A network consists of a single DMX512 controller, or “master,” and one or more slave devices. An example would be a lighting console acting as the controller for networked devices, including dimmers, fog machines, and moving lights.

DMX512 is commonly used to coordinate lighting and effects at the specific command of a person or a pre-defined routine in a software program. The system does not react to changing conditions in the space. Therefore, for the purposes of this report, Pike Research does not consider this an intelligent control system. It is included here for informational purposes only.

3.3.4 Other Approaches

Not all lighting control systems use the same architecture or put certain functionality in the same place within the system. Vendors have developed different approaches and built on them over time.

3.3.4.1 Ballast-Level Intelligence

Some systems place most of the system’s intelligence in the ballasts, circumventing the need for control panels throughout the facility. Lutron, for example, connects all of the ballasts with low voltage wiring so they can form their own intelligent network. Leviton’s Sector system also uses intelligent ballasts, and the company states that an important benefit to this approach is the simplified installation that results from the elimination of such devices as controllers and power packs.

3.3.4.2 Distributed Intelligence

In this approach, the relays (the power switching devices) are distributed throughout the system. They can be attached to luminaires or placed along circuits anywhere the designers feel is appropriate. Relays do not need to be in a central panel (though this is an option), but can be located in smaller panels or individually all over the building. As a result, a great deal of control over zone definition can be achieved without the need to wire everything back to a central panel. This approach could replace central control, but is more often used to supplement it, with the management interface for the entire system still available to a single user. This type of approach is used by Encelium and by Acuity Brands’ Sensor Switch nLight system.

3.3.4.3 Automatic Configuration

Watt Stopper/Legrand introduced its Digital Lighting Management (DLM) product line in 2009. According to Watt Stopper, the DLM products, including room controllers, occupancy sensors, switches, and photocells, recognize each other upon initial installation and automatically configure themselves for the most energy-efficient operation based on the equipment that has been installed in the space. This greatly eases the installation process.

In addition, DLM can connect to the plug load in the space and help manage that power consumption, too.

3.3.5 Dimming Systems

A traditional dimming system consists of dimming panels and control stations that manage multiple lighting zones across a building or large section of a building. These components are typically connected with low-voltage wiring for the control signaling. This is in contrast to a standalone dimming setup, where the controls for a particular space are connected directly to the lighting for just that space.

Table 3.5 Dimming Systems versus Standalone Dimmers

	Dimming System	**Standalone**
Control	Intelligent control station	Wall box or other simple controller
Advantages	Control of multiple control zones; multiple adjustable settings; wider range of calibration and adjustment	Simpler installation; generally lower cost; basic operation
Disadvantages	Generally higher cost; more extensive installation	Less adjustment flexibility; can only control one zone
Ideal applications	Larger rooms or facilities with several zones of control within each room, such as open office areas, classrooms, banquet/convention/ meeting rooms and hospitality	Small spaces in a building where dimming is used in select rooms or groups, or where daylight contributions are relatively even or balanced

(Sources: Lighting Controls Association; Pike Research)

A digital control system that uses DALI or a proprietary protocol does not require dimmer modules or dimming panels. The ballasts and controllers are normally wired directly to each other and then to a master controller.

Table 3.6 Analog versus Intelligent Digital Dimming

	Analog	**Digital**
Feature set	"Lower end"	"Higher end"
Intelligence	Centralized in the dimming panel microprocessor	Centralized or decentralized to control stations for greater reliability
Controllers	Slide controls	Preset/programmable integrated controls with multiple scenes that can be programmed, stored in memory, and recalled
Interfaces	Slide controls	Interfaces such as LCD touchscreens available
Time clock integration	No	Yes, allowing programmable scheduling
Designate one controller as master controller	No	Yes
Communication	Limited to connected control stations	Can communicate with other building systems via DMX-512, RS-485, RS-232, etc., resulting in easier integration
Feedback	No	Communication from ballasts on load status, etc.
Connectivity	Typically one pair of wires per zone	One network control wire per dimming panel or system, resulting in easier wiring

(Source: Lighting Controls Association)

3.3.5.1 *Dimming Panel (for Analog Systems)*

Dimming panels supply power to the lights. Most dimming panels are compatible with almost any dimming ballast and lamp type. The following are some of the primary functions of the dimming panel.

- To provide an enclosure to house the dimmer modules
- House high densities of dimming and non-dimming circuits
- Provide a wiring termination point
- Provide a power disconnect for each dimmed/non-dimmed circuit
- Enable programmable scheduling if the panel includes an internal time clock (intelligent panel)

3.3.5.2 *Control Station (for Analog Systems)*

The control station contains the intelligence of the dimming system. It provides the instructions to the dimming panel. Among the control station's primary functions are to provide:

- Programmable scene-recall
- Individual circuit control
- Scheduling

In a standalone system, a wall-box dimmer controls a single group of lights. A control station, however, provides interfaces between users and the many dimmers in the dimming panel. While both types of controllers may be able to program dimming scenes for later use, the control station will commonly be able to control a number of lighting circuits from the same unit.

Control stations usually come with buttons that are preset at the factory for specific functions or can be configured by the installer. Each button can be programmed for a dimming scene, a fade rate, an on/off function, etc.

3.3.5.3 *Master Control Station (for Digital Systems)*

Digital dimming systems normally have one control station designated as the master controller for the entire system. Even with a master controller, each control station can be programmed by local occupants. However, it is more common that all of the control stations are programmed and administered centrally by a facility manager.

In large lighting control systems, the master controller is directly accessed through sophisticated software programs that either reside on a dedicated computer or are increasingly available as Internet-based applications. The manager, then, is able to use a robust graphical interface to program the control system and receive information about its operation. These same systems are available for the initial commissioning process as well as later for system additions or upgrades.

3.3.6 Actuators

Actuators are the components in a control system that control or vary the operation of a physical device or process. The controlled devices can include relays, variable dampers, motors, and lighting ballasts. Within a lighting system, actuators take commands from the controller and cause operations such as turning on or off a circuit and commanding a ballast to dim a lamp.

3.4 Controlling Light Sources

3.4.1 Fluorescent Lighting

Fluorescent lighting accounts for about 30% of the electricity load in the commercial market in the United States. Much of this lighting is of older vintages, however, presenting a prime opportunity for upgrades. While upgrade activity has been ongoing for some time, very little of it has included dimming systems. This is evidenced by the fact that during the 12 months ending March 2010, only 1.1% of ballasts sold in the United States were dimming fluorescent (Vista Information Services). Another indication of the scale of the upgrade opportunity is that almost 10% of the ballasts sold during that period were still the old, inefficient magnetic variety. These figures are most likely similar to those in other regions of the world, though with even more magnetic ballasts and fewer dimming ones in the mix.

Another major opportunity for fluorescent lighting is the replacement of probe-start metal halide technology. Unlike metal halide and other HID lighting technologies, fluorescent lamps turn on instantly, without a warm-up period, and can turn back on quickly (known as instant-restrike) after being turned off. HID lamps have a restrike delay before a lamp that was recently turned off can be relit.

Fluorescent lamps do have their own operational idiosyncrasies, however. When there is high switching activity, such as six or more on/off cycles per day, programmed-start ballasts should be used so as not to drastically reduce lamp life.

3.4.1.1 Compact Fluorescent Lamps

Though CFLs may be best known these days for their increasing penetration of residential markets, they already have a significant history in commercial applications. CFLs are widely used as downlights in offices and hallways in all types of buildings.

There are two primary types of CFLs. The screw-base version is designed to fit into the same sockets as regular incandescent A-bulbs. Most screw-base CFLs have integrated ballasts (and are commonly known as self-ballasted). The downside of this is that when the lamp fails, the ballast must also be disposed of. The rated lives of self-ballasted CFLs are in the range of 6,000 to 15,000 hours. With modular CFLs, it is possible to change out a failed lamp without needing to replace the ballast. Since these ballasts have rated lives of 50,000 hours or more, this can result in significant savings over the long term.

Most of the CFLs used in commercial applications have been of the modular type, and dimming ballasts have been available for these for a number of years. Dimming CFLs can be controlled just like other fluorescent lamps, either in standalone or networked configurations. Modular CFLs can usually be dimmed down to as low as 5%.

As the use of CFLs has grown, it has been difficult to find quality self-ballasted dimming CFLs. However, manufacturers have recently made significant progress with these products and their quality has greatly improved while prices have declined. Most self-ballasted CFLs can only be dimmed down to as low as 20%.

3.4.2 High-Intensity Discharge Lighting

HID lighting accounts for approximately 12% of all lighting electricity consumed by the commercial sector in the United States. HID light sources, ranging from 20 W to 2000 W in size, are used in warehouses, big-box stores, and other larger indoor spaces.

HID lamps can be dimmed using stepped dimming or continuous dimming, but characteristics of HID lighting make it more complex to design dimmable systems for them. For example, high pressure sodium lamps can take three to five minutes to warm up. They hot-restrike in less than a minute, though not instantaneously, but do not reach full output for another three to four minutes. Traditional metal halide lamps take from two to ten minutes to warm up and 12 to 20 minutes to hot-restrike. Newer pulse-start metal halide lamps are much faster, but can still take one to two minutes. In addition, HID lamp life is commonly rated by manufacturers assuming a minimum of ten ON hours per start. Shorter durations per start will lead to shorter lamp life.

HID lamps are also not supposed to be dimmed below 50% of their rated power, or they may experience reduced efficacy, changed color, and degraded lumen maintenance. Some may just turn off. Moreover, dimming below 50% of rated power may reduce lamp life by 90%, voiding warranties. Given this, there are limited options for dimming systems for HID lamps. Lamps cannot simply be turned off and restarted based on occupancy, for example. If the lights must be left on even when the space is unoccupied, an energy-saving opportunity is lost.

3.4.2.1 *Stepped Dimming*

Stepped dimming is a good option for HID lighting systems for spaces where full light output is needed quickly. It is also a relatively low-cost approach, as far as controls are concerned. The lights are maintained at a lower level, usually 50% of output, while the space is not occupied. Then, based on a signal from a manual switch, a scheduling device, an occupancy sensor, or a photosensor, the light level is quickly raised to 80%. As the lamp warms up, it will reach 100%.

Stepped dimming works with all types of HID lamps, and represents a suitable approach for spaces that are unoccupied for a majority of the time, but still need to have some level of light for security or other reasons. Parking lots and warehouses are prime examples.

3.4.2.2 *Continuous Dimming*

Technologies are now available to enable smooth, continuous reduction of HID lamp wattage. These include panel-level HID dimming and relatively new electronic HID ballasts. A primary purpose for HID dimming is to adapt light levels to meet a range of uses for a space, such as sporting arenas, industrial facilities, and auditoriums. Continuous dimming can also be used for daylight harvesting applications, such as in big-box stores.

Electronic dimming ballasts for HID lamps provide continuous dimming, typically from 100% to 50% for metal halide and from 100% to 30% for high pressure sodium lamps. Electronic ballasts are also more energy efficient than traditional HID ballasts. While they may be too costly to pay off in retrofit applications, electronic ballasts may be a good alternative when installing new fixtures. These ballasts work with occupancy sensors, photosensors, and time-programmable systems. The control signals can be transmitted along either the power circuit or low-voltage wires.

3.4.2.3 *Efficacy and Color*

When an HID lamp is dimmed, the reduction in wattage is not proportional to the reduction in light output. Efficacy declines at the lower light levels. In general, light output reductions are about 1.2 to 1.5 times the power reduction for metal halide lighting systems, and about 1.1 to 1.4 times the power reduction in high pressure sodium lighting systems. However, this loss of efficacy does not apply when electronic ballasts are used.

Moreover, the color of HID lamps can shift when dimmed, and their color rendering ability can decline. Metal halide lamps, which start out more white and with better color rendering, are more susceptible to these changes than high pressure sodium lamps, which give off yellowish light and have poor color rendering ability to begin with.

3.4.3 LED Lighting

In general, the solid state technology in LED lights makes them excellent for dimming applications. In addition, the lower current flowing through the LED when dimmed reduces the operating temperature, increasing the lifespan of the light. Frequent switching also has no negative impact on life expectancy.

However, not all dimmers are compatible with all LEDs. In fact, there have been significant compatibility problems between SSL luminaires and dimmers, especially in the residential sector. There are even reports of poor dimming performance when using dimmers recommended by the SSL manufacturer. Problems have included:

- Less of a dimming range than expected (not 100% to 1%)
- Unclear relationships between the dimmer control position and light output
- The LED turning OFF during the travel of the dimmer
- Noticeable flicker when the LED product is dimmed
- Color shift when the LED product is dimmed

There is a drive in the industry to define the compatibility requirements between dimming controls and dimmable LED products. NEMA determined that the first SSL dimming area to address should be SSL dimming for incandescent replacement products. The American National Standard Lighting Group (ANSLG) and NEMA are working on developing a NEMA standard for LED dimming. ANSLG will then take the NEMA standard forward through finalization using the open ANSI process, with a target for acceptance as an ANSI standard in mid to late 2011. The standard will address:

- Requirements to prevent damage to dimmer
- Requirements to prevent damage to dimmable integrated LED lamp
- Dimming performance system requirements

For now, compatibility issues are reviewed in a whitepaper recently published by NEMA's Solid State Lighting Section. The paper, LSD 49-2010 *Solid State Lighting for Incandescent Replacement: Best Practices for Dimming*, can be downloaded for free from NEMA's website.

3.5 Increasing Integration with Building Management Systems

A building management system (BMS) has some energy management functions, including the HVAC and lighting systems, but also includes the monitoring of fire and security systems among other building and mechanical controls. In contrast, a building energy management system (BEMS) is similar to a BMS but is specifically focused on controlling electrical loads to manage energy consumption for *energy efficiency optimization*. BEMS are generally brought to market by vendors that solely focus on energy efficiency and energy management. A BEMS can exist either as a standalone system or integrated within a BMS.

BEMS have normally been capable of switching large blocks of lighting loads; however, only a relatively small percentage actually control lighting levels. According to a 2003 U.S. DOE report, BEMS controlled HVAC systems in buildings that accounted for 24% of commercial floor space in the United States, but controlled lighting systems in buildings that only accounted for 7.4% of floor space. This percentage has surely increased since the time of the report, but industry estimates are that less than 20% of all commercial lighting is controlled at all – and only a portion of this control is connected to a larger BEMS.

One problem is that the traditional BEMS have not been capable of working with the advanced lighting control strategies that are gaining popularity. Daylighting control, occupancy sensing, and dimming controlled by digital controllers are not sufficiently compatible with the legacy BEMS control approaches. Therefore, more complex lighting control systems have often been left to run in parallel with the rest of the BEMS. This leaves two separate software packages and system interfaces for building managers to administer.

There is increasing demand, however, for the integration of lighting control systems with broader BEMS and BMS environments. These drivers were discussed in Section 2.2.6. BEMS suppliers have been looking to lighting management system (LMS) vendors to provide this capability. The preferred approach has been to make the lighting systems compatible with BACNet or LonWorks, protocols that enable integration without requiring a translation gateway.

In some circumstances, it will even be possible to leverage the investment in the lighting control system to provide information for and control of other building systems. For example, an interface could make sense between an occupancy sensor and HVAC control for the space, or between an occupancy sensor and a security system.

3.5.1 BACnet

BACnet started out as an ASHRAE standard back in 1995 and is now is an international standard, ISO 16484-5. From the start, BACnet was intended to help manage the wide variety of systems in a building, including HVAC, fire and alarm, security, elevators, and lighting, by providing a means of communication between any type of automation device. The most common application is for control of HVAC systems. There can be ties, for example, to the fire system so that the HVAC system can be shut down in the event of a fire. In a more advanced building, there can also be networked communication among the HVAC, fire, access control, lights, and elevator systems.

BACnet works on a client-server model: A client sends a message, known as a “service request,” to a server device. The server performs the service and reports the result back to the client. All the devices on the network look and act in the same general way. BACnet also includes a network layer protocol to define communication between different network types.

BACnet was originally designed to be flexible and extendable and, unlike some standards in different industries, has successfully been applied to an increasing variety of applications. BACnet has been applied to lighting applications since the beginning, but new lighting-centric features are under development.

BACnet is supported and maintained by ASHRAE Standing Standard Project Committee 135. Within Committee 135, there is a Lighting Applications Working Group, which works with the NEMA Lighting Control Council and the IES Controls Committee.

There is an extension under development for a proposed Lighting Output object type. This includes features specific to lighting such as ramping, fading, blinking, and incremental stepping of lighting levels. The extension also enables a clear mapping of lighting system functions that are used in DALI. This extension has gone through a number of review cycles, and the working group is making progress toward a fifth review later this year. If all goes well, this addendum to BACnet could be finalized before the end of 2011. Work also continues on topics such as support for color lighting, though an addendum incorporating those additional features would be farther in the future.

3.5.2 Modbus

Another protocol that can be used for communication between lighting control systems and BEMS is Modbus. One controls vendor reported that after BACnet over IP, the second most requested interface type is Modbus.

Modbus was developed in the 1970s as a communication protocol for programmable logic controllers, which are primarily used in manufacturing. It enables communication between many devices connected to the same network. Over time, applications of Modbus expanded due to the fact that it is an open standard and is available royalty-free. It is widely used for communication between electronic devices in manufacturing and process industries. A frequent application of Modbus is the connection of a supervisory computer with some type of remote terminal or other device.

As a mature protocol, some integrators are very familiar with Modbus and how to work with it. The primary disadvantage is that it is typically implemented over the electrical specification known as RS-485, which results in much lower data throughput rates than any protocol implemented using IP on Ethernet. This lower speed can have a negative effect on system performance when feedback is slower in returning to users. To quote the engineer from the controls vendor, “Nothing is more disconcerting than having the lights change state when the monitor in front of you does not indicate that it should be happening.” This feedback situation can get worse for larger systems. This is not always a problem, however, depending on the specific characteristics of the system and the user interface.

3.5.3 LonWorks

The LonWorks protocol is also used throughout many building systems and can be used to integrate lighting control systems with larger BEMS and BMS. LonWorks was discussed earlier in Section 3.3.3.7.

3.6 Commissioning

The IES Handbook defines commissioning for a daylighting system as “a systematic process that ensures that all elements of the daylighting system perform interactively and continuously according to documented design intent and the needs of the building owner.” Professor Konstantinos Papamichael, associate director of the California Lighting Technology Center at UC Davis, has a simpler definition: "Here it is. Make it work."

Making a system work properly is truly the core of the commissioning process. When lighting control was simply a matter of switches, lighting or general electrical contractors were able to perform the installations and easily verify that the lights worked. Current best practices encourage the commissioning agent’s involvement in a lighting control system project as early as possible. Commissioning such a system can require:

- Design documents that include specific performance expectations including information such as time-out settings for occupancy sensors and threshold levels for daylight harvesting systems.
- As part of installation, all controls, such as dimmers and override settings, need to be tested.
- Sensors then need to be calibrated, including occupancy sensor sensitivity and threshold levels for photosensors.

Training is also a critical part of the commissioning process. The maintenance staff needs to be able to calibrate the sensors, for example, and end users should be familiar with how the system functions and why the sensors and controls were designed to operate as they do. As the Lighting Design Lab, a consulting and education service sponsored by the Northwest Energy Efficiency Alliance, puts it, "This type of training can do away with the 'Dixie cup over the photosensor' phenomenon and may eliminate costly service calls for occupancy sensors that are functioning properly."

The California Lighting Technology Center provides these more detailed lists of commissioning tasks.

3.6.1.1 Traditional Commissioning Tasks

- Device Placement
  - Lighting Systems
  - Occupancy & Photo Sensors
- Wired Connections
- Wireless Connections
- Established Communications
- Physical Testing & Verification

3.6.1.2 Emerging Commissioning Tasks

- Software-based Setup
- Customized Control Strategies
- Customized Control Algorithms
- Software-based Monitoring & Diagnostics
- Remote, Web-based Commissioning
- Long-term Commissioning Services
- Reconfiguration of Strategies & Algorithms

3.7 Wireless Control

One of the main impediments to the greater use of lighting controls is the difficulty retrofitting the systems into existing buildings. To install the sensors, wires must be run to provide power and carry the control signaling; this makes labor a major component of the total cost of a lighting control retrofit. Installing the wiring can account for anywhere from 20% to 80% of the total cost of adding a system to an existing building.

Wireless systems have been developed to carry the control communication, and have the capacity to greatly reduce the labor costs associated with system installations. In addition, wireless provides more flexibility regarding the placement of sensors. Systems can also be reconfigured much more readily when, for example, an office area is reconfigured or a space is repurposed for a different use.

The use of wireless actuators and sensors has three primary challenges: Wireless systems are vulnerable to radio interference; the security of the signaling is a concern; and the need to provide and manage power is critical for the long-term success of the system.

Even with wireless control, the need to power the sensors and actuators still exists. Actuators are connected to the equipment they control, so power is available for them most of the time. Sensors are sometimes integrated into or installed along luminaires, making power readily available to these, as well. However, optimal placement of sensors is more often on walls or ceilings or near windows – not near a power source. So, wireless sensors will either still require a power supply or operate off of batteries.

3.7.1 New Construction or Retrofit?

Whether wireless controls will be a benefit to a project will depend on the nature of the project. Common thinking in the industry is that wireless is generally not worth the additional product expense and technological uncertainty when applied to new construction. Power is going to be run throughout the building, and running extra wiring for control signaling is not thought to be much of an incremental cost. Similarly, if the project is a major lighting retrofit where all of the lighting fixtures are going to be replaced, the wiring to provide the luminaires with power is going to be redone anyway. Again, in these instances, the incremental cost of running control wiring may not be too great.

Of course, proponents of wireless control systems have responses for this. They point out that control wiring can still require literally miles of additional wiring and conduit, and that in high cost labor markets, even a few additional hours can add significant costs to a project. Even in new construction, a wireless system could save about 15% of the labor cost. In addition, proponents will explain that wireless systems come with much more flexibility. The final positioning of switches, for example, can potentially be delayed until the interior spaces are configured and built. Similarly, the best locations for equipment are not always known during the design process, and specific users come into the picture even later. There is flexibility for the future, too, as the use of space within the building changes.

It is easier to make the case for considering wireless controls for retrofit projects. In addition to saving the miles of wire and conduit, wireless systems eliminate the need to pick up floors or go through walls or ceilings. Overall, the labor component of the project could be reduced by as much as 75%. In addition, the disruption to occupants and business operations is significantly reduced.

It is impractical or very undesirable to try to wire systems throughout many older, historic buildings or ones constructed out of concrete or stone. Also, some facilities such as hospitals, museums, labs and data centers often house materials requiring very precise and stable air conditioning, making the mess of a wired system installation unacceptable.

Although wireless is more accepted as a solution for retrofit situations, throughout the world only a relatively small percentage of retrofit projects are taking advantage of the technology. There is plenty of opportunity for wireless systems to gain a share of this very large and growing market.

Table 3.8 provides some additional benefits of wireless controls.

Table 3.7 Features of Wireless Sensors and Controls

Features	Benefits
Improved flexibility	Not necessary to locate sensors near wires. Wireless sensors can be easily relocated as the indoor space undergoes reconfiguration. For instance, a wireless light switch can move with the interior wall. Some spaces, such as conference and exhibition halls, warehouses, and auditoriums are restructured frequently.
Ease of servicing	Wireless sensors can be easily removed from their location for recalibration or replacement in case of failure.
Extendibility of existing wireless network	Once a wireless network is established, additional sensors and controllers can be easily added at the cost of an additional wireless device

(Sources: Pacific Northwest National Laboratory; Pike Research)

3.7.2 In-Room, or Building-Wide Wireless

There are two broad categories of wireless systems: in-room and building-wide. In-room systems are small and simple. They are for deployment in localized spaces and primarily involve wireless communication between a switch and/or sensors and the ballasts controlling the luminaires in the space. The room can be as small as a private office, or a larger space such as an open office area, conference room, cafeteria, etc. These types of systems have reached the point where they are very robust and reliable.

Building-wide wireless systems involve communication with the luminaires throughout the building. There are still questions regarding how many nodes or points of contact such a system can contain and still achieve the quality and reliability of a wired system. There are certainly plenty of anecdotal examples of problems with larger-scale wireless systems and this talk will continue to constrain the progress of wireless in the market.

3.7.3 Wireless System Technologies

A number of technologies are being used for wireless control systems. Some vendors have built their systems around proprietary implementations of Wi-Fi type radios, or even more customized radio communication methods. However, the two most widely used technologies are ZigBee and EnOcean.

3.7.3.1 ZigBee

ZigBee is a wireless networking standard designed for low-power control and monitoring applications. It is managed and specified by the ZigBee Alliance, an industry organization with more than 300 member companies. The Alliance touts ZigBee as "the only standards-based wireless technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks in just about any market."

ZigBee is built on top of the IEEE 802.15.4 Medium Access Control (MAC) and physical (PHY) layers. The standard is designed for devices that will self-assemble into wireless mesh networks in the 2.4 GHz band. In a mesh network, each device (node) also acts as a relay point for the communication being sent by other devices. Mesh networks are generally very reliable since there is no single point of failure.

ZigBee devices are intended to operate for years on low-cost batteries. In reality, however, wireless devices that are constantly communicating, as are nodes in a mesh network, cannot currently achieve such long battery lives. The approach that appears to be in use to reconcile these facts includes the sensor devices at the periphery of the networks taking advantage of “sleep” modes to extend the life of their batteries, and the wireless routers that actually comprise the mesh and must be frequently communicating with each other having access to hardwired power.

ZigBee processors and software are available from many vendors, including Ember Corporation, Freescale Semiconductor, and Texas Instruments. In high volumes (10,000 units), ZigBee chips can be purchased for less than $6.00 each.

ZigBee has a number of standards defined for markets such as Home Energy, Retail Services, and Remote Controls. The ZigBee Building Automation standard is being designed for “efficient commercial spaces.” This standard specifically addresses applications such as HVAC and lighting control. Although the Building Automation standard has yet to be finalized through the standards process, the differences between it and the core ZigBee standard are minor enough that lighting control systems can apply ZigBee without danger of being out of compliance.

The ZigBee Alliance joined forces with BACnet to fully support BACnet over ZigBee Building Automation networks. This will enable wired BACnet-based building systems to expand into additional spaces with the wireless ZigBee products. Moreover, the Joint Sections Committee on DALI is also working with the ZigBee Alliance to facilitate wireless communication for DALI systems.

3.7.4 EnOcean

EnOcean is a standard for battery-less, wireless systems for building controls and automation. The technology was developed by EnOcean GmbH, which spun off from Siemens in 2001. Now, the nonprofit EnOcean Alliance, with 160 member companies, controls the standard and ensures interoperability among products. There are currently more than 700 certified products in the categories of Switches, Sensors, Actuators & Controllers, Gateway & Building Management Systems, and Accessories.

A primary advantage of a wireless control system is that wiring is not needed to carry the control signals. However, power must still be provided to the devices, either via connection to a wired power source or via a battery that would eventually require replacement. EnOcean addresses this problem by defining ways for the devices to collect power on their own. EnOcean devices “harvest” energy created from slight changes in motion, pressure, light, temperature, or vibration. For example, the motion of a person pressing a switch provides the power for that switch to wirelessly signal the devices it controls. A photosensor collects power from the ambient light so that it can provide information to the rest of the lighting control system. Even in windowless spaces, an occupancy sensor in manual-on, auto-off mode will receive enough energy from the artificial lighting in the room to complete the auto-off function.

Without needing any other physical connections, EnOcean devices can be, quite literally, “peel and stick.” And many of the products do indeed come with adhesive backs.

An EnOcean receiver can be connected to other systems via DALI or BACNet, or just configured to receive the signal from a simple switch.

EnOcean got its start in Germany and has taken hold in that country. During April 2009, EnOcean devices were installed in their 100,000th building. By now, most specifiers and users are already very familiar with and comfortable with the technology. According to the EnOcean Alliance, products with the EnOcean standard are probably installed in more than 50% of the new large commercial buildings in Germany, and in a somewhat lower but still significant percentage of small office and residential projects. In fact, there are buildings with as many as 12,000 EnOcean switches and sensors.

Use of EnOcean technology is also spreading throughout the rest of Europe and is catching on in Asia. There are some initial systems in North America, but now that a number of major control vendors have begun releasing products for the North American market, expansion there should pick up within a couple of years.

3.7.5 Concerns with Wireless Controls

Wireless control systems face similar obstacles and concerns to many other complex solutions, including control systems. These include concerns regarding a relatively more expensive initial cost than alternatives and questions about reliability.

In addition, wireless solutions also face some unique concerns, including:

- How robust are the systems when exposed to RF interference? Will there be router problems?
- How robust is the system on a facility-wide basis?
- Are there going to be problems in steel buildings? Difficulties with foil-backed insulation? Problems with other materials not normally friendly to radio transmissions?
- Many utilities are not yet sufficiently convinced of the reliability of wireless systems to fully include them in their energy efficiency rebate programs. Beyond short-term reliability, there are questions such as whether the batteries will be replaced when needed in order for the energy savings to persist.
- Ongoing maintenance costs may be high. “It works until it doesn’t.” Anyone familiar with RF systems knows that it can then be very complicated to figure out what the problem is. It could take expensive specialists some time to solve the problems.
- The traditional lighting and lighting controls markets do not have wireless expertise. The major vendors will make the products available, but they may not have much incentive to push wireless solutions. Wireless is a bigger risk for them, too.

3.7.6 When Will Wireless Really Take Hold?

It takes time for any new technology to gain acceptance in a market with so many incumbent vendors and products. Wireless lighting controls face barriers due to issues related to the use of lighting controls themselves plus concerns about wireless. However, EnOcean, especially, is booming in Germany, and various wireless lighting control offerings have already gained a foothold in most countries.

One vendor offered some insight based on the shift of the building security system market to wireless. Even though wireless security systems were available for some time, it took 10 years until the technology achieved a 50% penetration of the U.S. market. This occurred only three years ago. Lighting should reach this level faster.

- There is less risk associated with trying something new with an organization’s lighting system than its security system.

- There is far greater savings potential from using wireless due to the pervasive nature of lighting in a facility.
- There is more general comfort with wireless technology, as wireless communications technologies are in the process of saturating just about all developed and many developing countries around the world.

So, look to 2015, or around that time frame, for wireless lighting controls to achieve a 50% market share – at least in retrofit projects in developed markets.

3.8 Standards versus Proprietary Systems

As vendors began to offer more functionality in their lighting control systems, especially sophisticated dimming and daylight harvesting schemes along with more sophisticated user interfaces, their only option was to design them as well as they could without regard for interoperability with equipment from other vendors. There were no standards, officially sanctioned or *de facto*, capable of supporting these advanced capabilities. Over time, more products and services were added to these systems. They became robust, highly functional, fully integrated from end to end, and proprietary. The prime example of this approach has been Lutron.

Many customers appreciate the one-stop shopping and single point of responsibility offered by proprietary systems. In addition, an integrated, proprietary system from a well-established vendor removes a great deal of the implementation risk. Confidence is bolstered by the vendors' ability to provide numerous relevant case studies and reference clients. For decades, there was a saying in the information technology industry that "Nobody was ever fired for buying IBM." In other words, even if something went wrong, the decision-makers would still have been seen as having chosen a good system with the lowest risk. A similar statement could probably be made about Lutron products for much of the recent history of lighting control systems.

Other potential customers feel constrained by the proprietary approach. They fear that they are paying a premium for what may or may not bring them extra value. "Why do I need such expensive intelligent ballasts for my bathrooms? We're never going to use continuous dimming in there." They are worried about getting "locked in" with a single vendor for any future system expansion. They probably are in contact with other vendors who claim, for example, that they have a better occupancy sensor for a particular situation that the customer would not be able to use with the proprietary system. Many of these customers choose to accept less functionality at a lower cost while maintaining a greater degree of flexibility for the future. In the near term, those attractive energy savings and improvements to the work environment can be achieved through many different system solutions.

Some of the newer vendors in the market are offering proprietary systems. A couple of major examples are Adura and Redwood Systems. These companies are still funded by venture capital and have only recently been installing commercial systems. Potential customers may wonder what would happen to their investments if they purchase a system from a vendor like this, who then goes out of business.

Standards are still lacking for the kinds of complete proprietary lighting control systems that are available today. Standards exist only for parts of the system, not the totality of it. For example, the 0-10VDC analog communication standard applies to ballast control and the DALI standard applies to digital communication with ballasts. Protocols such as LonWorks and BACnet cover more of the system, but without some of the functionality particular to lighting. In fact, there have been some problems bringing these standards deeper into the HVAC environment and there are fears of similar difficulties in lighting controls.

From a vendor perspective, a big problem with an open system is that it is very difficult to maintain any kind of product-related competitive advantage. Attractive features that one vendor adds are usually replicated and brought to market by others within a year. Vendors do not like being seen as a commodity. Consequently, even when standards are available, vendors start to make tweaks to their products to develop some level of differentiation. For example, ZigBee wireless is being used as a standard communication pipe, but some vendors are making custom modifications to the protocol.

There are vendors who firmly believe in the standards approach. For example, EnOcean is an open standard that has already gained significant traction in wireless lighting controls. Also, Daintree has made a commitment to pure ZigBee and is providing its core technology to component vendors who wish to be part of a community using the same open standard.

Will there be a winner in the proprietary versus open standards battle? In some industries, there have been a winner and a loser in this type of competition. In the lighting controls industry, however, Pike Research believes there is room for both approaches to thrive.

3.9 Other Technology Trends

3.9.1 Integral Controls

Traditional control system configurations have required low voltage wiring and power packs for each sensor. To help lower the initial cost of these systems, manufacturers have developed options for sensors that mount directly to luminaires and operate on line voltage. The lamps in the luminaires can then be controlled directly by the sensor without any additional control wiring. In some cases, these sensors are integrated into the luminaires by the vendor. Otherwise, they can be connected during installation.

These are examples of integral control configurations that may be appropriate for a lighting retrofit project:

- For an open office: Direct/indirect fixtures with an integral occupancy sensor; if placed in a daylight zone, can also include a photosensor and dimmable ballast
- For high bay lighting: Fluorescent fixtures with integrated or mounted line voltage occupancy sensors; if space receives sufficient light from skylights, photosensors could also be added

The integrated high bay lighting products offered by Lumetric (with HID lighting) and Digital Lumens (with LED lighting) represent this trend taken to further lengths. These products were briefly described in section 2.4.7.3.

3.9.2 Photocontrol Trends

Photosensors are not able to evaluate the quality of light in a space. While light quality is subject to the perceptions of the occupants, general parameters include lighting intensity, distribution of the lighting, lighting spectrum, and lighting contrast (including glare). Improved sensors are needed to detect and evaluate lighting along quality measures such as these.

To date, efforts have been mainly focused on managing the control of artificial lighting in daylit spaces. Increasing emphasis will be placed on the real-time control of how much daylight enters the space. Actively controlled interior and/or exterior blinds are already integrated into some high-end lighting control systems. In addition, work is proceeding on glass that adjusts to let in more or less light based on light striking it from the outside, or on commands from a control system. Pike Research's forthcoming report on Smart Glass will cover this topic in more depth.

One industry engineer speculated that low-resolution cameras could take the place of photosensors in some applications. They may be better able to compensate for changes in room interiors, such as surface reflectance.

3.9.3 Integrated Power Metering

Customers want proof of savings from their lighting control systems. Without detailed sub-metering and external monitoring, this had been very difficult to provide on any more than a theoretical level. Cooper Controls recently introduced power metering functionality into its architectural dimming systems. The data to compute the savings can now be provided automatically to an application that resides in the control system. Other vendors are incorporating similar functionality into their products.

Interest in metering is also resulting from the increased use of the LEED for Existing Buildings Operations & Maintenance (EBOM) rating system. To earn certain points, LEED EBOM requires information on actual energy use for key sub-systems, including lighting.

3.9.4 Tools

Tools for designing and commissioning lighting control systems can be very valuable due to their ability to reduce the amount of time that specialists must spend on a project as well as to ensure better long-term results.

The following are brief descriptions of a sampling of tools that are available to the public at no cost.

3.9.4.1 SPOT Version 4.0

The Sensor Placement & Optimization Tool (SPOT) "is intended to assist a designer in quantifying the existing or intended electric lighting and annual daylighting characteristics of a given space and to help establish the optimal photosensor placement for the space relative to annual performance and annual energy savings."

SPOT was developed by the Architectural Energy Corporation, an engineering and sustainable design consulting firm. The first version of the product was developed with support from the California Energy Commission PIER Lighting Research Program. Subsequent versions have also been supported by a variety of NGOs and utilities.

At the 2008 LightFair International trade show and conference for architectural and commercial lighting, the SPOT Version 4.0 software won the top award for the Most Innovative Product of the Year.

The tool is available at www.archenergy.com/SPOT/.

3.9.4.2 Commercial Lighting Solutions

The U.S. DOE introduced the Commercial Lighting Solutions (CLS) program in 2009. CLS for Retail was developed first, and CLS for Office was launched in May 2010. CLS is a free web-based tool that allows people to customize lighting templates designed to produce 30+% energy savings compared to ASHRAE 90.1-2004. The tool includes extensive lighting control templates developed in collaboration with the Lighting Controls Association.

The DOE website describes the tool this way: "The Commercial Lighting Solutions provide actionable 'how to' guidance on ways to improve your building interior lighting efficiency and reduce your energy consumption, without compromising quality design criteria. Strategies include the use of high performance commercially available products, daylighting, and lighting controls, all within the context of integrated designs supported by performance specifications."

CLS accepts a wide variety of input, including the dimensions and characteristics of the space being modeled, assumptions on the types of new lighting that will be used, lighting control strategies, and the current lighting configuration in the case of an existing facility. CLS then produces detailed schematics for implementation of the lighting system. It also provides information that may be required to claim rebates and tax incentives.

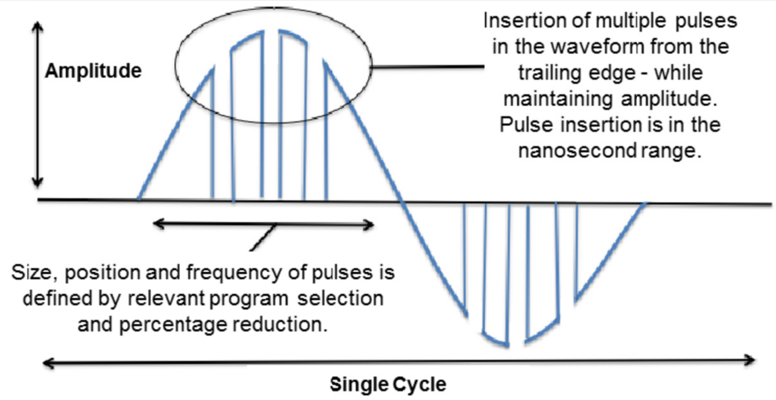
The tool is available at www.lightingsolutions.energy.gov. Training is being provided by the Energy Center of Wisconsin's Energy Center University.

3.9.5 Waveform Modification

Waveform modification is not an intelligent lighting control technology within this report's working definition of the term. In fact, though it can help reduce energy used for lighting, it is not clear that it is really a "lighting control" technology at all. Semantics aside, however, Pike Research believes that Cavet Technologies' implementation of waveform modification could be significant enough to the lighting industry that the decision was made to include it here.

Cavet has introduced the LumiSmart ILC (Intelligent Lighting Controller) and claims that use of the product can save 30% or more of the energy used to power fluorescent lights. Cavet explains that "LumiSmart applies waveform modification to the electrical sine wave. By inserting on-off pulses in to the sine wave, LumiSmart is able to dramatically reduce electrical consumption with minimal impact on lighting levels." Another way of describing this is that LumiSmart uses digital techniques to vary the power applied to the ballast so rapidly – shutting off the electricity for nanoseconds at a time – that there is no perceptible drop in the light emitted. Figure 3.5 illustrates this concept.

Figure 3.6 LumiSmart Adaptive Waveform Modification



(Source: Cavet Technologies)

LumiSmart received UL certification in November 2010. According to Cavet, the product is being piloted in dozens of installations in a wide variety of building types in North America and Europe. As of the writing of this report, no major orders have been announced.

3.9.6 A Glimpse at the Future

What does the future hold for lighting controls? For one, since lighting exists virtually everywhere in the building, control systems that monitor lighting will provide managers with a great deal of information about their buildings and how they are being used. The following are just a few examples that merely scratch the surface of the possibilities:

- Which areas of the building are occupied at different times of the day/week?
- When and how often are storage rooms accessed?
- When are conference rooms not being used even though they have been booked? (Some facility managers report that the most frequent complaint they receive is from people who cannot get a conference room for a meeting.)

Professor Michael Siminovitch is director of the California Lighting Technology Center and associate director of the Energy Efficiency Center there. The following is an excerpt from a videotaped interview on SmartPlanet.com:

"Looking down five to ten years in terms of lighting, what we're going to see is tremendous advances in what we call smart or intelligent lighting systems. These are systems that we're going to have in our homes and our offices that are highly responsive to our needs. Lights will vary in terms of intensity and spectral distribution to satisfy human desires. We're going to see a big jump forward in very responsive lighting systems."

3.10 Research Topics

The U.S. Department of Energy's wireless controls research projects at Pacific Northwest National Laboratory (PNNL) include the following:

3.10.1 Ambient Power Harvesting

PNNL researchers are investigating methods for harvesting ambient power from temperature differences, flows, electromagnetic fields, and light to power wireless sensors. After an initial examination of several concepts, researchers began development of the use of thermoelectric technology to harvest energy from temperature differences in the environment (e.g., the air inside and outside an HVAC duct). Significant advancements are anticipated in the process and cost of producing thermoelectric elements, which will become the centerpiece of sensors powered by temperature differences.

3.10.2 Wireless Infrastructure for Performance Monitoring, Diagnostics, and Control for Small Commercial Buildings

PNNL researchers are working with a team led by NorthWrite Inc. to create an innovative wireless technology platform for performance monitoring, diagnostics, and control of equipment and systems in small commercial buildings. The platform will provide cost-effective energy management and maintenance services, making them available via an Internet browser on the server of an application service provider (ASP). The proposed infrastructure will integrate wireless mesh networking technology with wireless telemetry, automated fault detection, diagnostics, control, and the ASP delivery model. The system will be tested by applying it to rooftop HVAC units and lighting systems. The development team also includes Sensor IQ, Trane, and Texas A&M Energy Systems Laboratory.

3.10.3 Additional Research Topics

In 2005, PNNL prepared a report for the U.S. DOE titled "Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways." The report recommended research into the following topics related to lighting controls:

- Ability to easily bind sensors to lighting fixtures
- Ability to develop occupancy patterns and use them to better predict occupancy rather than motion
- Determination of set points based on lighting quality needed, rather than lighting level over the entire spectrum
- Development of user interfaces that couple automation with human needs for lighting control
- Lighting interactions with demand-responsive systems
- Interaction of lighting systems with HVAC control set points

Additional research recommendations involving lighting controls:

- Demand response
- Whole-building simulation tools
- Adaptive controls
- Advanced sensors
- Sensor & control system integration
- Actuators
- Building control networks
- Protocol and standards
- Performance monitoring
- Automated fault detection and diagnosis

Section 4

KEY INDUSTRY PLAYERS

4.1 Introduction

This section profiles a number of important players in the global lighting controls industry. Pike Research did not select these merely by size, though the largest companies are included. Rather, certain companies are profiled because of unique or important positions in the market, or because they are illustrative of the challenges facing a larger number of companies.

4.2 Companies

The profiled companies appear in the following sections alphabetically.

4.2.1 Acuity Brands Controls

Acuity Brands, headquartered in Atlanta, Georgia, was founded in 2001. The company had net sales of $1.63 billion for its fiscal year ending August 31, 2010, down 1.8% from 2009. International (non-U.S.) sales were $181 million (11% of total), up 1.7% for the year. Acuity is one of the world's leading producers and distributors of lighting fixtures. According to PAA Research, Acuity is number two in the North American lighting market with about a 19% share.

Acuity designs, produces, and distributes a broad array of indoor and outdoor lighting fixtures and lighting controls for commercial, industrial, infrastructure, and residential markets throughout North America and select international markets. The company has a broad product line consisting of roughly 500,000 active products sold to approximately 5,000 customers. Acuity manufactures its products in 14 plants in North America and two plants in Europe. The company has approximately 6,000 employees.

Acuity's principal customers include electrical distributors, retail home improvement centers, national accounts, electric utilities, municipalities, and lighting showrooms. The Home Depot has historically represented more than 10% of its sales. In North America, Acuity's products are sold by about 200 independent sales agencies and about 300 factory sales representatives who cover specific geographic areas and market segments. The company operates two separate European sales forces and an international sales group that coordinates export sales outside of North America and Europe.

Acuity Brands Controls is a leading supplier of lighting controls and energy management systems. Its brands include Lighting Control & Design (LC&D) and Sensor Switch, both acquired during fiscal 2009, Synergy, and ROAM (roadway and outdoor lighting). The acquisitions represented part of a strategy to focus on energy-efficient products and services. Part of the strategy is to provide complete lighting systems, which the company believes will be an integral part of the development of "smart building" energy management.

Acuity offers its lighting control products as components or as systems.

- The company says that Sensor Switch, which was originally founded in 1987, has the "widest array of sensors offered from any manufacturer" including occupancy sensors and power packs, self-calibrating daylighting controls, and standalone programmable relay panels. Technical support for customers includes modeling control designs using its Data Logger Monitoring System and custom Sensor Switch menus for AutoCAD Software.

- LC&D, which was founded in 1987, provides highly scalable centralized and distributed dimming and switching control systems. It also offers extensive support services, BACNet controls for dimming and switching, and DALI integration. In 2008: LC&D's daylight harvesting control strategies and products enabled the U.S. DOE's National Renewable Energy Laboratory (NREL) to become the first federal laboratory building to receive a LEED Platinum rating.
- Synergy, founded in 1985 as Lithonia Controls, focuses on lighting control systems for large buildings, campuses, manufacturing plants, etc.
- Acuity's SIMPLIFY5 integrated lighting solutions include lighting products from Acuity's various lines, plus controls.

The company opened a new training facility in Connecticut during 2010. Lighting control solutions are featured, but Acuity LED products are also present.

"The right control solution for every application, every performance requirement, every budget—every lighting system." "That's the Acuity promise: Control with confidence."

Table 4.1 Acuity Brands Controls SWOT Analysis

Strengths	Weaknesses
• Good relationships with major customers, supported by focus on service and innovation. • Well-known brands, including Sensor Switch. • Offers fully integrated control solutions. • Good name recognition and reputation among commercial customers and consumers. • Successful ongoing cost reduction efforts to maintain profitability in slow sales period.	• Significant portion of sales concentrated with a few large customers, such as The Home Depot. • Heavily dependent on the strength of construction activity in North America.
Opportunities	**Threats**
• Accelerate investments in energy-efficient products, such as controls. • Expand offerings of integrated control systems outside of North America, especially ones designed to be easier to install and configure, such as nLight. • Continue diversification into renovation market. • Expand marketing of SYNERGY5 integrated lighting and control solutions. • Develop more solutions focused on vertical markets. Education exists; Healthcare? Small/medium office? • Leverage training resources to overcome lack of knowledge among upper management, not just the technicians.	• Despite reputation, sales still very dependent on being price-competitive. • Continuing weakness in general economic activity, especially non-residential construction, through 2011 and beyond. • Some larger competitors can provide even more integrated offerings, including other electrical and building automation products. • Asian control markets are starting to take off. Acuity may not be positioned to participate in this growth.

(Source: Pike Research)

4.2.2 Adura Technologies

Adura Technologies, Inc. was founded in 2004 under the auspices of research grants provided by the California Energy Commission's Public Interest Energy Research grant program. The company is based in San Francisco, California. A private company, Adura has received $17 million in venture capital funding. Hoover's lists annual revenues at $1.4 million, but this is almost surely dated information as it also lists the number of employees at 14. Recent company statements have put the number of employees at 35, with plans to grow to 50 by March 2011.

Adura designs, manufactures, and commissions lighting management solutions for the retrofit of commercial buildings, with a concentration on interior office lights. It has an energy management solution (scheduling, daylighting, occupancy sensing, and personal control), a demand response solution, and an enterprise application suite (integrated software modules to commission, manage, monitor, and control lighting infrastructure in multiple facilities) that can be integrated with existing BMS.

Adura's systems can be used by both new and existing commercial properties, but its marketing focus is on retrofit opportunities – especially within older buildings that would be more difficult to wire for controls. Its retrofit solutions are available through major VARs and system integrators, including EMCOR, Honeywell, and Johnson Controls.

The core wireless technology of the Adura LightPoint System was developed at the University of California, Berkeley Center for the Built Environment by Charlie Huizenga, one of Adura's founders. Adura subsequently developed an IP portfolio based on uses and improvements to the core technology. The Wireless Light Controllers plug into florescent light fixtures next to the ballasts. They include radios based around the ZigBee protocol in a low-power wireless mesh network.

As of May 2010, Adura had "dozens of customers including Google." Adura's CEO stated that its systems already controlled the lighting for 1 million square feet of real estate, and that the figure would be at least double that by the end of 2010, and would multiply "tenfold" by the end of 2011. The company's big target is 100 million square feet by 2014.

Adura may have figured out how to get beyond the split incentive problem that is hindering energy efficiency investment in commercial real estate. A company that is leasing space can purchase the Adura system for the energy savings, then take it with them if they move.

"Wireless Energy Control + Energy Management Solutions"

Table 4.2 Adura Technologies SWOT Analysis

Strengths	Weaknesses
• System has received good "buzz" and has a good reputation. • ALPS Enterprise Database provides data for energy and operations applications beyond lighting control. • Executive team includes experience in electronics manufacturing and with a ZigBee solution provider. • Solution to get past the split incentive issue. problem.	• May still be reliant on venture funding for some time. • More expensive initially than some wired options with equivalent functionality. • Still have limited direct distribution.

Strengths	Weaknesses
• Quickly developing a strong customer base.	

Opportunities	Threats
• Participant in California Energy Commission's program to implement advanced energy efficiency technologies in local government facilities state-wide. • Potential retrofit market is huge in North America and globally. • Already prepared to satisfy customer requests for demand response solutions. • Expand relationships with ESCOs.	• Many in the market are still reluctant to commit to and rely on wireless. • Also potential reluctance to commit to a proprietary solution. • Still lack the long-term track record of larger, established competitors. • Customers contemplating eventual upgrades to LED lighting may not want to invest in Adura's system.

(Source: Pike Research)

4.2.3 Beckhoff Automation

Beckhoff Automation GmbH, a privately owned company based in Verl, Germany, was founded in 1980. Sales for calendar 2009 were €236 million. In a 2010 interview, the chairman of Beckhoff stated that the revenue target for 2010 was €340 million, and that the company is planning for 20% growth in 2011.

Beckhoff has subsidiaries throughout Europe, Canada, Brazil, China, India, South Africa, and the United Arab Emirates. The United States subsidiary has seven regional offices. Distributors provide coverage in an additional 35 countries. In 2009, the company announced that it employed 1,350 people worldwide, a 10% increase from the previous year. Its U.S. business is growing at a 45% annual rate, and China is growing even faster. Business in China already accounts for 15% of the company's revenue.

Beckhoff develops and implements open automation systems based on personal computer control technology. The company also provides embedded personal computers, power supply units, automation software, industrial motherboards, drive technology products, and programmable logic controller and motion control products. The company's products are used with machinery for a wide variety of industries including manufacturing, semiconductors, water management, plastics, and bio-technology. All hardware manufacturing is currently performed in Germany.

Lighting controls is part of Beckhoff Building Automation. Lighting products include dimmers and switches, a DALI master terminal, DMX master and slave controllers, and lighting system control software.

The modular Beckhoff Automation components enable solutions for all building types, including administration buildings, offices, hotels, hospitals, schools, stores, etc., and feature open interfaces based on information technology industry and Windows standards. The PC- and Ethernet-based control technology is well-understood by systems integrators.

Since building automation requirements are complex and varied, Beckhoff cooperates closely with partner companies, and supports its partners with hardware and software training geared toward system design and integration requirements.

In an article about PCs in manufacturing a few years ago, the writer made the following comment about the founder of the company: "Europe's most successful PC pioneer, Hans Beckhoff, has a simple two-part formula for success: 1. Put everything in software, on one platform, and 2. Give the customer everything he needs so he doesn't have to buy anything else."[2]

"New Automation Technology"

Table 4.3 Beckhoff Automation SWOT Analysis

Strengths	Weaknesses
• Offers complete, integrated building automation, not just for lighting. • PC-based control technology has been used for decades in industrial automation. • System is modular, very expandable and easily modified. • Approach is appealing to systems integrators. • Strong and growing global presence. • Use direct sales and service as much as possible. • Deep technical expertise in control technology.	• A very specific way of looking at building automation. Many opportunities will not fit into this model. (Not clear how well Beckhoff solutions would fit with many existing BMS.) • Though Windows-compatible, a custom PC board is required to operate the software.
Opportunities	**Threats**
• Still have only a small share of a huge and growing global market.	• The company is sharing a lot of technology with Asian partners. Partners can become competitors. • As a very engineering-oriented company, Beckhoff may not be able to work as well with architects and designers as some of its competitors. This may become more of an issue as LED lighting opens up more creative options. • No indication yet that the company is embracing wireless (based on secondary research).

(Source: Pike Research)

4.2.4 Cavet Technologies

Cavet Technologies is a private company based in Toronto, Ontario. There is no public information on revenue and the number of employees is still very small. At this point, the only information about Cavet is from the company itself.

Its product, LumiSmart, is based on technology that has been under development since 2001 and that is covered by six patents. LumiSmart is installed along the power circuit to a fluorescent ballast. Using waveform modification, the total amount of electricity provided to the ballast is reduced without a noticeable drop in light levels. Cavet claims that savings of at least 30% can be achieved.

The company has stated that LumiSmart is being sold for a low enough price – just $2,000 for a unit that can manage up to 150 luminaires – that payback can be achieved in less than two years even in locations with relatively inexpensive electricity. Product

[2] Michael Babb, "New Kids On The Block," *Design News*, April 6, 2003.

development plans include a version that will support demand response applications.

LumiSmart received UL certification in October 2010 and has been installed in dozens of locations under pilot agreements. According to the company, these pilot locations include facilities of some of the world's largest retailers, technology companies and other major owners of real estate.

Cavet is taking a low-capital approach to the business and has contracted with Celestica, a major contract manufacturer of electronics, to produce LumiSmart. The company's direct sales staff is also still very small. There has been a focus on signing up partners, including Sweden-based Elekrolution for the Nordic countries; Brightpath Technology Ltd. For the United Kingdom, France, Italy, Germany and Spain; Bright Negawatts Inc. for Canada, the United States, the Caribbean, Australia, Japan, the United Arab Emirates and Kuwait; Enersave Solucoes Ecologicas Ltda. for Brazil; and Element Controls in the United States.

Cavet has said that major sales announcements should be forthcoming during the second quarter of 2011.

Also, it appears that the company's patents are on the algorithms and are not restricted to lighting. Cavet believes it may eventually be able to expand into other systems that consume a lot of electricity, such as HVAC.

"The Better Way to Manage Your Lighting Systems"

Table 4.4 Cavet Technologies SWOT Analysis

Strengths	Weaknesses
• Unique, patented technology. • Strong manufacturing partnership. • Single product for worldwide use.	• A single-product company will live or die by that product.
Opportunities	**Threats**
• At this point, "the world is their oyster." There isn't anything they've said they won't do. • Alternate financing arrangements.	• Distributor network is primarily composed of small companies that may not have the strength to push into all available markets. • Despite relatively low cost and promise of fast payback, potential customers may still face capital constraints. • As with many new technologies, many observers think the story is "too good to be true."

(Source: Pike Research)

4.2.5 Daintree Networks

Daintree Networks, Inc., which was founded in 2003, is based in Mountain View, California and has an R&D facility in Melbourne, Australia. No financial results are available for this privately held company. Investors include Lend Lease, a global integrated real estate company, which subscribed to an $8 million private placement in March 2010.

Daintree's founders came from the advanced networks division of HP, where they built test and measurement tools. Daintree's Sensor Network Analyzer (SNA) quickly became the industry-standard tool for wireless embedded development and testing. The SNA has supported ZigBee application development, commissioning and certification in smart meters and other applications for nearly 400 customers. The SNA has also been used as the standard tool for ZigBee compliance testing.

A couple of years ago, Daintree made a strategic market shift into delivering wireless lighting control solutions for commercial buildings by developing an operational platform for ZigBee applications. The company discontinued sales of the SNA during 2010.

Daintree's three primary strategies are:

- Build on its history of working with embedded wireless technology
- Focus on open standard lighting system and software, allowing different devices to operate on it, and expanding the number of device makers that can work with it
- Develop with and sell through partners

Daintree's ControlScope is a network- and software-based open-standards platform for commercial wireless lighting controls and energy management. ControlScope works with lighting control devices including switches, sensors, ballasts, and LED drivers. These other devices are made by Daintree's partners. The company says, "We provide the wireless network communications and controls intelligence, while our partners continue to do what they do best – manufacture high-quality devices." Daintree provides its core technology to its partners for incorporation into the partner devices. "We work to support and enable existing lighting companies, not to compete with them. As wireless experts, our goal is to make it easy for our customers and partners to bring wireless products to market." Daintree Wireless Adapters provide the option to add external radios to existing wired devices, allowing them to communicate within the wireless network, too.

Daintree's approach uses the building's existing AC power infrastructure for power and wireless links for communications. In a Daintree-based solution, the wireless mesh network takes the place of dedicated control wiring and physical control panels. Facility managers can manage the lighting control network through Daintree's web-based Lighting Control Application software. These applications are also able to integrate with demand response and demand management programs. To build its network of interoperable devices from partners, Daintree is promoting strict adherence to the ZigBee standard. (In some other ZigBee-based systems, vendors add custom enhancements to the standard.)

Now that the system has been launched into the marketplace, Daintree has been building its management team. The CEO appointed during 2010 had previously led multiple lighting businesses from their start-up phase at Philips Lumileds. In addition, the chief solution architect has been active in the ZigBee Alliance and holds patents related to wireless systems and commissioning, and the vice president of Sales and Business Development has extensive experience in both energy management and lighting retrofit applications.

"Leading the Wireless Lighting Control Revolution"

Table 4.5 Daintree Networks SWOT Analysis

Strengths	Weaknesses
• Technology based on open standards to promote interoperability. • Business model of partnering with existing control device vendors, not competing against them. • Management team with directly relevant experience. • The system can handle all lamp types, not just fluorescent technology.	• Must rely on partners to sell their products to enable Daintree sales • May still be reliant on venture funding for some time.
Opportunities	**Threats**
• Very large retrofit market. • Can work in new construction, though not as much advantage there over wired systems. • Opportunities outside North America: Asia and especially Europe are receptive to open-standards approaches. • Should be able to expand beyond lighting controls using same core technology. • Connecting with ZigBee-based devices on the "outside" of the building – on the Smart Grid	• Another company could adopt Daintree's business model, taking advantage of the assistance Daintree has provided its partners. • Many in the market are still reluctant to commit to and rely on wireless.

(Source: Pike Research)

4.2.6 Digital Lumens

Digital Lumens Inc., a private company founded in 2008, is based in Boston, Massachusetts. The company has taken in $11.3 million through two rounds of venture financing. No other financial information is available at this time.

Digital Lumens was formerly known as GroomLED. The impetus for the company was the realization by management at Groom Energy Solutions that its commercial and industrial customers could greatly benefit from an LED-based lighting system that met their high-wattage needs. A team was put together that included people with LED lighting experience at pioneering company Color Kinetics (purchased by Philips), plus others with networking and distributed computing backgrounds. As of June 2010, there were almost 20 employees and an expectation for 30 by the end of 2010.

The company's objective has been to develop a cost-effective lighting retrofit solution for high bay lighting in warehouses, cold storage facilities, and manufacturing plants "because these are enormous footprints that use lots of energy." Digital Lumens' concept is that energy should be a managed asset. "How you deploy energy in your facility is important. You shouldn't just pay your energy bill, you should manage it."

Digital Lumens' approach was to develop fully integrated "Intelligent Light Engines" (ILE), LED-based luminaires that include controls, occupancy sensors and a ZigBee mesh networking module for communication with their LightRules Software. The software gives managers the ability to effectively manage lighting delivery and usage.

Between the savings that can be achieved through the use of intelligent lighting controls and the additional efficacy advantage of the LED lighting used in their products, Digital

Lumens' customers have been saving 90% of the energy used to provide their lighting. One customer reported a 95% savings.

In August 2010 Digital Lumens' CEO said that the company had "almost a dozen customers and a very significant pipeline of trials," with each customer and trial project representing "a firm with tens and hundreds of facilities." Many of these customers' facilities average 250,000 ft^2 to 1 million ft^2. The ILEs are designed to be one-for-one replacements of 400 W HID and T5 or T8 fluorescent fixtures, but consume only 165 W. Since the typical HID high bay fixture covers about 400 ft^2, that is a potential for a lot of ILEs at $1,250 each (list price).

The CEO went on to describe the company's focus areas for the remainder of 2010 and into 2011:

- Launching new types of fixtures for applications other than the company's current high bay lighting offering. (A "mid-bay" ILE was introduced in November 2010.) In addition, Digital Lumens plans to continue developing its software package to allow more automation and integration with a growing number of energy management and demand response systems.
- Signing up new partners to help them extend their reach and relationships.
- Avoid the "existing Byzantine and baroque channels" for lighting projects that often put more emphasis on aesthetics, and instead target companies that are already considering retrofits as part of efforts to reduce energy use and operating costs.

Digital Lumens is looking to expand more aggressively both in the United States and internationally. The company also seeks to "expand our footprint in terms of what we can do inside buildings." It's not clear what this footprint means, but developing ILEs for applications other than warehouses and factories leaves a number of opportunities available to them. Examples would include high-power ILEs for spaces such as auditoriums and arenas (different lighting characteristics and control logic), or a move toward lower-power ILEs for offices and other low-ceiling spaces.

As one more piece of the puzzle, Digital Lumens has been working on financing. In late January 2011 the company announced that RELAMP LED, a New Jersey-based financing company that specializes in financing LED lighting projects, had started offering financing solutions for customers that purchase the Digital Lumens Intelligent Lighting System. RELAMP LED's program requires no upfront capital and is cash flow positive from the outset.

"Providing 100% of the light for 10% of the cost."

Table 4.6 Digital Lumens SWOT Analysis

Strengths	Weaknesses
• A compelling story with lots of positive "buzz." • Management team put together for this exact business opportunity. • Successful demonstration projects. • Already has demand response applications.	• May still be reliant on venture funding for some time. • Sales pitch may not transfer well to other applications and markets with much more formidable lighting control system competition, and lower priced alternatives.
Opportunities	**Threats**
• International expansion with its high bay product. • Adding mid-bay products to the portfolio, opening up additional applications to serve. • Additional products for other high-power lighting applications. • Additional products for low-power lighting applications, such as office spaces, cafeterias.	• Many in the market are still reluctant to commit to and rely on wireless. • Alternatives to traditional distribution channels may not be accepted by customers comfortable working with them. • All manufacturing is contracted in China. Depending on the contractor, Digital Lumens' volume may be too small to get priority treatment when needed.

(Source: Pike Research)

4.2.7 Eaton

Eaton Corporation, based in Cleveland, Ohio, had sales of $13.7 billion for the year ending December 31, 2010, an increase of 16% over 2009. The company's net income was $929 million, an increase of 143% over 2009, which was a difficult year due to the global slowdown in construction and other capital-intensive businesses that are important to Eaton. In fact, the company reduced its workforce by about 17% during 2009. Eaton sells products in about 150 countries and has about 70,000 employees worldwide. It has regional headquarters in Shanghai; Morges (Switzerland); and Mexico City.

Eaton was originally founded as the Torbensen Gear and Axle Co. in 1911, when the company built seven axles by hand. Today, Eaton's Truck segment is still a leader in its global market. Its other business segments are Automotive, Hydraulics, Aerospace, Electrical Americas and Electrical Rest of World. For 2010, the two electrical segments accounted for almost 48% of Eaton's sales. The electrical sector is based in Moon Township, Pennsylvania (near Pittsburgh). Its recent 120,000 ft^2 headquarters expansion, which featured many of the company's products and systems, earned LEED Gold certification.

Eaton's electrical product lines include automation and control, circuit protection, power quality and monitoring, and electrical distribution. The principal markets for these products are industrial, institutional, government, utility, commercial, residential, information technology, and original equipment manufacturers. Eaton also has a global Electrical Services and Systems team to provide support for design, power management and quality studies, and project management.

Eaton's lighting control systems are mostly sold under the Pow-R-Command name. (Until recently, many of Eaton's products, including lighting controllers, were identified with the Cutler-Hammer brand. Eaton had purchased Cutler-Hammer in 1978 for its extensive line of power control and switching devices. Now, as part of a company-wide growth strategy, the Eaton name is being emphasized for virtually all of its business lines.) Pow-R-Command is a family of lighting controllers that ranges from very basic, standalone panels, to controllers that are good for small to medium commercial and manufacturing facilities, to more sophisticated systems that can manage daylight harvesting applications, monitor the status of large systems, and be controlled through a web browser. Eaton also provides a wireless switch that operates on the 802.15.4 (ZigBee) standard and connects into its lighting controllers.

Eaton provides actuators for daylighting systems and blind control. Since the company also has HVAC control systems and variable frequency drives, it provides certain types of functionality to share information between the lighting control and HVAC systems. It also brings capabilities to integrate its metering products into control systems for more detailed real-time information. In addition, Eaton has products and control systems for residential power applications.

Although Eaton has not been as aggressive as some of its larger competitors in the area of acquisitions, it did make an important move in this area last year. On July 15, 2010, Eaton acquired EMC Engineers, Inc. According to Eaton, EMC "delivers energy efficiency solutions for a wide range of governmental, educational, commercial and industrial facilities. The firm is a leader in retrofitting and modernizing mechanical, electrical and control systems, as well as energy modeling and analysis, facility commissioning, and energy savings performance contracting." The ability to integrate solutions, particularly within retrofit situations, is critical for a company to differentiate itself in the controls market.

Eaton is teaming with IBM on the Smarter Building Initiative, which will create a working demonstration of a Smarter Building solution at the Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center in Raleigh, N.C.

"Powering Business Worldwide"

Table 4.7 Eaton SWOT Analysis

Strengths	Weaknesses
• Good global presence in building-oriented electrical products and systems. • Full range of controllers for lighting applications, plus many related products. • Experienced engineering and system integration organization. • Successful cost-reduction efforts to improve profitability in slow sales period. • Growing familiarity with Smart Grid opportunities.	• Heavily dependent on the strength of global construction activity. • Without sensors, does not have a complete lighting control system offering.
Opportunities	**Threats**
• Expand capabilities to address lighting control retrofit opportunities. • Leverage and grow systems integration capabilities. • Leverage presence in Asia to expand business in this rapidly growing market. • Leverage strong position in industrial controls to bring lighting controls into the manufacturing sector. • Develop solutions focused on vertical markets: education, healthcare, etc.	• Some larger competitors can provide even more integrated offerings, including other lighting and building automation systems. • Controllers for lighting control are not well differentiated from many competing systems. • Smaller companies focused on lighting controls may be better able to address specific applications needs and react to changes in the market. • Lighting control startups based on new technologies and/or approaches could change the way lighting control systems are designed and sold.

(Source: Pike Research)

4.2.8 Echoflex Solutions

Echoflex Solutions, Inc., a private company, was incorporated in 2005. It is located in Squamish, British Columbia, Canada. Echoflex became one of the first companies in North America to develop products based on the EnOcean wireless technology. EnOcean integrates the harvesting and storing of energy with low-power radio technologies. Echoflex was named the EnOcean Distributor of the Year for 2008.

In 2009, Masco Corporation made a strategic investment with Echoflex. Masco is one of the world's largest manufacturers of products for the home improvement and new home construction markets and one of the world's leading building product suppliers.

Echoflex develops products for the commercial building automation market with a specific focus on lighting and HVAC controls. The primary focus of the company's solutions is energy conservation. Echoflex's products include switches and sensors (task ambient photosensor, temperature sensor, occupancy sensor, photosensor for outdoor use), all of which are wireless and self-powering.

The automation solutions that Echoflex develops are based on "a distributed control model, where intelligence is located in the controlled space." In other words, these are standalone control solutions, not normally networked into a central controller. If desired, though, the technology can be connected to a BMS, providing wireless sensing through interfaces and gateways. Echoflex solutions are also capable of responding to demand response signals.

Since the company is very interested in relationships with systems integrators and OEMs, it offers them a $149 evaluation kit. The kit enables potential partners a rapid and straightforward evaluation of EnOcean radio and energy harvesting technologies.

Echoflex continues its product development efforts; recent announcements have described easier commissioning of products and extended communication ranges. The company primarily sells through lighting and lighting design companies in Canada and the United States.

"Innovative and Sustainable Energy Solutions"

Table 4.8 Echoflex Solutions SWOT Analysis

Strengths	Weaknesses
• An acknowledged leader in implementing EnOcean technology. • Simple, easy-to-deploy products and solutions. • Broad product line due to partnerships.	• Success is tied to EnOcean's acceptance in North America. • Website and marketing materials emphasize the company's "green" heritage and culture, but this may not be appealing to many bottom line-oriented decision-makers.
Opportunities	**Threats**
• More aggressive outward marketing to build demand for EnOcean solutions. • While EnOcean is used in huge projects in Germany, the company should focus on smaller to medium-sized opportunities in North America. Find an association whose members fit this bill.	• At some point, larger companies will adopt and promote EnOcean in North America. (Leviton already has a full line of EnOcean products.) • Larger customers may prefer a networked controls solution with a central management interface.

(Source: Pike Research)

4.2.9 Encelium Technologies

Encelium Technologies, Inc., a private company headquartered in Teaneck, New Jersey, was founded in 2001. The company does not release sales figures, but a December 2010 Encelium press release stated that annual sales had increased nearly 100% over the past two years. (An earlier article quoted the CEO as saying the company had grown 200% a year over the last two years.) In December 2010, Encelium raised $11 million in a financing round led by Siemens Venture Capital (SVC), the corporate venture capital organization of Siemens. SVC joined the existing owner, Townsend Ventures, which had purchased the company in 2008.

Encelium has more than 70 employees and operations in the United States, Canada and Europe. The company recently opened an office in New York City to get close to the design community there. Encelium offers its products through more than 15 representatives throughout the United States and Canada. The company's European operations are managed from Belgium.

Encelium is led by a CEO who was brought in for new leadership and for his background in commercial real estate (formerly CEO of the Americas for Cushman & Wakefield, a major real estate firm). The COO and CTO co-founded Encelium; both had worked at Lumion, a ballast and lighting control company.

Encelium has recently been focused on building its sales capabilities by adding distributors and making direct hires. During January 2011, the company announced the hiring of a new vice president of Sales and a new director of Sales for Northern California and the Pacific Northwest.

Encelium specializes in addressable lighting control and energy management systems for commercial buildings, applicable in both retrofit and new construction projects. The company sells the Energy Control System (ECS), which it describes as "the world's first addressable lighting control system geared specifically for energy management." ECS includes central control software that enables facility managers to control each fixture in a building either from a desktop PC or remotely via the Internet. In addition, occupants can control their own workspace lighting levels from their desktop PC via its Personal Control Software (PCS).

ECS integrates and deploys energy management strategies on a facility-wide basis and can be used for energy peak shaving or demand response strategies. Also, according to Encelium, ECS "constantly monitors energy usage and can predict and avoid sharp increases in energy demand." ECS can integrate with BMS and BEMS through a BACnet Interface Module or a Niagara Driver. Also, due to the nature of the digital ECS network, control zones become completely independent of electrical circuiting and can be reconfigured remotely. Last year, Encelium launched "ECS Lite" to provide more cost-effective solutions for smaller buildings. However, one potential downside to ECS is that it uses Encelium's own GreenBus communications platform, and some building owners are reluctant to get "locked in" to a proprietary solution.

Encelium's product strategy is to keep total costs low by utilizing standard light control components in the architecture. The company provides a universal input/output module that connects to standard lighting components, such as low voltage non-dimming ballasts, occupancy sensors, or photo sensors.

Encelium has installed its systems in schools, parking garages, big-box stores, warehouses and other types of buildings. The company has an agreement for energy efficiency services for the healthcare market with Premier Purchasing Partners, an alliance of more than 2,200 U.S. hospitals and 63,000 other healthcare sites. Moreover, Encelium solutions have been utilized in hundreds of new and retrofitted buildings around the globe, including more than 35 million square feet of commercial space.

"Lighting Control for the Smart Building"

Table 4.9 Encelium Technologies SWOT Analysis

Strengths	Weaknesses
• Powerful, flexible digital system solution. • Good installed base and rapidly growing sales. • ECS is added to an existing lighting system with adapters. • Includes integration with BMS and demand response features.	• May still be reliant on venture funding for some time. • Could be purchased by Siemens (but is that a weakness?)
Opportunities	**Threats**
• Continue building distribution capabilities. • Look to rapidly growing Asian markets. • Offer i/o module capability to OEMs for integration into lighting system components. • Develop wireless capability to expand retrofit opportunities.	• Some customers are reluctant to go with a proprietary system. • May be excluded from some retrofit business due to lack of wireless offering.

(Source: Pike Research)

4.2.10 ETC / Electronic Theatre Controls

Electronic Theatre Controls, Inc., a private company, was started in 1975 by four "college-student entrepreneurs" in the basement of a Madison, Wisconsin apartment. The founding idea was that there was a better way to make a lighting control console. Those college students developed one of the first microprocessor-based lighting control systems, "which boasted the then blindingly fast 2 MHz 8080 CPU!"

The company, which currently employs more than 700 people worldwide, is now based in Middleton, Wisconsin. ETC expanded into Europe and Asia in 1995. Between 2002 and 2004, it acquired lighting and control companies in Germany, France and the Netherlands. ETC currently has 200 authorized service providers around the world. Estimates of annual revenue from various sources range from $50 million to $160 million. About 10% of the company's revenue comes from sales in Asia and another 25% from Europe. In addition to manufacturing at ETC's international headquarters in Wisconsin, ETC has production capability in Germany and Holland.

ETC is an entertainment and architectural lighting company. It designs and manufactures products such as entertainment control systems, dimming and switching solutions, lighting fixtures, LED fixtures, networking products, and software-based products. It also provides technical, project management, design consultation, and lighting installation services.

ETC's original focus was the entertainment market. Over time, it expanded to other venues that needed entertainment-style lighting, such as theme parks, casinos, malls, mega-churches, museums, etc. More recently, ETC has looked to the architectural lighting market (lighting inside and outside commercial buildings) due to the limited growth in entertainment lighting and the applicability of the company's products to other venues.

ETC's lighting controls include:

- Entertainment Controls – "Our consoles have set the industry's standards for performance. Whichever ETC console you choose, you have the power to create unlimited lighting effects."

- Architectural Control Systems – "The most comprehensive architectural control systems on the market. Lighting designers and specifiers swear by ETC products, used in thousands of venues around the globe."
- Dimming & Switching - A full range of powerful dimming and switching solutions.

ETC says that it has the most extensive in-house R&D department in the industry, with more than 65 people engineering and designing innovative hardware and software.

Table 4.10 ETC SWOT Analysis

Strengths	Weaknesses
• Long heritage of innovation and quality products and service. • Reputation as a market leader. • Broad product line that can produce complete solutions for a variety of applications.	• Not known for a background in lighting control for energy efficiency. • Not as involved in the expansion of BEMS and connections with the Smart Grid.
Opportunities	**Threats**
• The architectural lighting market is 50 times larger than the entertainment lighting market (according to an industry consultant). • Expand use of LED lighting in entertainment industry.	• No wireless control offering. (Wireless is not generally accepted in entertainment lighting.) • Reputation may not transfer into broader commercial market for intelligent lighting controls.

(Source: Pike Research)

4.2.11 GE Total Lighting Control

GE Total Lighting Control (TLC) is a unit of GE Appliances and Lighting, which is part of GE Energy Industrial Solutions, a part of GE Energy. The General Electric Company's total sales for the year ending December 31, 2010 were $150.2 billion, a 3% decrease from 2009. GE Energy revenue was $30.9 billion in 2010, an 8% decrease from 2009. (GE reorganized its business units as of January 1, 2010.) GE has more than 300,000 employees worldwide, and its total research spending in 2008 was $4.3 billion. Its worldwide research staff totals more than 2,800 people, including over 1,000 PhDs.

Among its business lines, GE Energy Industrial Solutions is an industry leader in major appliances, lighting and integrated industrial equipment, systems, and services. It provides solutions for commercial, industrial, and residential use in more than 100 countries throughout North America, Europe, Asia, and Latin America. While some products are primarily directed at consumer applications (e.g., major appliances) and some mainly at industrial applications (e.g., switchgear), others are directed to both markets (e.g., lighting).

Until recently, GE TLC was located in a different part of GE Energy Industrial Solutions. The unit was transferred to GE Lighting about a year ago to increase the opportunities for synergy between the businesses. So far, there have been no major announcements to reflect the benefits from this synergy. GE Lighting is headquartered in Cleveland, Ohio. TLC has a worldwide presence, including a "smart lighting control system" business in China to serve that emerging market.

TLC products include relays, control panels and systems, occupancy sensors, photocells and controllers, and LonWorks open system architecture for integration with BMS. The TLC website presents a matrix that correlates lighting control applications (Retail, Office, School, Arena, etc.) with its product families. The matrix also describes three "Automation Levels." TLC promotes these levels as a migration path for upgrades or expansions.

- Level I – Standalone systems
- Level II – Intelligence, connectivity and interoperability (clock functions, switches, enhanced programmability, LonMark open system protocol).
- Level III – Front-end monitoring and programming, networked panels, expanded functionality (alarms, events, trending, tenant billing, etc.)

TLC's marketing message emphasizes that "choosing a lighting control system means more than selecting hardware features; it means choosing a long-term partner for your building's operations." This ties TLC into GE's extensive portfolio of long-standing businesses that serve the buildings market, including lighting, motors, and electrical products. For example, GE Industrial Solutions provides electrical distribution and control products, lighting and power panels, and switchgear and circuit breakers that are used to distribute and manage power.

To enhance its ability to provide a full-service, integrated approach to energy savings, GE Lighting recently established an ESCO Energy Services Program and created alliances with ESCOs. The company's goal with this program is "to go far beyond the circuit breaker, switch, and lamps. We want to help customers meet and exceed their energy goals."

There has been speculation since the 1990s that GE would sell off the lighting business, as it was not the type of high-growth technology business on which corporate management wanted to focus. However, lighting has remained a part of GE and investments continue.

Table 4.11 GE Total Lighting Control SWOT Analysis

Strengths	Weaknesses
• Good reputation and strong brand name. • Broad line of control products and a full range of lighting control solutions. • Excellent opportunity for synergy with other building and grid-related businesses. • One of the top three global lighting giants, participating in virtually every major lighting application and most niche applications. • Well-established worldwide distribution channels to the commercial and industrial markets. • Significant high-tech manufacturing capabilities and resources. • Profits from lamp sales can help fund new developments. • Large amounts of R&D spending with focus on adapting technologies to bring products to market. • Aggressive acquisition strategy if a technology will fill a hole in the product line.	• May not be viewed as a lighting controls market leader, especially outside the United States. • Cost structure of a large company may hurt competitiveness. • (The former) C&I businesses, as a whole, have faced declining revenues for the last few years. • Lighting has long been a "poor stepchild" in the GE corporate structure due to limited growth and low profitability.

Opportunities	Threats
• Leverage existing worldwide lighting distribution and customer relationships to expand lighting controls business globally. • Package lighting controls and lighting with other products and services for the energy efficiency market (ESCOs). • Increase packaging of building-related and grid products to market energy efficiency solutions to specific industries and/or applications. • Look at the lighting control startups to see if one or more fits within the GE Energy business as a possible acquisition.	• Smaller companies focused on lighting controls may be better able to address specific applications needs and react to changes in the market. • Overall lighting business, as well as GE Energy in general, is very sensitive to overall economic conditions. • Lighting control startups based on new technologies and/or approaches could change the way lighting control systems are designed and sold.

(Source: Pike Research)

4.2.12 Honeywell Lighting Controls and Ex-Or

Honeywell International, Inc. is as a diversified, worldwide technology and manufacturing company based in Morristown, New Jersey. Sales for the year ending December 31, 2010 were $33.4 billion, an 8% increase over 2009. Honeywell offers aerospace products and services, control, sensing and security technologies for buildings, homes, and industry. Honeywell had approximately 122,000 employees as of December 31, 2009, of which approximately 54,000 were located in the United States. In 2009, 38% of the company's revenue was from outside the United States. Honeywell's stated areas of focus for 2010 included: "Achieving sales growth, technological excellence and manufacturing capability through global expansion, especially focused on emerging regions in China, India and the Middle East."

Lighting controls are located in the company's Automation and Control Solutions (ACS), the largest of its four segments. Segment sales for 2010 were $13.7 billion, 41% of Honeywell's total and up 9% from 2009. ACS offers HVAC and building control solutions and services; energy management solutions and services; security and asset management solutions and services; enterprise building integration solutions; and building information services. ACS's stated areas of focus for 2010 included: "Products and solutions for energy efficiency and asset management; extending technology leadership: lowest total installed cost and integrated product solutions."

Honeywell's lighting control products include photocells and lighting controllers based on the photocells. The company also has an extensive line of building controllers. Some are focused on HVAC or alarm systems, but most also include the capability to control other systems. Many support LonWorks.

In 2007, Honeywell acquired Ex-Or, a private company located in Merseyside in the United Kingdom. Ex-Or has designed, manufactured, and installed lighting management systems since 1984, and is "best known in the United Kingdom as the leading brand for environmental and combustion controls." Ex-Or employs more than 80 people at its headquarters and manufacturing plant, and currently serves commercial and industrial customers throughout Europe. Offering a variety of control solutions, Ex-Or's presence-detection technology forms the basis of both its standalone LightSpot range and the networked Digital Managed Lighting System (MLS).

MLS is based on distributed intelligence. There is no central controller and no area controllers. All intelligence is in the 'local' devices, such as the occupancy sensors. MLS includes a PC front end with real-time zone occupancy display, basic occupancy run-time reporting, and a CAD layout. MLS communicates with two types of Integral Communicating Detectors, which are controllers designed for integration within a luminaire. Ex-Or also has a line of photosensors and PIR and microwave-base occupancy sensors.

Ex-Or also sells its Connect Quick Connection Systems, which offer "plug-in simplicity via a range of purpose-designed connection centres offering varying degrees of sophistication." These connectors reduce installation time and effort and are intended to eliminate wiring mistakes, since the luminaires are pre-wired at the factory. In addition, Ex-Or supplies the LooSpot Washroom Management System. LooSpot uses occupancy sensors to regulate the flow of water to automatic flushing cisterns, and to switch off lights and fans in unoccupied toilet areas.

Ex-Or stresses its technical expertise and commitment to research and development. Its goal is for its Lighting Management Systems to "continue to be the most technically advanced and user friendly available."

"Making Light Work"

Table 4.12 Honeywell Lighting Controls and Ex-Or SWOT Analysis

Strengths	Weaknesses
• Honeywell is a recognized world leader in building automation and controls. • Ex-Or acquisition gives the company a strong presence in lighting control systems in Europe.	• Honeywell lacks an integrated lighting control system beyond the Ex-Or business. • Ex-Or's systems address the low to moderate tiers of needs. No offering for customers who require large, advanced lighting control networks and desire an integrated solution.
Opportunities	**Threats**
• Expand Ex-Or's offerings to better serve the retrofit market without requiring purchase of new luminaires. • Expand Ex-Or's geographic scope into the growing Asian markets. • Integrate MLS with Honeywell building controllers to provide a more robust system solution. • Develop solution packages focused on specific types of buildings (education, health care, etc.)	• Ex-Or could lose share in Europe, or at least grow slower than the general market, in the face of increasing competition from integrated solution providers. • Honeywell could be marginalized in the market for sophisticated lighting control systems, and this could hurt its broader control business. • Without a wireless control option, many retrofit opportunities will be unattainable. • Some customers may be reluctant to purchase a system based on proprietary protocols like MLS.

(Source: Pike Research)

4.2.13 Hubbell Lighting Controls

Hubbell Incorporated, which is based in Orange, Connecticut, had sales of $2.5 billion for the year ending December 2010. This was an increase of 8% compared to 2009. Hubbell was founded in 1888 when Harvey Hubbell invented what could arguably be called the world's first lighting control device, the pull chain switch.

Hubbell is primarily engaged in the design, manufacture, and sale of electrical and electronic products for a broad range of non-residential and residential construction, industrial, and utility applications. It has two major business segments: Electrical (electrical systems, lighting fixtures and controls) and Power (operations that design and manufacture transmission, distribution, substation, and telecommunications products primarily used by the utility industry). Hubbell's largest served market is non-residential construction. The company has approximately 12,700 employees, and roughly 55% are located in the United States.

Products are sourced complete, manufactured, or assembled by subsidiaries in North America, Europe, China, Brazil, and Australia. Hubbell also participates in joint ventures in Taiwan and China, and maintains sales offices in Singapore, China, Mexico, South Korea, and the Middle East. Much of the foreign production is imported into the United States, but international shipments from foreign operations directly to third parties amounted to only 16% of total sales in 2009. The Home Depot is probably Hubbell's largest customer.

Hubbell expects the non-residential construction market in 2011 to be slightly down from 2010. However, the company anticipates that this market will continue to benefit from stronger demand for renovation, relight and controls.

Within the Electrical segment, Hubbell's Lighting Products unit provides both indoor and outdoor fixtures for the commercial, industrial, and residential sectors. Also within the Electrical segment is Hubbell's Building Automation business that provides energy-saving lighting controls, including occupancy sensors and daylight harvesting systems. Hubbell has three brands for lighting controls and sensors.

Bryant Electric, originally founded in 1888, was purchased by Hubbell in 1991. Bryant produces dimmers, sensors, and timers, and sells them through distributors. Hubbell Wiring Device-Kellems produces switches, dimmers, occupancy sensors, and lighting controls for the residential market.

Hubbell Building Automation (HBA), headquartered in Austin, Texas, is the company's primary provider of lighting control products and systems for non-residential markets. According to the company, Hubbell introduced the industry's first self-adaptive occupancy sensor and today HBA "produces the most comprehensive line of occupancy sensor products on the market bar none." HBA products include sensors (wall switch, wall mount, and ceiling mount versions of infrared, ultrasonic and dual technology sensors), daylight harvesting products, and high-bay lighting controls for both HID and fluorescent lighting. Hubbell's LX series of networked lighting control products were designed to be easier to install and use due to a graphical touchscreen interface.

In early 2009, Hubbell acquired Varon Lighting Group, a manufacturer of lighting fixtures and controls designed for indoor commercial and industrial lighting retrofits. This move aimed to boost Hubbell's capability to deploy energy-saving relighting solutions through lighting service companies, ESCOs, and electrical distributors.

During January 2011, HBA announced the HBA WASP2 fluorescent high bay sensor product line. According to the press release, the WASP2 line was "designed specifically for high mounting applications such as warehouses, distribution centers, and similar facilities." Also, "the HBA WASP2 sensors provide significant energy savings in addition to those typically associated with T5, T5HO and T8 fluorescent fixtures. By using this new sensor, facilities with fluorescent fixtures can expect an additional energy savings from 50 to 90%." This is a significant product launch, since fluorescent fixtures are progressively replacing HID technology in high bay applications.

In addition, all models of the WASP2 sensor include a built-in photosensor. This device can override the occupancy sensor to keep the lights off when there is sufficient ambient light. The WASP2 sensor is also available in low-temperature and water-tight versions to support freezer and wet location applications.

Table 4.13 Hubbell Lighting Controls SWOT Analysis

Strengths	Weaknesses
• Good reputation as a manufacturer of quality products; the Hubbell brand is known for quality and contractor-preferred features. • An in-depth knowledge of the electrical distributor and contractor markets. • A long heritage in lighting control and a broad sensor portfolio. • Continuing development of products for new applications, such as WASP2 for high bay fluorescent.	• Largest served market, non-residential construction (40%), is having rough times and is always subject to cyclicality. • Lack of high-end networked lighting control solution keeps them out of this segment of the market. • Relatively small amount of non-U.S. sales.
Opportunities	**Threats**
• Retrofit and re-lamp business expected to remain healthy. • Leverage application knowledge into non-U.S. markets, especially growth areas in Asia. • Build more of a networked control capability to address the market for advanced lighting controls that also interact with BMS and demand response applications. • Increased focus on energy efficiency solutions to take advantage of product line that is broader than just lighting.	• Continuing weakness in general economic activity, especially non-residential construction, through 2011 and beyond. • Over time may get squeezed by lighting controls specialists with a stronger presence and broader offerings, and the startups with attractive, new digital technologies. • Despite reputation, sales still very dependent on being price competitive.

(Source: Pike Research)

4.2.14 Leviton

Leviton Manufacturing Co. Inc., founded in 1906, is still controlled by the Leviton family. In May 2009, the company moved into its new “green” headquarters building in Melville, New York. The building received LEED certification under the USGBC’s Commercial Interiors rating system. Leviton’s annual revenue is estimated at about $800 million (Indeed.com, SalesFuel, Gale). Its first product was a mantle tip for gas lighting. As lighting converted to electricity, so did Leviton. The company’s first electrical product was a pull-chain lamp holder. Leviton now manufactures more than 25,000 different products and is North America’s leading electrical and electronic wiring device producer. The company’s products are used in nine out of ten homes in the United States and Canada, as well as in commercial facilities, industrial plants, and OEM operations.

Leviton’s electrical and electronic devices are produced in company-run factories throughout North America and in China and Mexico. It fabricates virtually all parts for the devices it produces. The company sells its products through distributors, in retail, and to OEMs. Each of these channels has a dedicated marketing division. The International Division has regional headquarters and offices serving Latin America, China, India, South Korea, Australia, Europe, and the Middle East/Africa, with a presence in more than 80 countries. The company has nearly 7,000 employees.

Leviton recently restructured its sales organization to focus on high-growth markets. Among the markets it is pursuing are lighting, energy management, commercial and industrial maintenance and repair operations, and retrofits. A new commercial and industrial sales solutions team was created.

Leviton prides itself on its history of customer satisfaction and maintains a large, centralized customer service staff to ensure efficiency and satisfaction.

Lighting Controls is one of about nine primary business lines. Others include Electrical (switches, outlets, and other wiring devices), Network Solutions (telecommunications cabling and accessories), and Energy Management (sensors and controls for commercial and residential applications).

Leviton's lighting controls business, Lighting Management Systems (LMS), is based in Tualatin, Oregon. Its product line includes architectural controls, daylighting controls, photosensors, dimmers, occupancy sensors, relay panels, timer switches, and lighting control networking. Leviton offers a range of systems from the EZ-MAX Plus standalone system to building-wide networked control systems. Leviton has products that support a wide range of protocols, including some that are compatible with DALI systems. The company packages its lighting controls with other control and electrical products to focus on major markets such as healthcare and government.

In early 2009, Leviton announced a strategic partnership with EnOcean GmbH for its wireless building automation technology. In November 2009, it introduced a full line of devices using EnOcean's technology, the LevNet RF Wireless Self-Powered Solutions. These products were chosen by Consulting-Specifying Engineer magazine as the best lighting control product of the year for two consecutive years.

Leviton surely expects its lighting controls business to grow. An October 2009 article in the Portland (Oregon) Business Journal said that the company was looking for a new building for offices and manufacturing, one that could be twice the size of the current Tualatin facility.[3]

Table 4.14 Leviton SWOT Analysis

Strengths	Weaknesses
• One of industry's widest array of products for lighting control. • Does virtually all of its own manufacturing to ensure quality control. • Focus on customer service and satisfaction. • Strong product development capabilities throughout the company. • Able to integrate outside technology to expand product offerings.	• Stronger in basic control systems than in advanced networked controls. • Current smaller size and private status may limit resources available for expansion to fully capitalize on rapidly growing market. • Will always be very dependent on the cyclical construction markets.

[3] Erik Siemers, "Efficiency Drives Leviton Lighting Growth," *Oregon Business Journal*, Oct. 29 2010.

Opportunities	Threats
• Still a huge installed base of totally uncontrolled lighting systems in the United States alone. • Continue to develop integrated energy efficiency offerings for additional commercial markets and applications. • Expand integrated offerings to additional international markets.	• Many companies are getting into lighting controls, including some medium to very large lighting manufacturers that are much bigger than Leviton. Some of these companies could invest significant resources into lighting controls. • Could be outmaneuvered in a variety of growing niche markets by startups focusing on specific types of control systems.

(Source: Pike Research)

4.2.15 Lumenergi

Lumenergi, Inc. is a private company headquartered in Newark, California. It was founded in 1974 as Luminoptics to develop an early electronic dimming ballast. It now offers lighting and energy management solutions throughout the United States. No financial results are available. In a 2009 article, Lumenergi reported having 35 employees and projected that number to increase to 50 by the end of 2009. The company serves commercial, institutional, retail, education, hospitality, government, manufacturing and distribution, freight terminals, and airports markets.

Two private placements were completed during 2010. The second one was for $12.7 million. The company stated that it would spend this money to expand into large-scale commercial and industrial buildings in regions with high energy use. It will also hire sales, marketing, and customer service employees.

During a January 2010 interview, Lumenergi CEO Michael D'Amour said, "We aim to create energy-efficient, demand response-enabled buildings that can nimbly respond to ever-changing electricity market conditions. Our system is affordable, efficient, easy to use, and offers impressively fast payback. We think that our solution, and others like it, is a key component of a Smart Grid."

One of Lumenergi's primary products is the Dimming Electronic Ballast (DEB) for fluorescent lighting. The DEB is powered by an intelligent microprocessor that allows for advanced dimming functions and supports a wide range of dimming control strategies. It is compatible with industry-standard 0-10VDC controls and integrates with either Lumenergi's Lighting Management and Control System (LMCS) or with industry-standard control systems from other manufacturers. DEB ballasts support DALI, for example.

The LMCS is comprised of the LMCS Controller and the LMCS Remote Server. With the LMCS, the lighting system can provide real-time monitoring, feedback, and control. From usage data, building managers can determine where lighting is being improperly used and can modify the lighting directly from the computer screen. The two-way communication between the ballasts and the LMCS allows the system to monitor each individual light, ensuring that the whole system is operating as efficiently as possible. The LMCS enables a wide variety of lighting strategies including daylight harvesting, scheduling, task tuning, occupancy sensing, demand response, and load shedding. Lumenergi is already working with the California utility PG&E on the automated response to electronic demand reduction requests. If desired, the LMCS server may be connected to an existing BMS through BACnet. "Through this communication, we can actually make HVAC smarter."

Lumenergi's collaboration with WattStopper shows the advantage of having open and interoperable ballasts and controls systems. The CEO of WattStopper stated, "Lumenergi's versatile lighting technology seamlessly integrates with our control devices, combining the benefits of each company's products."

Lumenergi has retrofit at least a dozen large federal buildings in the northeast, southwest and western United States as part of the U.S. GSA's commitment to reduce energy consumption, cut costs and improve occupant comfort in all government-owned buildings.

"Innovative Lighting Control Solutions"

Table 4.15 Lumenergi SWOT Analysis

Strengths	Weaknesses
• Full-featured lighting control system with interfaces to BMS and Smart Grid. • Focus has been on core competence: ballasts and controllers. • Use of open standards allows for customer choice of sensors. • Success with U.S. GSA.	• Without sensors, does not have a full system offering. • May still be reliant on venture funding for some time. • Lack of a wireless offering will keep them out of certain types of retrofit situations.
Opportunities	**Threats**
• Win additional GSA business. • Develop more non-exclusive partnerships with sensor vendors. • Look to expand in high-growth Asian markets, possibly in conjunction with a sensor partner.	• May lose business to fully integrated solutions from other vendors. • Though an inexpensive dimming system, still more expensive than a more basic non-dimming system that will appeal to the large, cost-conscious segment of the market.

(Source: Pike Research)

4.2.16 Lumetric

Lumetric, Inc., a private company, was founded in 2007 as HID Laboratories and changed its name in September 2010. The company is based in Fremont, California and has a research and development facility in Oak Ridge, Tennessee. There are no financials available.

Lumetric's focus is on large area lighting applications, including warehouses and temperature-controlled warehouses, distribution centers, industrial facilities, ultra high bay facilities, and retail. The company's innovation has been a solid state direct driver for standard HID lamps. The direct drive light engine does away with the inefficient transformer from the typical magnetic ballast. Lumetric says that it, "has transformed 150-year-old legacy HID lighting into an exceptionally energy efficient, highly cost-effective platform for Smart Grid and demand response services." The life of the lamp should also be extended.

As HID Laboratories, the 20-person company sold about 250 of its first-generation warehouse HID lighting fixtures. It then suspended its sales efforts until the recent re-launch as Lumetric.

Lumetric's SmartPOD is an integrated, high-output light source for large areas. Motion detectors and photosensors can be attached to the SmartPOD so that only areas where people are working are lit, and so that the system can account for daylight already present and only turn lights on as brightly as necessary. The SmartPODs communicate with each other through either wired or wireless networks. They can also communicate with a network end point for connection to demand response systems through smart meters.

Lumetric is a pure HID retrofit play. The DOE estimates that 4% or more of the electricity in the United States is consumed by HID lighting. Lumetric is frequently compared to Digital Lumens, another startup company that is addressing the same market with an integrated LED-based solution. Lumetric responds that the up-front cost of the Digital Lumens system is much higher and that the SmartPOD's efficacy is as good. In addition, HIDs work well in broader temperature ranges than fluorescent lamps and LED lighting, and Lumetric states that its lighting systems provide the highest light quality and color rendering in the industry.

The current CEO of Lumetric is John Schwallie, who is known for building and restructuring businesses. He replaced Cheryl Diuguid, who was hired only in October 2009.

"More Light, Less Energy"

Table 4.16 Lumetric SWOT Analysis

Strengths	**Weaknesses**
• Apparently solid product with very good performance; well-matched to the target application. • HID lighting does have advantages over fluorescent and LED, once disadvantages of lower efficacy and poor dimming performance are removed as Lumetric has done.	• HID is "old technology" so has not gained the "buzz" of Digital Lumens. • May still be reliant on venture funding for some time.
Opportunities	**Threats**
• Very large installed base of HID luminaires that are the exact target of Lumetric's retrofit product. • Possible expansion into other HID applications in smaller areas such as enclosed parking structures, with a product variant.	• Dominant trend in the large area lighting space has been to retrofit with fluorescent technology. • Target market may not be easy to reach without going through traditional sales channels. • Even with good payback story, much of target market may still be capital-constrained. • Need to document more successful projects before customers will listen.

(Source: Pike Research)

4.2.17 Lutron

Lutron Electronics Co., Inc., a privately held company, was founded in 1961 and is headquartered in Coopersburg, Pennsylvania. The company's estimated annual sales are about $110 million. Lutron is one of the world's leading lighting control companies. It designs and manufactures lighting controls and lighting control systems for both residential and commercial applications. The company offers a wide variety of light dimmers, whole-home and whole-building dimming systems, controllable shades, and other lighting and control accessories, and reports that it has sustained an average annual growth rate of 20% since its inception.

All of Lutron's manufacturing occurs in the United States, Puerto Rico, and St. Kitts. Late in 2009, the company announced plans to set up a manufacturing unit in India within three years. Lutron has expanded production of its digitally addressable ballasts in the United States to offer light control solutions compliant with the Buy American provision of ARRA. The company has numerous sales and service offices located throughout the United States, Canada, and Mexico. In June 2010, Lutron established a 3,100 ft^2 "experience center" in Washington, D.C. Along with other activities, this is strong evidence that the company is pushing to increase its business with the federal government to help make up for downturns in the construction industry.

Global sales and service efforts are supported by a European headquarters in London, an Asian headquarters in Tokyo, and other sales and service offices located throughout Europe, the Middle East, and Asia. Lutron controls have been sold in more than 90 countries around the world. According to Hoovers, the company has about 1,500 employees.

As a private company, Lutron states that its priorities include taking care of its customers and people, maintaining the highest quality, and investing in innovation. Joel Spira, the founder and owner of Lutron, invented the first solid state electronic dimmer in 1961. Lutron also brought to market the first dimming ballast and the first reliable wireless lighting control system. The company has expanded into controlling natural light, as well, with a broad offering of mechanical window shades and similar products. Lutron is known for its innovation and has a strong intellectual property portfolio. The company invests at least 10% of revenue back into R&D.

Lutron's product line covers the full spectrum of commercial and residential lighting control, including standalone dimmers, timers and sensors; single room controls; occupancy and daylight sensors; fluorescent ballasts; LED drivers; lighting fixtures; and shading systems. The company offers fully integrated whole-home systems and whole-building systems. The building systems allow facility managers to manage both electric light and daylight through desktop applications. There are reporting and trending features to monitor system activity, lighting energy usage, fluorescent lamp failures, etc. The systems also enable demand response and integrate with BMS.

Lutron has had wireless components and systems for a number of years, especially focused on the retrofit market. ClearConnect is its latest generation of radio frequency technology. Lutron uses a frequency band that differs from most other local wireless technologies, claiming that it is "quieter" (less used, so less interference). Lutron also uses a "fixed" network with directed messaging, rather than a mesh configuration like ZigBee.

Lutron partners with utilities and energy service companies. Lutron Services Company, a division of Lutron, provides total solutions for upgrading or replacing existing lighting control systems. In November 2009, Lutron announced that it had formed a new Energy Solutions business unit that will help accelerate the use of the company's technologies in a broad range of energy-saving products. For example, Lutron is working with Telkonet to offer a fully integrated in-room, occupancy-based HVAC energy management and lighting control system for the hospitality industry. This will be part of a new Lutron Hospitality Solution. In addition, Lutron is working to help connect utilities' smart meter plans to the electrical infrastructure in both residences and commercial spaces.

During 2009, Lutron launched an LED section of its website to help the market understand the issues involved with dimming LED lights. As the LED industry enters the market of general illumination, it has become clear that several emerging LED products are not compatible with existing control standards. For instance, Lutron has pointed out that many products in the market are not dimmable, or falsely claim to be dimmable.

Lutron is a supporter of LED lighting, but emphasizes that "like any light source, LEDs need to be properly controlled to ensure optimal user satisfaction and maximum energy savings." The company recommends that dimmable LED drivers (such as its Hi-lume A-Series) should be part of a lighting system, because then the LED fixtures can fully contribute to advanced lighting energy management strategies such as daylighting and personal control.

Lutron also goes beyond technology to satisfy its customers' needs. For example, its Maestro dimmer with occupancy sensor is available in 27 colors, including "Sea Glass," "Merlot," and "Hot."

"Total Light Management"

Table 4.17 Lutron SWOT Analysis

Strengths	Weaknesses
• Large R&D investment and very good history of innovation. • Well-established global distribution. • Willingness to partner to develop new solutions. • Strong customer-service orientation. • Reputation for quality; proven and reliable. • Flexibility of a privately held company. • Already established strong position in LED lighting controls market.	• Current smaller size and private status may limit resources available for expansion to fully capitalize on rapidly growing market. • Will always be very dependent on the cyclical construction markets.
Opportunities	**Threats**
• Still a huge installed base of totally uncontrolled lighting systems. • Continue to press for U.S. federal government business and other business supported by federal funds. • Expand the energy efficiency solutions business. • More partnerships with other product and service companies to integrate control of lighting with other systems.	• Many companies are getting into lighting controls, including some medium to very large lighting manufacturers (which are much larger than Lutron). Some could invest significant resources into lighting controls. • Could be outmaneuvered in a variety of growing niche markets by startups focused on specific types of control systems. • If a major LED lighting provider comes out with product that is not compatible with Lutron controls, customers may blame Lutron.

(Source: Pike Research)

4.2.18 OSRAM Lighting Controls

OSRAM GmbH is a member of the Siemens family of companies. It is a division within the Industry Sector, Siemens' largest sector. Siemens and OSRAM are based in Munich, Germany. The Industry Sector is one of the world's leading suppliers of production, transportation, building, and lighting technology. The Sector aims to "make customers more competitive by automating the entire lifecycle of customer investments." Its products are designed "specifically to increase the productivity and flexibility of its customers and to help them make more efficient use of resources and energy." Average product lifetimes in the Industry Sector's businesses tend to be short (typically ranging from one to five years from introduction) and are even shorter when software and electronics play an important role.

For the fiscal year ending September 30, 2010, Siemens' global sales were €76.0 billion and the Industry Sector's sales were €34.9 billion. OSRAM's global sales for the year were €4.7 billion, a 13.7% increase from the previous year. OSRAM profits more than doubled due to a significant improvement in market conditions, including strong demand for LED products. The U.S. subsidiary is OSRAM Sylvania, which is headquartered in Danvers, Massachusetts. OSRAM uses the Sylvania brand name in the United States, Mexico, and a few other countries.

OSRAM states that it "supplies lighting solutions for all aspects of life and living environments," which pretty much covers everything; as the world's second-largest lighting company, it is likely justified in making that claim. OSRAM's consumer products include home lighting, luminaires, and automotive lighting. Professional products include general lighting and luminaires, electronic lighting control equipment, and Opto Semiconductors and LEDs. OSRAM is also involved in lighting design with its Light Consultant software and OSRAM Lighting Services consulting business. OSRAM has 46 production facilities in 17 countries, sells in about 150 countries, and has approximately 39,000 employees worldwide.

The ELOGIC energy control line includes an array of products that can be used to control daylight sensing, occupancy sensing, and many other applications. The new PowerSHED System includes sensors, dimming ballasts, controls and load-shedding applications. Various OSRAM lighting control products also support DALI and/or DMX, and there are products that convert from DMX protocol into DALI signals.

OSRAM also provides Light Management Systems (LMS). The emphasis of these systems is not only on energy but also on "the right light in the right amount at the right place and at the right time." The energy savings line within LMS includes three solutions: light management systems for daylight-dependent and presence-dependent lighting; light management systems with maintenance-free EnOcean radio technology; and sensors for non-systems-specific use. These solutions include products such as DALI ballasts and controllers.

In the United States, OSRAM Sylvania's major lighting control brands, ELOGIC and QUICKTRONIC, control lighting systems with LED, HID, fluorescent, halogen or incandescent lighting technology. The QUICKTRONIC brand also includes efficient POWERSENSE dimming ballasts for T5 and T8 fluorescent lamps and the PowerSHED Instant Demand Response System.

In November 2010, OSRAM opened a new LMS showroom in Treviso, Italy, where "Innovative lighting management systems from OSRAM are displayed in spectacular fashion," providing "an ideal opportunity to get a glimpse of what the future may hold." The showroom is designed as a modern conference and training center. It is intended as a place where lighting professionals, their employees, customers and business partners can view "the possibilities of dynamic lighting in action."

Siemens invests tremendous resources into R&D. One of the Industry Sector's goals is to accelerate processes to reduce time to market by as much as 50%. In an industry such as lighting controls, where innovations tend to be fairly easy to replicate, such speed could provide real advantages.

OSRAM sees LED technology and lighting as keys to future success. In a December 21, 2009 presentation, OSRAM CEO Martin Goetzeler stated "We are shaping the lighting market of the future and are a leading manufacturer in all stages of the LED value chain. We already achieve 15% of our sales with these new technologies. We are already investing around 50% of our research and development expenditure in new technologies."

LED control systems are marketed under the Sylvania name. They include a comprehensive system of LED fixtures and standalone controllers that make up a fully integrated lighting control solution.

Table 4.18 OSRAM Lighting Controls SWOT Analysis

Strengths	Weaknesses
• World's second-largest lighting company. • Very strong customer relationships. • Good that Siemens' lighting controls business is a part of OSRAM. • Lighting controls product line has been expanding quickly, with a focus on demand response and similar applications. • Profits from lamp sales can help fund new developments.	• Not always able to meet new market needs as well as some of the specialized or local companies, especially in Europe, China, and India. • Large part of the lighting business is still dependent on the construction business and, therefore, a healthy global economy.
Opportunities	**Threats**
• Find more opportunities to combine LED capabilities with lighting controls. • Bring more EnOcean over to North America and other regions. • More cooperation and integration with Siemens Building Automation. Apogee is a successful wireless brand there. • Build more energy efficiency solution packages focused on specific industries or applications.	• Lighting Controls is so much smaller than the rest of OSRAM that it could start getting pulled in too many directions more quickly than it can handle as traditional lighting businesses look for ways to put a new shine on their offerings. • Subject to competition in multiple growing niches from startup companies. • Little historic presence in North America lighting controls; could be tough to break into.

(Source: Pike Research)

4.2.19 Panasonic Electric Works

Panasonic Electric Works Co., Ltd. is a subsidiary of Panasonic Corporation and is headquartered in Osaka, Japan. The company was formerly known as Matsushita Electric Works, Ltd. and changed its name to Panasonic Electric Works in October 2008. Panasonic Electric Works (PEW) revenue for the year ending March 31, 2010 was ¥1.5 trillion (or $15.7 billion), down about 9% from 2009. Profit increased, however, largely due to lower cost of goods sold. Over 83% of sales were in Japan, about 3% in Europe and about 2% in the Americas. PEW had more than 58,000 employees worldwide as of September 2010.

PEW offers more than 200,000 products through a variety of business groups. These include Automation Controls, Lighting Products, Information Equipment and Wiring Products, Home Appliances, and others. Its products are used in houses, buildings, commercial and public facilities, and factories to support the communications industry and everyday living and working activities.

Lighting Controls is located in the Information Equipment and Wiring Products business group, not the Lighting Products business group. Information Equipment and Wiring Products includes everything from distribution panel boards to switches, power outlets, and other electrical equipment, as well as intercom equipment, fire alarms, sensors, access control and security systems, LAN wiring systems and other devices. One of PEW's primary objectives for the non-residential sector is to "win more orders in our energy conservation solution business, which includes building automation and control systems, lighting control systems and energy measurement equipment."

PEW's centralized monitoring lighting control system is called "Full-2Way." The system includes panels, control components, sensors, and switches and uses "building-block" components for a more simple design and installation. A low-voltage (24V) two-wire system connects each component, but there is great flexibility in the topology used, so the system is easy to install and expand.

Almost 6% of PEW's business is in China. It installed the lighting control systems for the 18,000 lights at the Beijing Olympic Park and in the 101-story Shanghai World Financial Center. One of the key strategies in PEW's new 3-year plan is to "thoroughly penetrate the AC&I (Asia, China & India) market."

PEW sells its Full-2Way systems through direct sales and VARs (value-added resellers). One of its VARs in the United States is PLC Multipoint, one of the best known manufacturers of sensors. Other products, such as relays, are sold through Panasonic Electric Works Corporation of America (PEWA).

In 1974 PEWA, formerly called Aromat, was established as a 100% subsidiary of Panasonic Electric Works Co., Ltd. PEWA is headquartered in New Providence, New Jersey and has offices in Mississauga, Ontario and Sao Paulo, Brazil. PEWA has a much narrower product line than the parent company. In fact, it is the only major PEW subsidiary that is focused on the manufacture and sales of lighting and automation control devices.

Lighting controls is located in PEWA's Lighting & GPS division, one of three divisions. Electronic Controls and Automation Controls are the other two. PEWA primarily sells its parent's lighting control relays and accessories to panel manufacturers and system designers. PEWA does not appear to be involved in distributing complete lighting control systems.

"Panasonic – Ideas for Life"

Table 4.19 Panasonic Electric Works SWOT Analysis

Strengths	Weaknesses
• Strong brand in home market of Japan. • Good lighting control system solution available, sold through high-quality VARs. • Good foothold in China.	• Highly dependent on Japanese market. • Lighting controls in a different business unit from lighting products restricts possibilities for synergy.

Opportunities	Threats
• Expand further into China, India and other developing Asian markets. • Add more functionality to the systems for management control, analysis and reporting. • Look to integrate with Smart Grid applications as this technology expands in Asia. • Coordinate business and product development efforts of lighting controls and lighting products.	• Stagnant Japanese economy has hindered growth for some time. This situation will not change much in the near to intermediate term. • Established European and American lighting controls vendors have much more robust offerings, so progress in either of those markets would be difficult. • Everyone else is also looking to China, and bringing broader product portfolios and experience with more diverse projects and customers.

(Source: Pike Research)

4.2.20 Philips Lightolier and Dynalite

Royal Philips Electronics NV, based in Amsterdam, had sales of €25.4 billion for the year ending December 2010, a 4.5% increase (on a comparable basis) over 2009. Philips Lighting has more than 51,000 employees, manufacturing facilities in 25 countries in all regions of the world, and sales organizations in more than 60 countries. It is generally believed to be the world's largest lighting company.

Philips' 2009 annual report included the following statement: The "transition is from bulbs and components as the point of value creation, to end-user-driven applications and solutions. Increasingly, these applications and solutions will include lighting controls. We believe that, going forward, a key differentiator among lighting suppliers will be the innovative strength to create systems and solutions that are truly customer-centric."

Lighting Controls is part of "Lighting Electronics and Controls" (electronic gear, electromagnetic gear, controls) in the Philips Lighting sector, one of three sectors (the others are Healthcare and Consumer Lifestyle). Lighting controls products and systems are mostly targeted toward commercial applications, but several residential lighting control products have also been launched. Philips Lighting Controls covers a broad range of applications and segments. Functionality can vary from basic switching to very advanced building automation.

Philips Lighting has been acquiring companies at a rapid pace for the last few years to build up specific target markets or product areas. It quickly became a world leader in LED technology as a result. Acquisitions have also been made in the lighting controls business.

Lightolier Controls, based in Carrollton, Texas, provides lighting controls and advanced lighting control systems for commercial, industrial, and residential applications. Lightolier became a part of Philips in 2007 when Philips purchased the Genlyte Group. (Lightolier had become a subsidiary of Genlyte in 1985 when BZ Acquisition, which owned Lightolier, merged into Genlyte.)

Lightolier Controls is a manufacturer of a broad range of digital lighting controls and multi-scene dimming systems. Lightolier says, "We pride ourselves in producing affordable, innovative and easy to install dimming products of the highest quality. Whether your needs are for an occupancy sensor solution or an entire building lighting control system, Lightolier Controls can help you." Lightolier Controls has seven regional sales teams in the United States, and distributors in the United States, Costa Rica, Mexico, the Dominican Republic, and Puerto Rico.

Dynalite, founded in 1989 and based in Sydney, Australia, was purchased by Philips in 2009. Over time it had become a major lighting control company with its energy management and building automation, architectural lighting control, home automation, and residential applications solutions. Initially developed for large-scale projects, Philips Dynalite's distributed intelligence system is said to be scalable down to smaller opportunities. Dynalite also has offices in the United Kingdom, China, and Dubai and has approximately 130 employees.

At the time of the purchase, the CEO of Philips' Lighting sector said, "The acquisition of Dynalite enables us to further strengthen our offering of integral energy management solutions to major corporations, property developers and hotel groups. Having a prominent lighting controls business will help us to further capitalize on the growing demand for energy saving solutions. This is fueled by trends towards net zero CO_2 buildings and the accelerating global switch to green energy saving solutions, partly enforced by increasing government legislations."

Dynalite's office solution, for example, provides workspace lighting using dimmable DALI fluorescent ballasts, automatic control using occupancy sensing, and daylight harvesting of natural light, and employs existing PCs and a LAN to give individual users control of the lighting in open-plan office space. Also available is an interface to BMS.

In February 2010, Philips introduced the Dynalite controls product line into North America, where it will be distributed by Philips Lightolier.

It is not clear how much should be read into this, but while Dynalite is listed as a Philips company on the Philips worldwide website, Lightolier Lighting Controls does not appear on either the Philips worldwide or U.S. websites. It still uses its old "lolcontrols.com" URL, though the Philips name does appear at the top of the page. The only lighting controls products that appear on the Philips Lighting U.S. website is the Philips OccuSwitch Wireless Control System.

Philips Lighting also has been building its strength in entertainment lighting and controls, and purchased Selecon, based in New Zealand, in 2009. In December 2010 it acquired NCW Holdings LTD of Hong Kong, another entertainment lighting and controls company with presence in Asia and Europe.

"Lighting that Makes a Difference" (Lightolier)

Table 4.20 Philips Lightolier and Dynalite SWOT Analysis

Strengths	Weaknesses
• The world's largest lighting company; global manufacturing and sales operations. • Cash cow traditional lamp business continues to fund new developments. • An aggressive acquisition strategy has been building the company's strength in lighting controls. • Lightolier and Dynalite have very good reputations and strong product and system portfolios.	• Large part of the lighting business is still dependent on the construction business and, therefore, a healthy global economy. • Commercial market presence is limited to lighting.

Opportunities	Threats
• Expand offerings of applications to tie into BMS and Smart Grid. • Increased focus on providing integrated energy efficiency solutions to specific markets and applications. • Bring more of the lighting controls portfolio to Asia.	• Some major competitors have much broader offerings for buildings and building automation, not to mention Smart Grid connections, and can provide larger, integrated solutions. • Subject to competition in multiple growing niches from startups.

(Source: Pike Research)

4.2.21 Redwood Systems

Redwood Systems, Inc., a private company, was founded in 2008 and is headquartered in Fremont, California. During 2010, the venture-backed startup obtained $15 million in financing from Index Ventures and existing funders Battery Ventures and U.S. Venture Partners. Redwood said the funds would be used to "enhance its innovative commercial lighting technology, grow its footprint in key markets, establish strategic sales channels and expand into international markets." The company's management team represents a great deal of experience in data communications from Cisco and other companies, plus lighting controls experience from Philips Lighting.

Redwood's business plan is to sell lighting systems to commercial buildings. Their primary target is "the carpeted office," but they believe they have a very good solution for data centers, too. Redwood describes its unique offering this way: "By combining three typically discrete systems (power, communications, sensors) into one low-voltage networked system, Redwood's platform will make smart buildings vastly simpler, easier, and lower cost to own and operate."

Redwood saw an opportunity to take advantage of the fact that LED lighting requires low-voltage DC current. It uses those same low-voltage wires to create a digital communication network to manage the lighting in a building. Redwood says that this data network will eventually be able to provide data and control information for HVAC, plug load, and just about anything else that uses power in a building.

Redwood's approach is based on four key technologies:

- Efficient Centralized Power Drive: Redwood has invented a new, centralized power system – the Redwood Engine – capable of individually powering up to 64 LED light fixtures via low voltage network cable.
- Best-in-class Dimming: By their digital, programmable nature, LED fixtures dim very well. In fact, when dimmed, LED fixtures operate cooler, run more efficiently, and last longer. Redwood is able to provide highly configurable, very precise (65,000 steps) control of dimming on a per fixture basis.
- Novel communication: Redwood has also developed a new way to integrate communications and power delivery on the same twisted pair of wire.
- The Redwood adapter is a small, integrated motion/daylight/temperature/power sensing platform. Deployed at every light, the adapter provides detailed environmental data about the lighting and other conditions in the building. With each light fixture typically covering a 10' by 10' space, Redwood's system can deliver detailed environmental data on every 100 ft^2 of a building.

In addition to enabling all the standard lighting control strategies, the Redwood system supports load shedding for demand response, reduced heating load (LEDs generate much less heat than other light sources) and very detailed reporting.

Part of Redwood's plan for distribution is through the Redwood Ready Partner program. This will include several of the leading LED luminaire vendors to commercial spaces. "Redwood Ready" fixtures will be capable of being remotely powered by the Redwood platform, and will be "profiled" to enable plug-and-play auto-commissioning into the Redwood engine.

In the largest deal Redwood has announced to date, SAP Labs' buildings in Palo Alto, California will install 337 LED fixtures connected to the Redwood system. The reported cost of the system is $434,000, and SAP expects to save $80,000 a year. Redwood has also shared with Pike Research information on a number of other projects in the offices and data centers of major companies. These deals were not yet announced at time of publication, but some will become public knowledge during the second quarter of 2011.

In October 2010, Redwood announced it had received a $1 million grant from the U.S. Department of Energy's Small Business Innovation Research (SBIR) program. In 2009, Redwood was awarded Phase I of the same grant to explore the feasibility of providing power and communications to LED lighting through a low-voltage networking system. After successfully demonstrating both the viability and effectiveness of its technology, Redwood applied for and received Phase II funding, which allows further commercial development and additional funds to bring the technology to international markets.

"Smart Lights, Smart Buildings"

Table 4.21 Redwood Systems SWOT Analysis

Strengths	Weaknesses
• An innovative, new approach to controlling and managing a lighting system. • Very powerful and extensive control and building information capabilities. • Management team with excellent, relevant experience. • Good "buzz" in the technology sector.	• May still be reliant on venture funding for some time. • More expensive up-front costs than other advanced lighting control solutions. (Prices will come down with LED costs, but how long can startups wait for things like this?) • Eventual market may be limited to high-end new construction and renovation that can take advantage of detailed management data.
Opportunities	**Threats**
• No shortage of potential prospects, if the price is right. • Expand relationships with BAS vendors to leverage detailed information on building conditions. • Systems can work just as well outside of North America. • Piggyback off of Redwood Ready Partners as distribution channel.	• Such an innovative solution is a tough sell to risk-averse building owners and managers. • Fully wired system will exclude the solution from a number of retrofit opportunities. • Many major LED vendors have own control solutions that they might prefer to sell.

(Source: Pike Research)

4.2.22 Schneider Electric

Schneider Electric SA, headquartered in Paris, France, had sales of €19.6 billion for the year ended December 31, 2010. This was a 24% increase over 2009 revenue, or a 9.3% increase not including acquisitions. The company had more than 110,000 employees as of February 2011 (43% in Europe; 25% in Asia Pacific; 24% in North America; 8% in 'Other').

As a global specialist in energy management with operations in more than 100 countries, Schneider engages in the design, development, and sale of products, equipment, and solutions related to the metering, management, and use of energy. Schneider states that it is either number one or number two in the world for businesses that make up 90% of its global revenue.

In 2009, Schneider restructured its operations around five businesses, each of which is responsible for its product line and end-customer segments: Power, IT, Industry, CST (Automobile, Aeronautic and Manufacturing technologies) and Buildings. There is also, a separate Services unit identified for solutions engineering audits and consulting (engineering, installation and energy audits, energy efficiency solutions, etc.)

The Buildings segment includes Building Automation and Security and four end-customer segments: Hotels, Hospitals, Office Buildings and Stores. The Buildings business represented 7% of 2010 sales, an increase of only 3.3% from 2009 (not including currency effects). This was less than each of the other Schneider businesses.

Schneider says that its distribution model is different than most of its competitors, relying more on distributors, systems integrators, contractors and specifiers than direct sales to end customers. For a business like lighting control and the broader building automation category, a strong roster of systems integrator partners is a great asset.

Schneider has been in the lighting control business for more than 30 years, working in commercial, hospitality, residential and retail applications. Schneider integrates all control features associated with lighting, including occupancy detection, dimming, daylight linking, scene-setting, and blind control. Systems can either be based on centralized intelligent control panels or set up as distributed systems. One of Schneider's unique approaches to lighting controls is that it designs every solution to integrate easily with other facility operations, such as HVAC, security, and safety systems. It accomplishes this by basing its solutions on standard systems integration practices and open protocols. As a result, customers have the ability to monitor and control each building function with a single system.

Schneider also leverages its experience in building electrical systems. For example, its Powerlink intelligent lighting control components mount in a typical lighting panelboard just like standard circuit breakers. This is a valuable feature for many retrofit projects.

This type of integration is reinforced by Schneider's current ONE Company program. The program seeks to capture additional value in the market through solutions with an end-market focus. This approach enhances the company's ability to offer complete solutions that will improve buildings performance.

As with many of its competitors, Schneider has been aggressive with acquisitions in key businesses. In June 2009, it acquired Conzerv Systems, a leader in the Indian energy efficiency market with a focus on industrial and commercial end users. In December 2010, Schneider acquired Vizelia S.A. Vizelia's software allows customers to obtain real-time data monitoring of energy consumption, maintenance planning and property management for both new and existing buildings. Schneider also acquired D5X in December 2010. D5X is a software company that offers comprehensive solutions for real-time tracking of building occupancy, room control systems (including lighting, blinds and ventilation), and data network management.

Schneider is willing to work with competitors to help grow markets. In February 2009, Schneider and Philips joined to announce a new vision for interoperability in home automation and building control. Their goal is to demonstrate ZigBee wireless networks that include components from multiple vendors.

"The Global Specialist in Energy Management"

Table 4.22 Schneider Electric SWOT Analysis

Strengths	Weaknesses
• One of broadest portfolios of products and services for buildings, along with a renewed focus on cross-business solutions. • Very strong presence in both developed and developing markets, worldwide. • Good portfolio of lighting control solutions. • Significant investments in R&D, including partnerships with academic and industrial organizations around the world. • Willing to acquire and partner in pursuit of key objectives.	• Unlike key competitors, does not have an actual lighting business. • Most of company's business is very subject to the cyclical construction industry.
Opportunities	**Threats**
• Leverage global presence to expand use of lighting controls in developing markets. • Bring more focus to retrofit opportunities. • Focus on Smart Grid expands possibilities for lighting controls.	• Lighting controls represents a smaller business unit than others in the company, but it can be more complex. Possible that "inside partners" may not be as enthusiastic about bringing them into projects. • Subject to competition in multiple growing niches from startup companies.

(Source: Pike Research)

4.2.23 WattStopper/Legrand

Legrand S.A., based in Limoges, France, had revenue of €3.9 billion for the year ending December 31, 2010. This was up nearly 9% from the prior year, though 2009 revenu had been very weak. Legrand's largest operations are in France and Italy, but it also has a good presence in the rest of Europe and in North America. Legrand's products are sold in 180 countries. The company has about 30,000 employees worldwide.

Legrand and its subsidiaries manufacture and sell products and systems for electrical installations and information networks used in residential, commercial, and industrial buildings. The company offers 170,000 products divided into 95 product categories. The weak financial results in 2009 show Legrand's heavy dependence on the construction industry, which has been slow during the last few years. Stronger 2010 financials are indicative of a recovery in many of the company's key markets.

Going forward, Legrand plans to emphasize its strong position in emerging economies. “Our company is a leader in these markets, with positions strengthened by recent acquisitions in China, Brazil, Russia and Turkey.”

In 1996, Legrand purchased The Watt Stopper, Inc., a company founded in 1984 to provide energy-efficient, convenient, and accessible controls for the work environment. Early in The Watt Stopper’s history, it introduced a new, innovative occupancy sensor product line.

WattStopper, still based in Santa Clara, California, does not publicly reveal its revenue, but estimates are that it amounts to approximately $100 million per year. One estimate puts the company’s number of employees in the 250 to 500 range.

WattStopper makes energy-efficient lighting controls for commercial and residential use. Commercial products include digital lighting management, such as room controllers, occupancy sensors, personal and day lighting controls; lighting control systems; standard wall switch, ceiling/wall mount occupancy, and outdoor sensors; controls for bi-level HID switching, plug load management, DALI systems; and Miro dimming controls.

WattStopper states that, “No other company has a larger selection of lighting control products…In fact, no other company has more unique and essential features than WattStopper.” Among WattStopper’s system features is the ability to integrate with a BMS.

WattStopper has been an innovator in the lighting controls industry. Some of its achievements include:

- First dual technology occupancy sensor.
- First remotely programmable and controllable daylighting dimming photosensor.
- Partnered with Architectural Energy Corporation and the California Energy Commission Public Interest Energy Research Program in hosting the first DALI demonstration in the United States.

Product announcements over the last few years have emphasized compliance with the Buy American provisions of ARRA.

Table 4.23 WattStopper/Legrand SWOT Analysis

Strengths	Weaknesses
• Very broad lighting control product line. • Excellent reputation for sensor products. • History of innovation in lighting controls. • Good success in federal and other public projects, as well as strong presence across most commercial markets.	• Parent company has many building-related products, but not in the area of automation. • Control systems are not as robust as those of some competitors.

Opportunities	Threats
• Continue to leverage Legrand's strength in developing markets to establish a strong position. • Seek more partnerships with companies that use open standards to expand demand for sensors. • Use DLM self-configurable controller to penetrate a wider range of contractors.	• Could face the squeeze: both from "above" by global giants with product lines that span building systems, and from "below" by new companies expanding from niches. • Possibility to be somewhat marginalized to the role of sensor supplier (though that is a more profitable part of the system).

(Source: Pike Research)

4.2.24 Zumtobel Group / Tridonic

Zumtobel A.G. (the Zumtobel Group) is based in Dornbirn, Austria. It had sales of €1.1 billion for the year ending April 30, 2010, a decline of less than 1% from the previous year. Australia/New Zealand were the Group's only growth markets. Sales in Europe declined 7.5%. The global economic slowdown during the last couple of years hit Zumtobel hard, but it responded with aggressive cost reductions including layoffs.

Zumtobel's segments include Lighting, which provides professional lighting solutions for indoor and outdoor applications and includes lighting management, and Components, which sells lighting components, modules, and systems, including electronic ballasts. The Lighting segment accounts for about 70% of the Group's sales. Zumtobel Group has 23 factories on four continents. It has sales in over 70 countries, though approximately 80% of its revenue is generated in Europe. Asia and Australia/New Zealand each account for about 9% of revenue and the Americas less than 3%. Total employment at the end of the last fiscal year was over 7,000.

The Zumtobel Group considers itself the "European market leader for professional lighting systems and one of the leading companies in the world for lighting components and light management systems." Its goal is "to become the worldwide authority in the lighting industry," and it states that its growth strategy is based on three pillars: Innovation, Energy Efficiency, and New Markets. The company lists the following as being among its key success factors:

- A rigorous focus on technical innovation
- Established market access channels in the professional project business sector
- Close collaboration with leading international architects and designers
- A special focus on the topic of energy efficiency

Zumtobel Group works directly with architects and specifiers, as well as developers and end users. In fact, the company says that it owes much of its innovation to years of collaboration with leading international architects, lighting designers, and artists. Zumtobel plans to continue combining technological expertise with experience gained from real-world project requirements to create innovative, often customized, LED lighting solutions.

Tridonic Jennersdorf GmbH (known as Ledon Lighting Jennersdorf until late 2010) is a subsidiary of Zumtobel AG and is housed within the company's Components segment. Tridonic is based in Dornbirn, Austria and has nearly 2,000 employees. Tridonic's sales for the year ending April 30, 2010 were €366.6 million (about 19% of this revenue is sales to other Zumtobel Group businesses). Tridonic also has sites elsewhere in Europe and in

Australia, Malaysia, and China. Tridonic has a presence in 73 countries with a recent emphasis on developing local sales resources wherever it operates.

Tridonic began in the 1950s with compact magnetic ballasts, but became a leader in electronic ballasts. It adopted the DALI standard in 2002 and has been developing complete lines of products that employ DALI since that time. In 2003, Tridonic succeeded in integrating lighting management into existing IT networks, an important advancement that led to even more options for lighting control. Tridonic's goal is to be the preferred partner for lighting components, lighting management systems and LED modules.

Tridonic produces a wide variety of electronic and dimming ballasts. Some of these include lighting control features, such as configurable time delays for when the ballast is connected to an occupancy sensor to determine when to turn off the light. SMART sensors, which are connected directly to the ballasts, register the available ambient light or the presence of a person in the room, allowing for regulation of the lighting with no additional sensors. These compact components are easy to integrate, enabling luminaire manufacturers to offer products with added intelligence. There are additional control inputs on the ballasts so that the luminaires can be integrated into a complete lighting system.

Tridonic also supplies a software-based lighting management solution that combines standard DALI technology with the TCP/IP internet protocol. This allows the lighting control system to be fully integrated in BMS so that everything can be controlled centrally.

The Zumtobel Group's Lighting segment contains three brands. One of them, the Zumtobel brand, sells a range of premium luminaires and lighting control systems for professional indoor lighting applications. The Zumtobel brand's controls include new DMX controls for architectural lighting. Zumtobel also has a DIMLITE modular lighting control system: "Simply connect piece by piece. The new DIMLITE lighting control system by Zumtobel is the ideal first step into the world of intelligent lighting control."

In addition, Zumtobel provides an entire range of lighting management systems as the LUXMATE line, which includes occupancy and photosensing features. Each variant of the line incorporates increasing levels of sophistication to fit the needs of many types of commercial buildings, from BASIC for lighting management in a single room, to PROFESSIONAL for building-wide or campus-wide control. All parts of the system are linked to a single control and monitoring center. In addition, there are interfaces for connection to a BMS. Lastly, Zumtobel offers the ZBOX lighting control system. This is a simple "plug & play system specifically designed for hotel rooms."

"Enlightening Your Ideas" (Tridonic)

Table 4.24 Zumtobel Group/Tridonic SWOT Analysis

Strengths	Weaknesses
• One of only a few global players in the lighting fixtures and components business. • Strong position in both lighting control systems and components. • Focus on a service-oriented approach to customers rather than a product-oriented approach. • Emphasis on technology and innovation. • Energy efficiency as the core of a product and market strategy.	• Although a global player in lighting, it is much smaller than the big three. • Sales are still concentrated in Europe. • Apparent heavy reliance on new construction spending. • Commercial market presence is limited to lighting.
Opportunities	**Threats**
• Expand in Asia and the Americas. • Continue to leverage its focus on the customer as a differentiator. • Look to the renovation and retrofit market to reduce dependence on new construction.	• Some major competitors have much broader offerings for buildings and building automation, not to mention Smart Grid connections, and can provide larger, integrated solutions. • Subject to competition in multiple growing niches from startup companies. • Continued weakness in new construction could make scarce the resources needed to develop new products and new markets.

(Source: Pike Research)

4.3 Research Organizations

The following is a partial list of research organizations in the fields of energy efficiency, lighting, and lighting controls.

Table 4.25 Research Organizations

Organization	Website
CLTC – California Lighting Technology Center	cltc.ucdavis.edu/
European Commission Joint Research Center, Institute for Energy	ie.jrc.ec.europa.eu/
LBNL – Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division	eetd.lbl.gov/eetd-org.html
Lighting Design Lab	www.lightingdesignlab.com/
LRC – Lighting Research Center	www.lrc.rpi.edu/
PNNL – Pacific Northwest National Laboratory, Energy & Efficiency Division	energyandefficiency.pnl.gov/

(Source: Pike Research)

4.4 Industry Associations

The following is a partial list of associations and collaborative organizations in the fields of energy efficiency, lighting, and lighting controls.

Table 4.26 Industry Associations

Association	Website
ASID – American Society of Interior Designers	www.asid.org/
ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers	www.ashrae.org/
CEEA – Canadian Energy Efficiency Alliance	www.energyefficiency.org/
DALI-AG	www.dali-ag.org/
DALIbyDesign	www.dalibydesign.us/index.html
Daylighting Collaborative	www.daylighting.org/
DLC – DesignLights Consortium	www.designlights.org/
DMXControl	www.dmxcontrol.org/
ECCJ – Energy Conservation Center, Japan	www.asiaeec-col.eccj.or.jp/
EnOcean Alliance	www.enocean-alliance.org/
ETS4 (KNX)	www.knx.org/
Green Building Council of Australia	www.gbca.org.au/
Green Building Council of South Africa	www.gbcsa.org.za/
IALD – International Association of Lighting Designers	www.iald.org/
IESNA – The Illuminating Engineering Society of North America	www.iesna.org/
India Green Building Council	www.igbc.in/
LCA – The Lighting Controls Association	www.aboutlightingcontrols.org/
LonMark International	www.lonmark.org/
National Apartment Association	www.naahq.org/
NEMA – National Electrical Manufacturers Association	www.nema.org/
New Buildings Institute	www.newbuildings.org/
Online Code Environment & Advocacy Network	bcap-ocean.org/
U.S. Green Building Council	www.usgbc.org/
ZigBee Alliance	www.zigbee.org/

(Source: Pike Research)

4.5 Government – Regulators and Programs

The following is a partial list of government organizations that work with energy and energy efficiency.

Table 4.27 Regulators and Programs

Regulators and Programs	Website
U.S. DOE, Office of Energy Efficiency & Renewable Energy	www.eere.energy.gov/
ENERGY STAR	www1.eere.energy.gov/buildings/ssl/energy_star.html
European Commission, Energy Efficiency	ec.europa.eu/energy/efficiency/index_en.htm
India Bureau of Energy Efficiency	www.bee-india.nic.in/
Japan Ministry of Economy, Trade and Industry – Agency for Natural Resources and Energy (Energy Conservation and Renewable Energy Department)	www.enecho.meti.go.jp/english/index.htm

(Source: Pike Research)

4.6 Other Information Sources

Table 4.28 Other Information Sources

Source	Website
United Nations Framework Convention on Climate Change Clean Development Mechanism	cdm.unfccc.int/

(Source: Pike Research)

Section 5

MARKET FORECASTS

5.1 Forecast Assumptions

In this report, Pike Research provides a forecast for Intelligent Lighting Controls in the nine building categories (eight types of commercial buildings plus residential common areas) discussed in Section 2.

The following applications are NOT included in the forecasts:

- Residential: Single-family homes and the living areas of multi-family residential buildings.
- Entertainment spaces: The parts of the building dedicated to the entertainment activity. However, other general spaces in the buildings (hallways, restrooms, offices, etc.) *are* included in the forecasts.

The following types of controls, products, and other costs are NOT included in the forecasts:

- Manual dimmers
- Theatrical lighting: Programmed lighting used in spaces specifically for entertainment
- Non-dimming ballasts
- Labor of any type
- Wiring, conduit, etc. used in the installation of lighting controls

For dimming ballasts in a new construction situation, only the incremental cost over a non-dimming ballast is included.

5.2 Forecast Units of Measure

The floor space in Pike Research's Global Building Stock Database is presented in square meters (m^2). In the following sections on the forecast methodology, however, initial figures are discussed in terms of square feet (ft^2). This is because of the common practice among vendors and customers in the United States for using dollars per square foot as the unit of measure for the cost of lighting control systems, not to mention almost all other costs related to building projects. Pike Research interviewed many people outside of the United States for this report, but the emphasis during those conversations was on determining the product and market factors that are unique to those regions. Therefore, fewer data points were measured in terms of m^2.

All US\$/ft^2 costs are converted to US\$/m^2 costs before being applied to the amounts of space in m^2.

5.3 Forecast Methodology

5.3.1 Basic Controls and Advanced Controls

There is a very wide range in the types of intelligent lighting controls that can be installed in a space. The simple end of the spectrum would involve a standalone occupancy sensor connected to one or two luminaires in a private office. In contrast, the complex end would include a building-wide system with occupancy sensors and photosensors connected by a digital network, possibly by wireless communications, to a control center that reacts to changing conditions throughout the building by adjusting lighting levels in some of the many layered zones. A zone may be as specific as an individual luminaire. The controller may be connected to a larger BEMS and manage applications such as demand response and interaction with the HVAC, security, and other systems.

To simplify, Pike Research defined two levels of lighting control systems – Basic and Advanced. Table 5.1 shows the elements assumed to be contained in these two levels.

Table 5.1 Components of Pike Research Basic and Advanced Lighting Control Systems

Component	Basic System	Advanced System
Occupancy Sensors	yes	yes
Photosensor		yes
Standard Ballasts (cost not included in forecasts)	yes	yes
Dimming Ballasts		yes (1)
Basic Control Circuits	yes	yes
Dimming Controls		yes
Network Communications, Master Controller, Interface to BEMS or BMS		yes
Wireless Controls		yes (2)

(Source: Pike Research)

Note(s) for Table 5.1:

(1) For a retrofit, the full cost of the dimming ballast is included in the forecast. For new construction, only the incremental cost of the dimming ballast over the standard ballast is included in the forecast since a standard ballast would have been required for uncontrolled lighting, anyway.

(2) Only a percentage of Advanced Systems are assumed to be wireless. This is a variable in the forecast model that is adjusted for each country and increased over time.

5.3.2 Product Costs

Costs of ballasts, sensors and other components can vary widely depending on specific functionality, communication protocol, vendor, and volume discounts. Pike Research used the following average prices in the forecast model.

Table 5.2 Device Costs Used in Pike Research Lighting Controls Forecast Model

Product	Sample Applications	Cost
Occupancy Sensor – wall switch	office, hospital room	$40
Occupancy Sensor – wall mount	hallway, staircase	$60
Occupancy Sensor – ceiling mount (large room)	conference room, classroom	$125
Occupancy Sensor – ceiling mount (large open space)	open office area, cafeteria	$175
Occupancy Sensor – high bay	warehouse (controls individual	$60

	luminaire)	
Occupancy Sensor – high bay aisle	warehouse (controls multiple luminaires in part or all of an aisle)	$175
Occupancy Circuit – basic	hotel room	$75
Photosensor – ceiling mount	all photosensor applications (in Pike Research model)	$110
Ballast – non-dimming		$15
Ballast – dimming, analog (non-proprietary)		$40
Control Circuit - basic		$150

(Source: Pike Research)

5.3.3 Application Areas and Building Categories

Virtually every building has several different spaces within. Even a warehouse, which is essentially a storage space, also has offices, restrooms, and hallways.

The U.S. DOE's *Lighting Market Characterization Report* from September 2002 includes an extensive analysis of application area by building type for the commercial markets (Table E-2 in the DOE report).

5.3.3.1 Building Categories

Pike Research consolidated the 25 building types in the *Lighting Market Characterization Report* into the eight commercial building categories described in this report. For example, Pike Research consolidated Food Sales, Strip Shopping, Enclosed Shopping Centers, Retail (excluding mall) and Service (excluding food) into the single Retail category.

5.3.3.2 Applications

Pike Research also consolidated some of the 15 applications in the DOE report, and then split a few others to produce the 13 applications used in this report. For example, Pike Research combined the Assembly and Athletic applications, since they have roughly similar lighting needs. Storage and Shipping/Receiving were similarly combined.

On the other hand, the DOE's Display application, which primarily applies to retail buildings, was split into "Display-Small" and "Display-Big Box" using the information from the U.S. DOE's 2003 *Commercial Buildings Energy Consumption Survey* (CBECS) – that 39% of retail space is in stores less than 25,000 ft^2. Also, the DOE's Office application was split into "Office-Private" and "Office-Open," and the Hall application was split into "Hall-Offices" (corridors) and "Hall-Open Spaces" (lobbies, etc.).

5.3.3.3 Application Areas by Building Category

The combining and dividing described above produced a table that contains the percentage of the floor space in each building category that pertains to each of the applications. For example, Table 5.3 illustrates the allocations for the Office and the Education building categories. The values for the remaining building categories are contained in the version of Table 5.3 in the spreadsheet file that accompanies this report.

For the Multi-Unit Residential Common Area building space category, Pike Research used information from the National Apartment Association to estimate the percentage of the common area that should be allocated to each application. The majority of this space was put into the Hall-Offices application since corridors leading to the apartments are the primary common area. Smaller percentages were allocated to applications including Office-Private, Hall-Open (for lobbies), and Utility.

Table 5.3 Allocation of Space in Office and Education Buildings by Application

Application	Office	Education
Assembly & Athletic	2%	10%
Bathroom	6%	6%
Boarding	1%	2%
Classroom & Dining	3%	32%
Display – Small	1%	0%
Display – Big Box	0%	0%
Food Prep & Shop	3%	2%
Hall – Offices	20%	30%
Hall – Open Spaces	6%	8%
Office & Healthcare – Private	12%	17%
Office & Healthcare – Open	25%	6%
Storage & Ship/Receiving	10%	7%
Utility	10%	15%
Total	**100%**	**100%**

(Source: Pike Research)

5.3.4 Equipment for Each Application

To develop costs per square foot, Pike Research made assumptions regarding the typical size of a room for each type of application space, then the amount of equipment that would be installed in a typical implementation of a lighting control solution in each type of application space. These assumptions are shown in Table 5.4.

In the Assumed Lighting Type column, "MH" designates metal halide HID lighting, "T5 + T8" indicates T5 or T8 fluorescent tube lighting, and "CFL & Misc" indicates CFLs or other fluorescent fixtures smaller than a typical 4-foot troffer. The Lighting Type also provides the assumed number of luminaires per basic control circuit, since this is related to the total amount of wattage controlled. For "MH" this figure is 3 luminaires per circuit. For "T5 + T8" the figure is 15 and for "CFL & MISC" it is 50.

Table 5.4 Number of Ballasts and Occupancy Sensors for Typical Application Space

Application	Typical Size of Space (ft^2)	Assumed Lighting Type	ft^2 per Luminaire and/or Ballast	Number of Luminaires and/or Ballasts	Number of Occupancy Sensors
Assembly & Athletic	20,000	MH	400	50	8
Bathroom	250	CFL & Misc	64	4	1
Boarding (1)	200	CFL & Misc	n/a	n/a	1
Classroom & Dining	500	T5+T8	150	3	1
Display - Small	5,000	T5+T8	150	33	4
Display - Big Box	50,000	MH	400	125	10

Food Prep & Shop	500	T5+T8	150	3	1
Hall - Offices	500	CFL & Misc	64	8	2
Hall - Open Spaces	1,000	CFL & Misc	64	16	1
Office - Private	150	T5+T8	75	2	1
Office - Open	10,000	T5+T8	150	67	5
Storage & Ship/Receiving	20,000	MH	400	50	8
Utility	1,000	T5+T8	150	7	1

(Source: Pike Research)

Note(s) for Table 5.4:

(1) The table does not include a number of luminaires or ballasts for the Boarding application. The assumption is that lighting in hotel and dorm rooms is primarily provided by lamps such as self-ballasted CFLs. In addition, the lighting control approach for this application is generally to switch virtually all in-room power at the same time based on the information from the occupancy sensor.

Using similar logic, Pike Research developed assumptions for photosensor-based dimming control for each application.

Table 5.5 Dimming Equipment for Typical Application Space

Application	Typical Size of Space (ft^2)	Number Dimming Ballasts	\$ / ft^2 for Dimming Ballasts: RETROFIT	\$ / ft^2 for Dimming Ballasts: NEW CONSTR	Number of Photosensors
Assembly & Athletic	20,000	50	0.10	0.06	2
Bathroom (1)	250	n/a			
Boarding (1)	200	n/a			
Classroom & Dining	500	3	0.27	0.17	1
Display-Small (1)	5,000	n/a			
Display-Big Box	50,000	125	0.10	0.06	10
Food Prep & Shop (1)	500	n/a			
Hall-Offices (2)	500	8	0.63	0.39	
Hall-Open Spaces	1,000	16	0.63	0.39	2
Office-Private (3)	150	2	0.53	0.33	0.2
Office-Open (4)	10,000	67	0.27	0.17	13.33
Storage & Ship/Receiving	20,000	50	0.10	0.06	10
Utility (1)	1,000	n/a			

(Source: Pike Research)

Note(s) for Table 5.5

(1) Dimming is not required or not common in bathrooms, hotel and dorm rooms, small retail, food preparation and workshop areas, and utility rooms. Photosensors are also not common in these application spaces.

(2) Most space defined as Hall-Offices is in the interior of buildings and not exposed to light, so no photosensors are required. However, dimming may be applied in these areas for energy savings, often based on input from occupancy sensors.

(3) For Office-Private, Pike Research assumes that only 20% of private offices and similar spaces have outside windows.

(4) For Office-Open, Pike Research assumes that only 30% of open office area is daylit, and that the coverage area for each photosensor is 15' x 15'.

5.3.5 Costs per Square Foot

The Pike Research model then combines the costs and ratios discussed above to result in a cost in US$/ft^2 for each application, for three different scenarios.

5.3.5.1 Basic Control Systems

For a Basic control system, the model uses only costs related to occupancy sensors and basic control circuits. There are no costs included related to ballasts, since there is no dimming. Only standard ballasts would be used regardless of the presence of an occupancy sensor. There are no costs related to photosensors or dimming.

In fact, Pike Research assumes that in a Basic system, some applications use only standalone occupancy switching, eliminating the need for any Basic Control Circuits. These applications are Bathroom, Boarding, Classroom & Dining, Display-Small, Food Prep & Shop, Hall-Offices, Office-Private, Storage & Ship/Receiving, and Utility.

5.3.5.2 Advanced Control Systems

For an Advanced control system, the model uses the costs related to occupancy sensors, basic control circuits, photosensors, dimming controls and network controls. Advanced control systems also include the costs for dimming ballasts – the full cost for Retrofit projects, but only the incremental cost over standard ballasts for New Construction.

Advanced control systems also incorporate an additional cost factor for those projects that use wireless controls. For the forecast model, Pike Research assumed that wireless occupancy sensors and photosensors would incur five times the cost of the similar standard sensors. No other product costs are changed within the model for wireless projects. The percentage of Advanced projects that use wireless controls is a variable within the model.

5.3.5.3 Costs per Square Foot for Application by Project Type

Table 5.6 contains the costs per ft^2 for each application for the three project types.

Table 5.6 Costs Per ft^2 for Each Application by Project Type

Application	Basic Project ($ / ft^2)	Advanced New Construction Project ($ / ft^2)	Advanced Retrofit Project ($ / ft^2)
Assembly & Athletic	$0.20	$0.42	$0.46
Bathroom	$0.50	$0.75	$0.75
Boarding	$0.38	$0.48	$0.48
Classroom & Dining	$0.25	$0.90	$1.00
Display-Small	$0.10	$0.24	$0.24

Display-Big Box	$0.16	$0.33	$0.37
Food Prep & Shop	$0.25	$0.42	$0.42
Hall-Offices	$0.24	$0.78	$1.01
Hall-Open Spaces	$0.22	$0.96	$1.19
Office & Healthcare-Private	$0.27	$1.08	$1.28
Office & Healthcare-Open	$0.15	$0.64	$0.74
Storage & Ship/Receiving	$0.07	$0.41	$0.45
Utility	$0.13	$0.29	$0.29

(Source: Pike Research)

5.3.5.4 *Example: Education Category*

Table 5.7 shows how a cost per square foot is computed for the Education building category.

The second column is the allocation of space by application in the Education category. (These are the same figures as shown in Section 5.3.3.3.) The third column is the result of the cost computations for each application. These are the costs for an Advanced system Retrofit project. The fourth column shows the costs applied to the space allocation, producing a pro-rated cost per ft^2. The total at the bottom of that column, $0.78, is the average cost for an Advanced control system Retrofit project per square foot of Education building space.

Table 5.7 Example: Advanced Retrofit Project per ft^2 of Education Building Space

Application	Space for each Application	$ / ft^2 for each Application	Pro-rated $ / ft^2
Assembly & Athletic	10%	$0.46	$0.04
Bathroom	6%	$0.75	$0.05
Boarding	2%	$0.48	$0.01
Classroom & Dining	32%	$1.00	$0.29
Display-Small	0%	$0.24	$0.00
Display-Big Box	0%	$0.37	$0.00
Food Prep & Shop	2%	$0.42	$0.01
Hall-Offices	30%	$1.01	$0.08
Hall-Open Spaces	8%	$1.19	$0.24
Office & Healthcare-Private	17%	$1.28	$0.02
Office & Healthcare-Open	6%	$0.74	$0.02
Storage & Ship/Receiving	7%	$0.45	$0.01
Utility	15%	$0.29	$0.01
Totals	100%		$0.78

(Source: Pike Research)

5.3.5.5 Costs per Square Foot by Building Category

Similar computations to those in Table 5.7 produce costs per ft^2 for each of the building categories for each of the three project types. These costs are shown in Table 5.8.

Table 5.8 Costs Per ft^2 for Each Building Category by Project Type

Building Category	Basic Project ($ / ft^2)	Advanced New Construction Project ($ / ft^2)	Advanced Retrofit Project ($ / ft^2)
Office	$0.14	$0.68	$0.79
Retail	$0.12	$0.43	$0.47
Education	$0.21	$0.78	$0.91
Healthcare	$0.13	$0.71	$0.85
Hotels & Restaurants	$0.12	$0.64	$0.71
Institutional / Assembly	$0.18	$0.61	$0.68
Warehouse	$0.10	$0.50	$0.56
Transport	$0.17	$0.74	$0.88
Multi-Unit Res Common	$0.05	$0.78	$0.99

(Source: Pike Research)

5.3.5.6 Costs per Square Meter

The $/$ft^2$ costs in the previous section were converted to $/$m^2$ with the conversion factor: $ft^2 = 0.093\ m^2$.

5.3.5.7 Cost Decrease over Time

Pike Research assumed that the general trend in cost for lighting control systems will be to decline over time. The costs presented in the previous sections were used for 2011. For the ensuing years, the price decline used in the forecast model was 3% per year for Basic systems and 5% per year for advanced systems. These produce the annual cost indexes in Table 5.9, with 2011 = 1.00.

Table 5.9 Indexes Used to Reflect Downward Trend in Costs over the Forecast Period

Project Type	Annual Rate	2011	2012	2013	2014	2015	2016	2017
Basic	3%	1.00	0.97	0.94	0.91	0.89	0.86	0.83
Advanced	5%	1.00	0.95	0.90	0.86	0.81	0.77	0.74

(Source: Pike Research)

5.3.6 Regional Forecasts

For geographic forecasting, Pike Research uses a standardized list of 224 countries, territories and other geographic divisions. These are divided into five global regions: Asia Pacific, Europe, the Middle East/Africa, North America, and South America.

The baseline data for the forecast is Pike Research's Global Building Stock Database.

To develop a forecast for each region, Pike Research created a specific forecast for certain of the major countries in each region, then a forecast for the total of the remaining countries and territories in that region. These were then summed to produce the forecast for each region.

5.3.6.1 *New Construction Activity*

For each country or region, new construction activity is based on the computed m^2 of new construction space for each of the nine building categories. The Global Building Stock Database provides an annual net growth in building space for each category. This annual net growth is not the same as the amount of new construction since it does not account for any buildings that may have been demolished. So, Pike Research estimated a retirement rate for each building category and multiplied the starting amount of space each year by that rate to determine the retired space. The amount of new construction space for each category, then, is the sum of the net growth plus the retired space.

5.3.6.2 *New Construction and Retrofit Forecasts*

For each region, Pike Research produced a New Construction forecast and a Retrofit forecast. These were summed to produce a Total forecast for the region.

5.3.6.3 *Base Case and Aggressive Case Forecasts*

For each region, Pike Research produced a set of “Base Case” forecasts (new construction, retrofit and total) and a set of “Aggressive Case” forecasts. The Aggressive Case methodology is the same as for the Base Case, except for the use of higher New Construction Rates and Retrofit Rates.

5.3.7 Base Case Forecasts

For each major country, country group, or region, Pike Research created four forecast tables that together make up the Base Case.

- New construction projects, basic controls
- New construction projects, advanced controls
- Retrofit projects, basic controls
- Retrofit projects, advanced controls

5.3.7.1 *New Construction Project Forecasts*

To create the New Construction project forecasts, Pike Research developed two series of annual control installation rates for each building category. These rates represent the percentage of the new construction activity for that building category in each year that would include a lighting control system. One series of rates represented the percentage that would be basic systems, and the other series represented the percentage that would be advanced systems. Please note that throughout the forecast model, the percentages in each series generally increase. The few exceptions are in those countries where the penetration of control systems is expected to be so high that the percentage of basic systems installed each year may eventually decrease as more of the advanced systems are built.

The next step was to produce two Control Installation Space tables: one for basic systems and one for advanced systems. These were produced by multiplying the control installation rate for each year by the number of m^2 of new construction for that year in each building category.

The next step was to produce two Control Installation Dollars tables: one for basic systems and one for advanced systems. The basic systems table was produced by multiplying the basic system control installation space figures (in m^2) for each year by the cost of a basic system per m^2 for that year in each building category. The advanced systems table was produced similarly, by multiplying the advanced system control installation space figures (in m^2) for each year by the cost of an advanced new construction system per m^2 for that year in each building category.

For the advanced control system new construction installations, a series of rates was also created to represent the percentage of those control system installations that would include wireless technology. To somewhat simplify the model, this same series of rates was applied to each of the building categories. When computing the advanced system new construction dollars, the additional cost for wireless was added.

In summary, the process is as follows for each building category for each year, for each of the two new construction tables.

New Construction Space (m^2)	X	New Construction Control Installation Rate (%)	=	New Construction Control Installation Space (m^2)
New Construction Control Installation Space (m^2)	X	Control System Cost ($/$m^2$)	=	New Construction Control Installation Dollars ($)

Again, this produces two tables: one for new construction basic controls and one for new construction advanced controls.

5.3.7.2 *Retrofit Project Forecasts*

The process for creating the Retrofit project forecasts is an exact parallel to that for the new construction project forecasts. The primary difference is the data used at the start.

The starting points for the Retrofit forecasts are the amounts of space that exist for each building category in each year. The series of rates Pike Research created, then, represent the percentage of the existing space for that building category in each year that would undergo a retrofit project that involves a lighting control system. One series of rates represented the percentage that would be basic systems, and the other series represented the percentage that would be advanced systems.

The simplified description of the process is as follows:

Total Existing Space (m^2)	X	Retrofit Control Installation Rate (%)	=	Retrofit Control Installation Space (m^2)
Retrofit Control Installation Space (m^2)	X	Control System Cost ($/$m^2$)	=	Retrofit Control Installation Dollars ($)

Again, this produces two tables: one for retrofit basic controls and one for retrofit advanced controls.

Just as for the advanced control system new construction installations, a series of rates was created to represent the percentage of the retrofit control system installations that would include wireless technology. These rates were applied in the same way.

5.3.7.3 Base Case Totals and Graphs

The final step was to produce the totals and sub-totals for each region and their graphs.

The new construction basic control dollars table and the new construction advanced control dollars table were added to create a new construction forecast table.

The retrofit basic control dollars table and the retrofit advanced control dollars table were added to create a retrofit forecast table.

The new construction forecast table and the retrofit forecast table were added to create the total forecast dollars table.

Although the new construction and retrofit graphs are not included in this document, the data series for them are in the spreadsheet file that accompanies this report.

5.3.8 Aggressive Case Forecasts

Exactly the same process was used to create Aggressive Case forecasts for each region. The same four tables were produced:

- New construction projects, basic controls
- New construction projects, advanced controls
- Retrofit projects, basic controls
- Retrofit projects, advanced controls

The differences were the higher control installation rates for each of the four tables and the higher wireless rates for the two advanced controls tables.

In every case, Pike Research set the aggressive case forecast for 2011 at 10% above the base case. Moving into the ensuing years of the forecast period, though, the variability between countries and regions is significant.

- In countries with low base case installation rates but growing economies, aggressive case forecasts exhibit the highest percentage increase over the base case forecasts (e.g. China).
- In countries with high base case installation rates, aggressive case forecasts do not exhibit as high a percentage increase over the base case forecasts (e.g. Germany, Japan).
- In regions with low base case installation rates and economies that are still developing, aggressive case forecasts are relatively higher than the base case forecasts, due to some upside potential, but the proportion is not as high as in rapidly growing economies (e.g. Latin America except Argentina, Brazil, Mexico).

5.4 General Assumptions by Building Category

Pike Research used the following *very general* assumptions about each of the building categories to guide its creation of the various control installation rates for each country and region. Any of these may or may not have been applied in varying degrees to a particular situation.

The Office building category will tend to have the highest lighting control installation rates. This will be the result of a combination of private companies and property owners seeking cost savings and green building certification, and government office space driven to save cost. In addition, the ESCO business model will be especially helpful in assisting governments to pay for energy saving projects. Office buildings also have a number of easy space types for basic controls, such as private offices and conference rooms. Even more sophisticated controls, such as dimming systems, can be implemented with relatively little additional cost and trouble when the general lighting is being upgraded to a more efficient technology such as new fluorescent tube luminaires. The anticipated penetration of LED lighting into office buildings in the coming years will bring more opportunity to install lighting controls. In addition, building owners in developed markets are increasingly interested in opportunities to participate in demand response programs.

The Education and Healthcare building categories will also tend to have high lighting control installation rates. These buildings are usually public or publicly supported and will have the benefit of access to long-term financing. In addition, major lighting and lighting control vendors have been developing solution packages specifically targeted at these industries. Higher education communities are also increasingly interested in sustainability efforts, so this should lead to more energy conserving measures in new construction and retrofits of older buildings.

Warehouses will have moderate lighting control installation rates, and rates will be lower in developing regions. Most warehouse facilities are very basic in nature and the businesses that operate them may not have capital for improvements. Although lighting is one of the higher operating costs in warehouses, significant efficiency gains can be obtained with upgrades to lighting technology, and the additional costs of lighting controls may be a hard sell. Most warehouses that do install lighting controls will tend to use the most basic occupancy sensors.

The Public Assembly and Transport building categories will have moderate lighting control installation rates. Many of these are publicly owned and will benefit from the ability to use long-term financing and work with ESCOs. In addition, these buildings are occasionally showcases for the local governments and, therefore, could sometimes receive additional funding for features such as advanced lighting control systems. New airports, for example, even in developing countries, are often built with an eye toward impressing visitors. Modern sports arenas often receive generous revenue streams from corporate sponsorships. On the other hand, many buildings in these two categories are older and utilitarian, and therefore unlikely to receive the kind of attention that would lead to much investment around systems like lighting controls (e.g., picture a sports arena in a smaller town, or a bus depot almost anywhere).

Retail will tend to have the lowest penetration of lighting controls of the eight commercial building categories. Lighting levels are critical in retail sales space, so showing off the product and making the space attractive to customers takes significant precedence over saving lighting energy. The majority of energy savings can be achieved through upgrades to higher efficiency lighting technologies, and retailers are taking advantage of opportunities to do so. (This industry is watching the progress of LED lighting very closely.) The incremental cost of lighting controls is not seen as a necessary investment. Even though non-retail space, such as offices and storage areas, composes a decent percentage of retail buildings, lighting control installations will not be top-of-mind projects for retailers. The exceptions in Retail are the big-box companies, some of which are looking to take advantage of daylight harvesting strategies through the use of skylights.

Hotels & Restaurants is a difficult building category about which to generalize. First of all, while these two hospitality industries share many commonalities from a business perspective, their physical facilities are very different. Some hotels do have restaurants, but their buildings are dominated by guest rooms, of course, plus lobbies, hallways, meeting rooms and a great deal of “back of the house” operations space. New high-end hotels may have very sophisticated building systems, including extensive lighting control installations. Some historic hotels will invest in retrofits to save any possible energy costs in their highly inefficient buildings. The mid- and lower-tier lodging establishments, however, probably do not have lighting controls on their radar. The main purpose of lighting in restaurants is to set the atmosphere in the dining area. Food preparation areas are almost constantly occupied, so they are not good candidates for occupancy controls. Restrooms are also frequently used during operating hours. That leaves storage areas and offices as candidates for lighting controls, so the occasional occupancy sensor may be installed.

Pike Research included the Multi-Unit Residential building category in this report for completeness. The common areas in these buildings have much more in common with some commercial spaces than with the insides of residential units, be they in multi-unit buildings or single-family residences. While there are application areas within these buildings that could benefit from lighting control strategies, especially around the use of occupancy sensors, Pike Research does not expect lighting controls to catch on much in these spaces. A number of newer buildings will install occupancy sensors in areas such as laundry rooms to prevent lights from being left on overnight, but dimming hallway and staircase lights even during off hours could meet with resident resistance. The occasional new high-end apartment building will have the latest and greatest of everything, including advanced lighting control systems. However, existing luxury apartment buildings are unlikely to invest much in lighting controls, even if they upgrade their lighting systems.

5.5 Forecasts

5.5.1 North America

Basic lighting controls have become fairly common in North American office buildings built during the last decade. Timers and occupancy sensors were required by ASHRAE 90.1-1999, which has been incorporated into energy codes in many states and territories.

More advanced control systems that include daylight harvesting and building-wide networks to enable demand response are becoming more common in new office buildings. In fact, some interviews estimated that as many as 15% to 20% of new office buildings are incorporating such functionality. While energy savings is a motivation, there is increasing interest from hospitals and other institutional buildings in the value of the information that can be gleaned from the lighting control system.

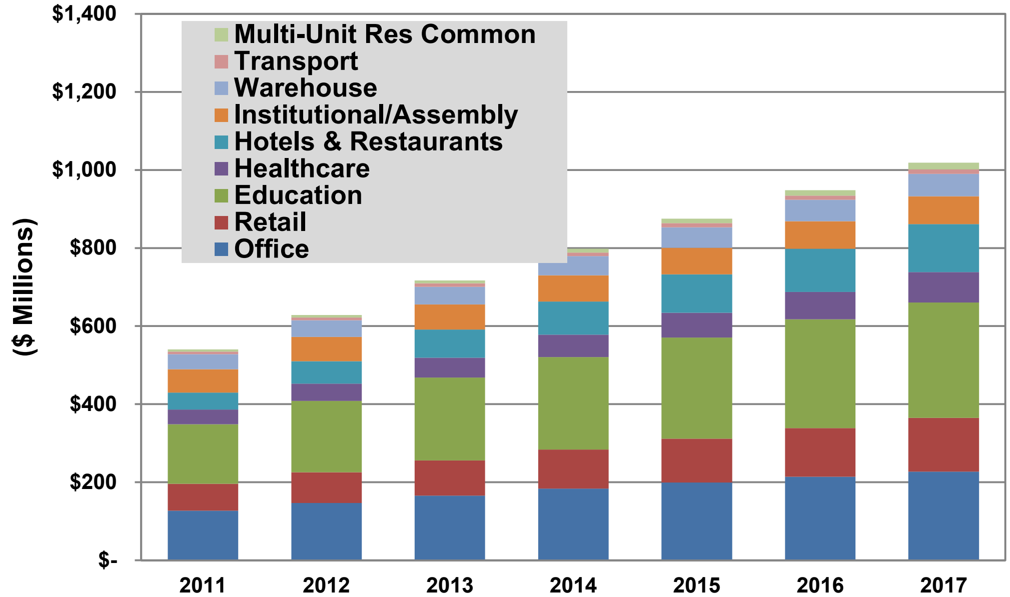
Basic controls are being increasingly deployed in categories such as retail, hospitality, and public assembly buildings, yet from a very low baseline level. When implemented, these controls are installed on a room-by-room or area-by-area basis, and are rarely controlled centrally.

Wireless controls have begun to catch on in North America, but still account for a fairly low percentage of installations, especially in new construction. The perception of high initial cost is also hurting wireless penetration in retrofit projects.

Finally, the lighting controls market in North America is dominated by the retrofit side of the business. This has been especially true during the recent economic slowdown which significantly reduced the amount of new construction activity. New construction activity will increase; however, the Pike Research Building Stock Database forecasts slower building space growth in North America than in most other parts of the world. Only Europe and Japan are slower.

Pike Research forecasts the 2011 North American market at $541 million, growing to $1.01 billion by 2017. That is an 11% CAGR.

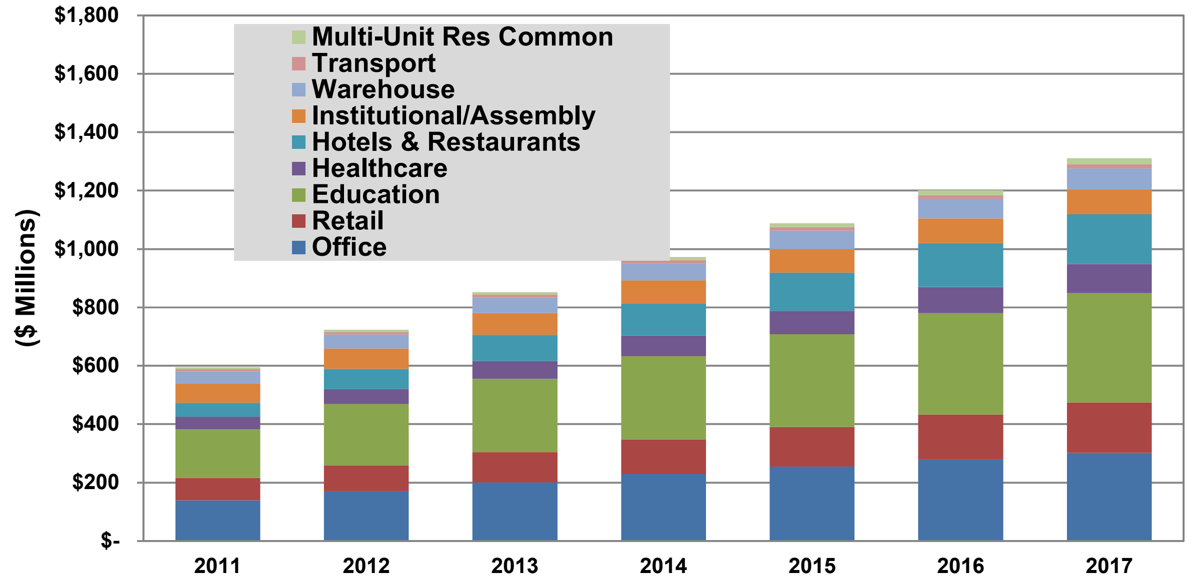
Chart 5.1 Lighting Controls Revenue by Building Category, North America: 2011-2017



(Source: Pike Research)

For an aggressive scenario, Pike Research forecasts the 2011 North American market at $595 million, growing to $1.31 billion by 2017. That is a 14% CAGR.

Chart 5.2 Lighting Controls Aggressive Revenue by Building Category, North America: 2011-2017



(Source: Pike Research)

5.5.2 Europe

Europe includes some of the world's most progressive countries in terms of adoption of energy efficiency measures. This specifically includes lighting controls. For example, recent construction in Germany includes extensive use of lighting controls. In fact, as the home of EnOcean, adoption of this wireless technology for lighting controls has progressed very rapidly, and EnOcean-based lighting controls are now included in as much as one-half of the newly constructed office buildings in Germany. Penetration of lighting controls is already high enough and growing fast enough that the Aggressive Case forecast for Germany is somewhat limited on the upside by a potential saturation of certain parts of the market.

Other European countries, such as Denmark, the Netherlands, and Sweden, are also leaders in the use of lighting controls. In addition, the United Kingdom has an aggressive public policy to reduce carbon emissions through energy efficiency, and this is backed by extensive financial and other support.

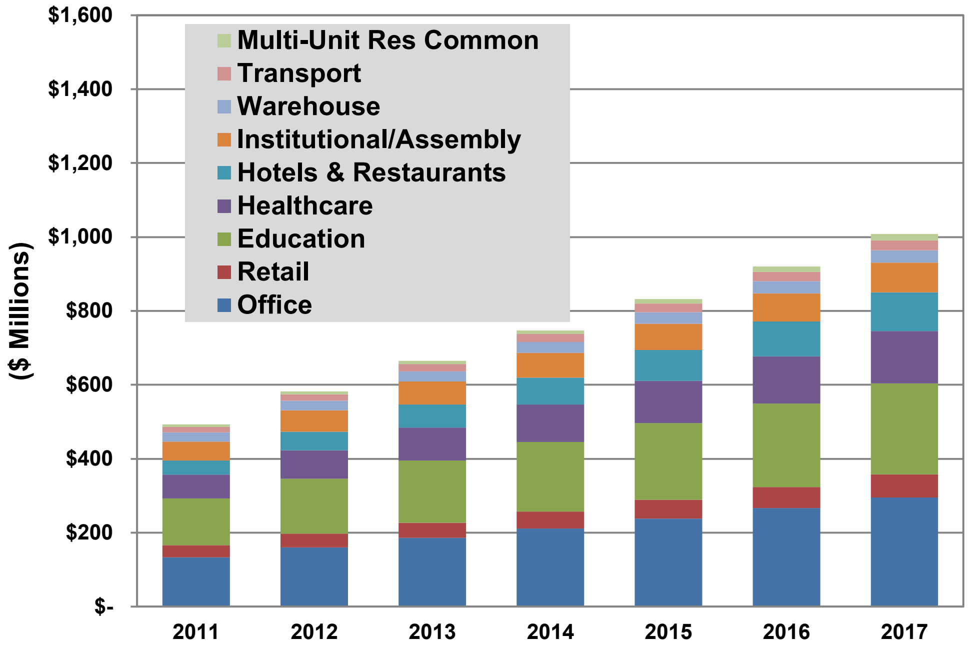
The next tier of countries includes the large markets of France, Spain, and Italy, plus the smaller Norway and Finland. These countries have put policies in place that are supportive of energy efficiency investment, but implementation progress is not as far along as in the leading European countries. The situation is similar in the rest of Western Europe.

Eastern Europe still faces an array of challenges as these countries try to modernize their economies and their building stock. There will be some use of lighting controls in this region, supported by the product availability and distribution strength from their Western European neighbors, but near-term growth will be slow.

New construction in Europe is not forecast to be very strong in the coming years. In addition, Europeans tend to assume that their buildings will be around for a long time and have built them to do so. Therefore, Pike Research expects the European market for lighting controls to be dominated by the retrofit business for the foreseeable future.

Pike Research forecasts the 2011 European market at $493 million, growing to $1.00 billion by 2017. That is a 13% CAGR.

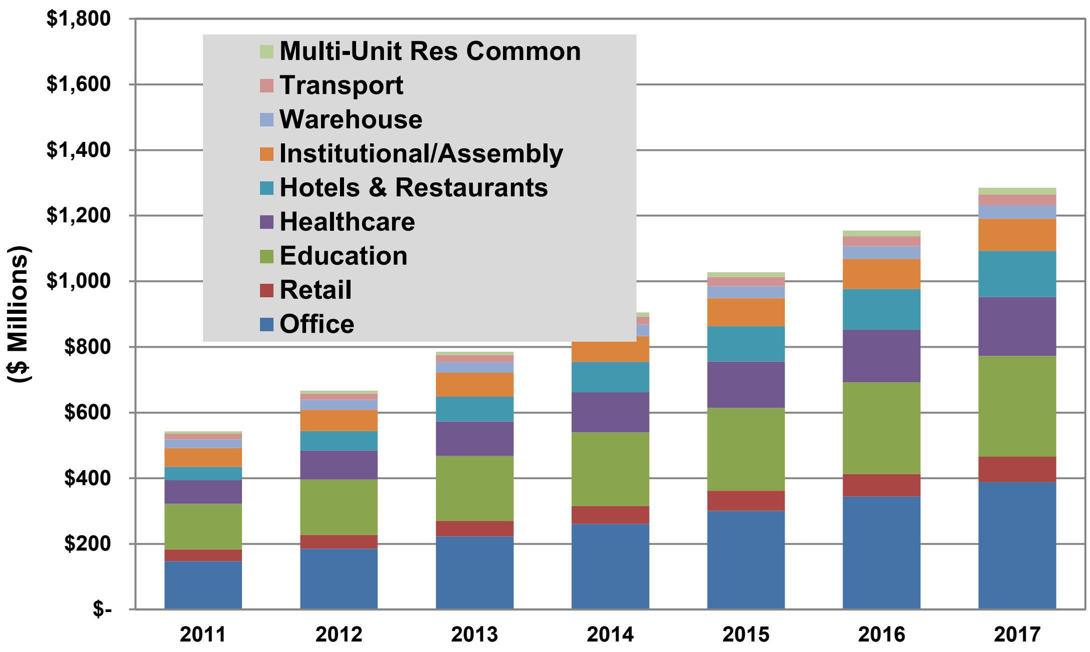
Chart 5.3 Lighting Controls Revenue by Building Category, Europe: 2011-2017



(Source: Pike Research)

For an aggressive scenario, Pike Research forecasts the 2011 European market at $543 million, growing to $1.29 billion by 2017. That is a 15% CAGR.

Chart 5.4 *Lighting Controls Aggressive Revenue by Building Category, Europe: 2011-2017*



(Source: Pike Research)

5.5.3 Asia Pacific

When it comes to Asia Pacific, the various countries stretch out along pretty much the entire spectrum of economic development. On one end is the very mature, slow-growing Japan. On the other is the hyperactive development in China.

Along with Germany, Japan is a global leader in the use of lighting controls. As in many industries, Japan has a lot of home-grown technology with dominant shares of the local market. Use of lighting controls will continue to increase in Japan, though the relatively low rate of new construction will cause retrofit business to dominate this market. The retrofit rates are somewhat lower than in countries such as Germany, though, because the tendency in Japan is to assume a relatively shorter life for buildings, and this may make investments in retrofits appear somewhat less attractive.

China currently has very little in the way of an intelligent lighting controls market. Interest has been driven by the few high-end and green building construction projects that have come online. However, the government is extremely interested in all potential energy-saving technologies, and lighting controls will surely be on this list. Public buildings, especially offices but also Assembly and Transport buildings, will be prime targets for lighting control installations. With the exception of certain historic buildings and hotels, it is very unlikely there will be much effort expended to upgrade older buildings. Therefore, the lighting controls market in China will be very heavily weighted toward new construction.

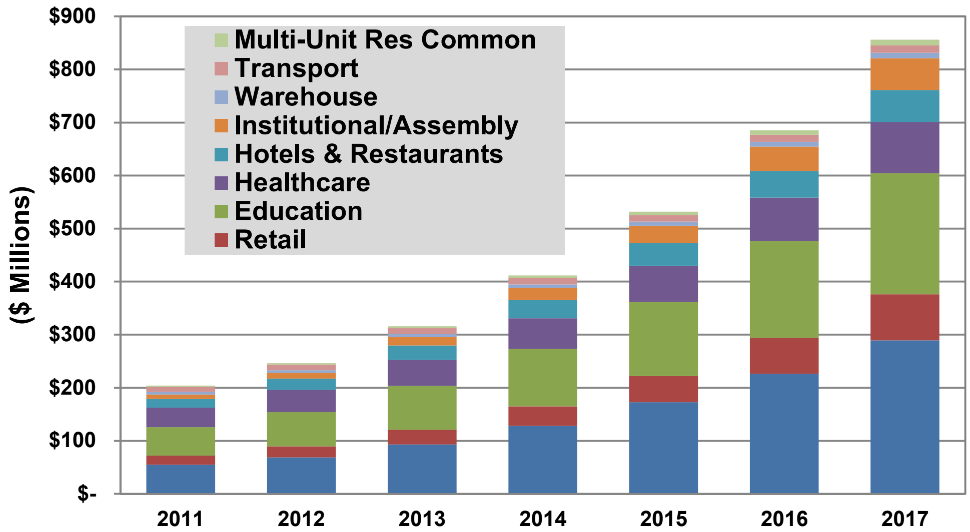
While an initial impression might be that India's profile would be along the lines of China's though with a somewhat less aggressive growth rate, this is not the case. The extensive research that Pike Research performed during the creation of the Global Building Stock Database showed that India's commercial building stock is considerably smaller than China's, despite India's huge population. As a result, the forecast model does not produce nearly the growth in lighting controls business in India. Due to an apparent shortage of building space and a relatively weak construction forecast, Pike Research assumes that investments in retrofits will be relatively more frequent than in most other Asia Pacific countries. India's lighting controls business is still expected to be more heavily weighted toward new construction, but the ratio will be much less exaggerated than for many of its regional neighbors.

Australia is a small, though well-developed country. There is already some good use of lighting controls, especially in government-owned buildings. The use of advanced, digital controls is also well-established. However, Pike Research expects Australia's construction industry to remain depressed through the forecast period, so the lighting controls market there will be dominated by retrofit business.

Most of the remaining Asia Pacific countries, with the exception of South Korea, Taiwan, and Singapore, are developing markets with low current penetration of lighting controls. Growth should be reasonably strong, though from a small base.

Pike Research forecasts the 2011 Asia Pacific market at $204 million, growing to $856 million by 2017. That is a 27% CAGR.

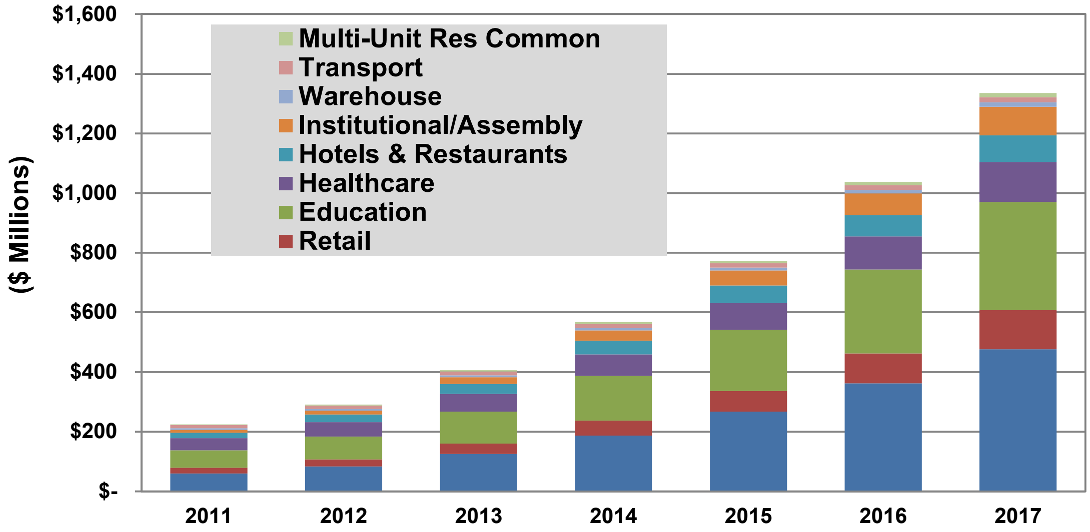
Chart 5.5 Lighting Controls Revenue by Building Category, Asia Pacific: 2011-2017



(Source: Pike Research)

For an aggressive scenario, Pike Research forecasts the 2011 Asia Pacific market at $224 million, growing to $1.33 billion by 2017. That is a 35% CAGR.

Chart 5.6 Lighting Controls Aggressive Revenue by Building Category, Asia Pacific: 2011-2017



(Source: Pike Research)

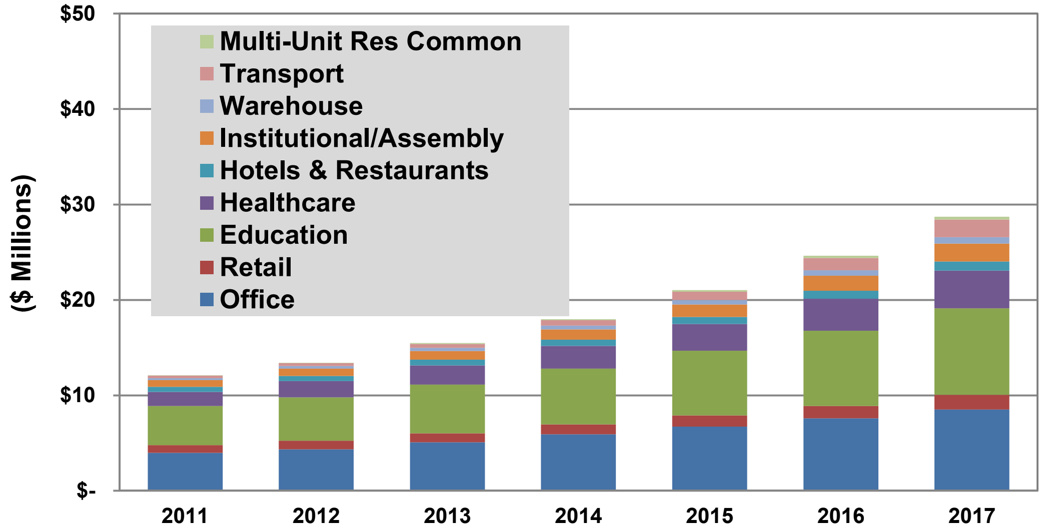
5.5.4 Middle East/Africa

South Africa is the most developed economy in Africa; lighting controls are in use there, and some very high-end commercial building projects in the region have incorporated sophisticated digital lighting control systems. There is some policy support for energy efficiency in South Africa, but the mandatory requirements are still weak and subject to interpretation.

One of the fastest growing regions of the world as far as building goes has been the United Arab Emirates. A great deal of new technology has been installed in showcase office buildings, hotels, and retail establishments. There is also a strong interest in sustainability, though water efficiency tends to take precedence over energy efficiency. However, the United Arab Emirates only accounts for about 5% of the building space in the Middle East. Pike Research allowed for it to have some influence in the Middle East/Africa regional forecast, but the impact was relatively minor due to the overwhelming amount of building space that is making very little use of lighting controls in developing markets throughout the rest of the region.

Pike Research forecasts the 2011 Middle East/Africa market at $12 million, growing to $29 million by 2017. That is a 16% CAGR.

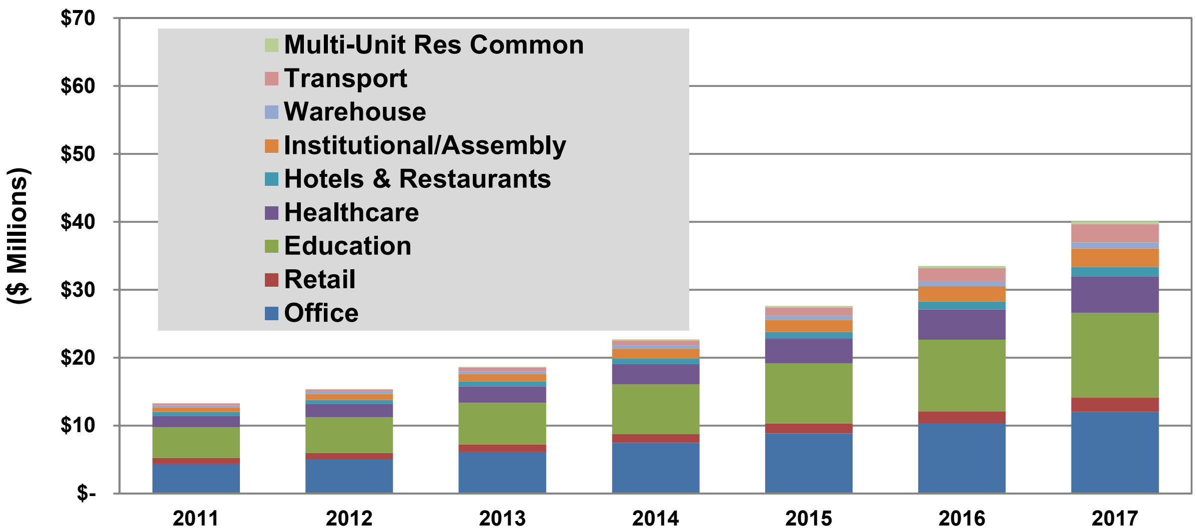
Chart 5.7 ***Lighting Controls Revenue by Building Category, Middle East/Africa: 2011-2017***



(Source: Pike Research)

For an aggressive scenario, Pike Research forecasts the 2011 Middle East/Africa market at $13.3 million, growing to $40.1 million by 2017. That is a 20% CAGR.

Chart 5.8 ***Lighting Controls Aggressive Revenue by Building Category, Middle East/Africa: 2011-2017***



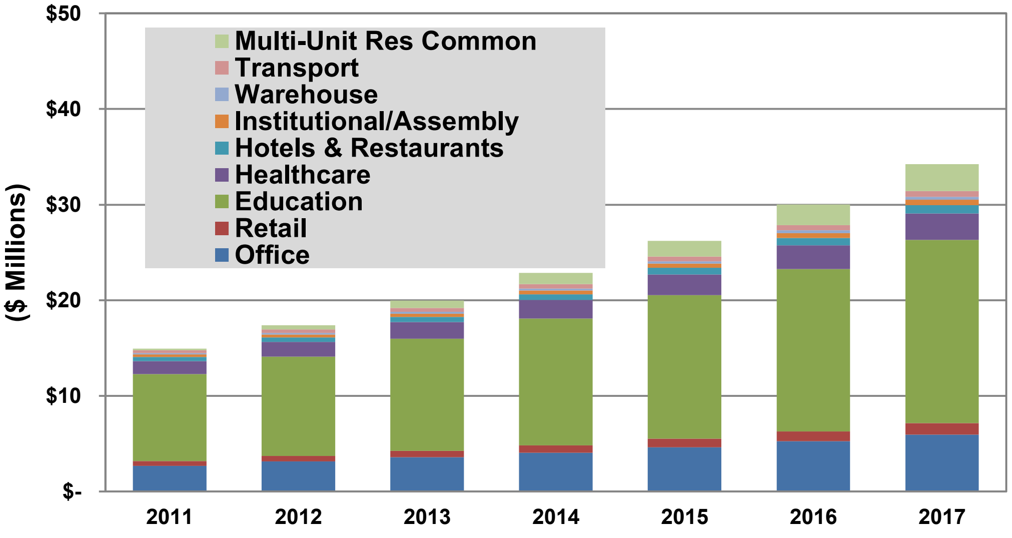
(Source: Pike Research)

5.5.5 Latin America

Brazil, Argentina and Mexico are the three largest and most developed economies in Latin America. Mexico, especially, has good access to technology, products and services from the United States. Pike Research believes that the use of lighting controls in these countries will be building from a relatively small, though solid base. And while lighting control installation rates will not approach those of the North American or European developed markets during the forecast period, there is significant upside in the forecast if the governments can build support for stronger energy efficiency policies.

Pike Research forecasts the 2011 Latin American market at $15 million, growing to $34 million by 2017. That is a 15% CAGR.

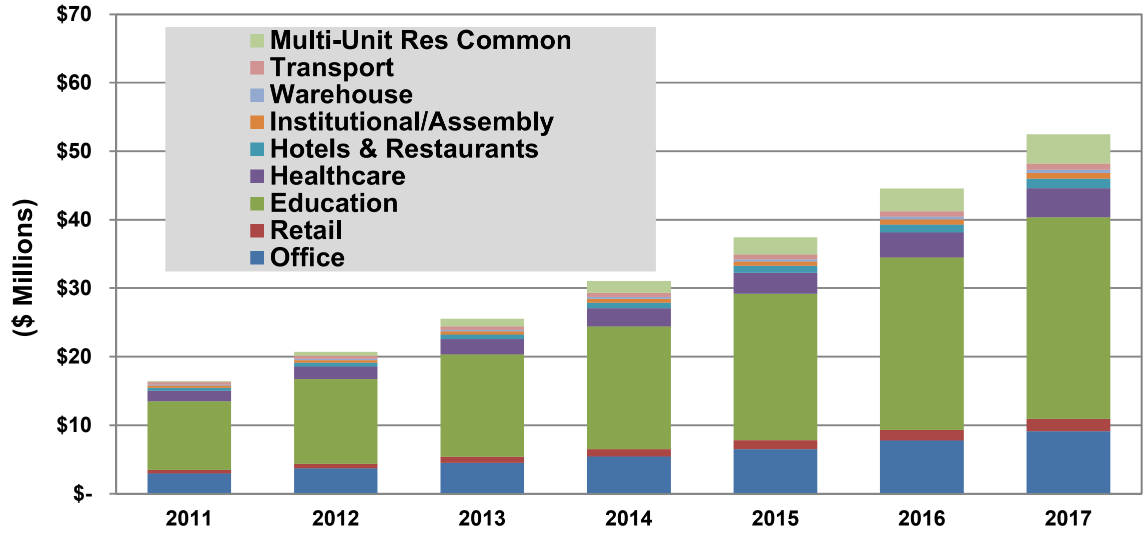
Chart 5.9 Lighting Controls Revenue by Building Category, Latin America: 2011-2017



(Source: Pike Research)

For an aggressive scenario, Pike Research forecasts the 2011 Latin American market at $16 million, growing to $52 million by 2017. That is a 21% CAGR.

Chart 5.10 Lighting Controls Aggressive Revenue by Building Category, Latin America: 2011-2017

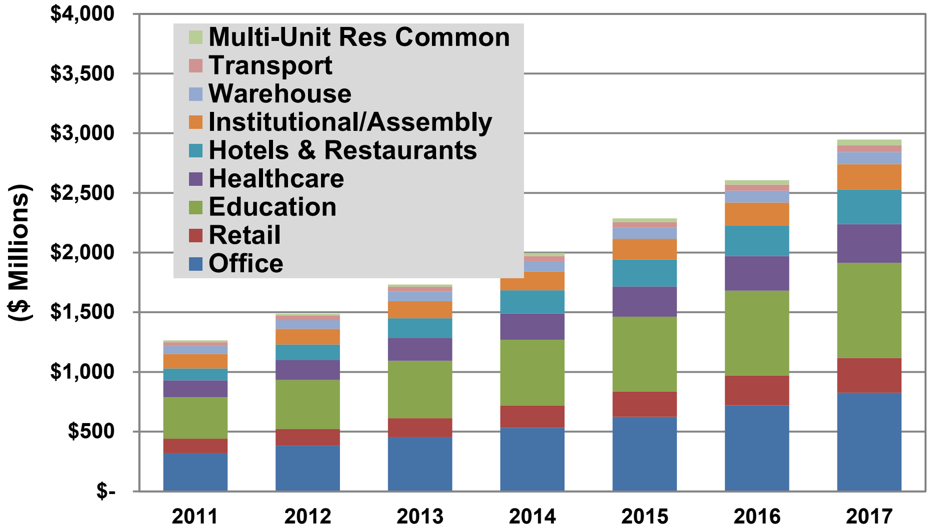


(Source: Pike Research)

5.5.6 World Totals

Pike Research forecasts the 2011 global market at $1.26 billion, growing to $2.95 billion by 2017. That is a 15% CAGR.

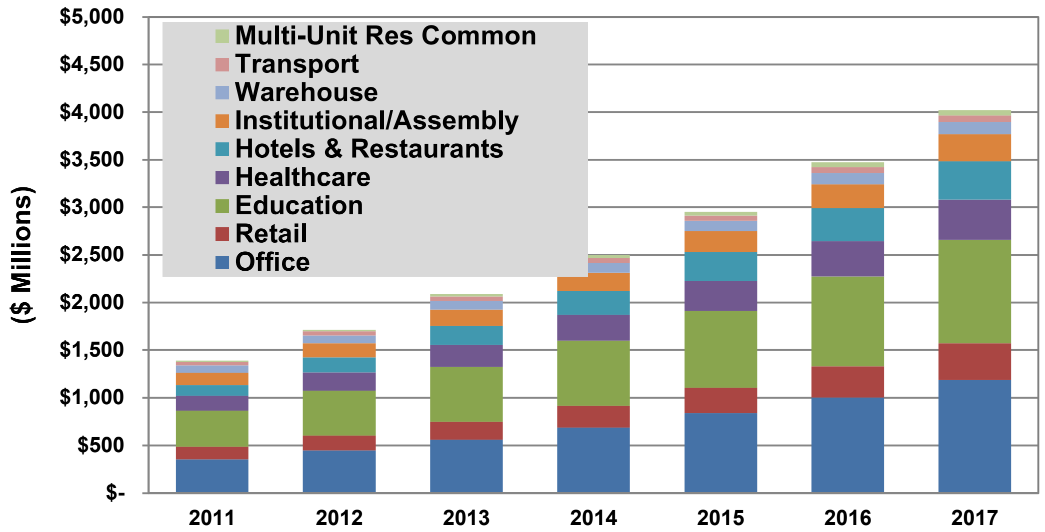
Chart 5.11 Lighting Controls Revenue by Building Category, World Markets: 2011-2017



(Source: Pike Research)

Pike Research's aggressive forecast for the 2011 global market is $1.39 billion, growing to $4.02 billion by 2017. That is a 19% CAGR.

Chart 5.12 Lighting Controls Aggressive Revenue by Building Category, World Markets: 2011-2017



(Source: Pike Research)

Section 6

Company Directory

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Germany
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+1.888.992.2838

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+44.0.1942.719229

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honeywell.com
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Fall River, MA 02720
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+1.508.679.8131

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Section 7

ACRONYM AND ABBREVIATION LIST

Alternating Current	AC
American National Standards Institute	ANSI
American Recovery and Reinvestment Act of 2009	ARRA
American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE
American Society of Interior Designer	ASID
Application Service Provider	ASP
Association of Southeast Asian Nations	ASEAN
Audio/Visual	A/V
Automation and Control Solutions (Honeywell)	ACS
Better Buildings Partnership	BBP
Building Codes Advisory Project	BCAP
Building Design Criteria for Energy Saving (Korea)	BDCES
Building Energy Efficiency Certificate	BEEC
Building Energy Management System	BEMS
Building Management System	BMS
Building Owners and Managers Association	BOMA
Building Research Establishment	BRE
Building Research Establishment Environmental Assessment Method	BREEAM
Bureau of Energy Efficiency (India)	BEE
California Lighting Technology Center	CLTC
Carbon Reduction Commitment Energy Efficiency Scheme (U.K.)	CRC
Chief Executive Officer	CEO
Chief Technology Officer	CTO
Clean Development Mechanism	CDM
Climate Change Levy (U.K.)	CCL

Commercial Building Incentive Program (Canada)	CBIP
Commercial Building Tax Deduction	CBTD
Commercial Lighting Solutions (U.S. DOE)	CLS
Committee for Electrotechnical Standardization (Europe)	CENELEC
Committee for Standardization (Europe)	CEN
Compact Fluorescent Lamp	CFL
Compound Annual Growth Rate	CAGR
Comprehensive Assessment System for Building Environmental Efficiency (Japan)	CASBEE
Consortium for Energy Efficiency	CEE
Database of State Incentives for Renewables & Efficiency	DSIRE
Department of Energy (U.S.)	DOE
Digital Addressable Lighting Interface	DALI
Digital Lighting Management (WattStopper)	DLM
Dimming Electronic Ballast (Lumenergi)	DEB
Display Energy Certificate	DEC
Electrical and Electronic Manufacturers' Association (Germany)	ZVEI
Emissions Trading System	ETS
Energieeinsparverordnung	EnEV
Energy & Atmosphere (LEED)	EA
Energy (BREEAM)	ENE
Energy Conservation Building Code (India)	ECBC
Energy Control System (Encelium)	ECS
Energy Efficiency Action Plan (Germany)	EEAP
Energy Independence and Security Act	EISA
Energy Performance Certificate	EPC
Energy Performance Contracting	EPC
Energy Performance of Buildings Directive (Europe)	EPBD
Energy Policy Act	EPAct

Energy Service Company	ESCO
Engineering Tool Software (KNX)	ETS
Environmental Protection Agency (U.S.)	EPA
European Regional Development Fund	ERDF
European Social Fund	ESF
European Union	EU
Future Renewable Electric Energy Delivery and Management	FREEDM
General Electric	GE
General Services Administration (U.S.)	GSA
Global Positioning System	GPS
Green Building Council of South Africa	GBCSA
Health & Wellness (BREEAM)	HEA
Heating, Ventilation and Air Conditioning	HVAC
High Output	HO
High-Intensity Discharge	HID
Hubbell Building Automation	HBA
Illuminating Engineering Society of North America	IESNA
Illuminating Engineering Society	IES
Indoor Environmental Quality (LEED)	IEQ
Information Technology	IT
Intellectual Property	IP
Intelligent Light Engines (Digital Lumens)	ILE
Intelligent Lighting Controller (Cavet)	ILC
Internal Rate of Return	IRR
International Code Council	ICC
International Electrotechnical Commission's (Europe)	IEC
International Energy Agency	IEA
International Energy Conservation Code	IECC

Japan Sustainable Building Consortium	JSBC
Kilowatt	kW
Kilowatt-Hour	kWh
Lawrence Berkeley National Laboratory	LBNL
Leadership in Energy and Environmental Design	LEED
Light Management Systems (OSRAM)	LMS
Light-Emitting Diode	LED
Lighting Control & Design (Acuity Brands)	LC&D
Lighting Controls Association	LCA
Lighting Management and Control System (Lumenergi)	LMCS
Lighting Management System	LMS
Lighting Management Systems (Leviton)	LMS
Lighting Power Density	LPD
Liquid Crystal Display	LCD
Local Area Network	LAN
Medium Access Control	MAC
Megawatt-Hour	MWh
Metal Halide	MH
Ministry of Construction (China)	MoC
Ministry of Housing and Urban-Rural Development (China)	MOHURD
Ministry of Land, Infrastructure, Transport and Tourism (Japan)	MLIT
Model National Energy Code of Canada for Buildings	MNECB
Model National Energy Code of Canada for Houses	MNECH
Municipal, University, School, and Healthcare	MUSH
National Australian Built Environment Rating System	NABERS
National Association of Energy Service Companies	NAESCO
National Development and Reform Commission (China)	NDRC
National Electrical Manufacturers Association	NEMA

National Renewable Energy Laboratory (U.S. DOE)	NREL
National Research Council (Canada)	NRC
National Research Council Canada – Institute for Research in Construction	NRC-IRC
New York State Energy Research and Development Authority	NYSERDA
Non-Governmental Organization	NGO
Online Code Environment & Advocacy Network	OCEAN
Original Equipment Manufacturer	OEM
Panasonic Electric Works Corporation of America	PEWA
Panasonic Electric Works	PEW
Passive Infrared	PIR
Personal Computer	PC
Personal Control Software (Encelium)	PCS
Physical	PHY
Power Line Carrier	PLC
Property Assessed Clean Energy	PACE
Research and Development	R&D
Return on Investment	ROI
Sensor Placement & Optimization Tool	SPOT
Siemens Venture Capital	SVC
Small and Medium Enterprise	SME
Solid State Lighting	SSL
South African National Standards	SANS
Sustainable Sites (LEED)	SS
Terawatt	TW
Total Lighting Control (GE)	TLC
Transmission Control Protocol/Internet Protocol	TCP/IP
Ultrasonic	US
United Arab Emirates	UAE

United Kingdom	U.K.
United Nations Framework Convention on Climate Change	UNFCC
United States Dollars	USD
United States Green Building Council	USGBC
United States	U.S.
Urban Development Fund	UDF
Value-Added Resellers	VAR
Volts Direct Current	VDC
Watt	W

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Section 9

TABLE OF CHARTS AND FIGURES

Section 10

SCOPE OF STUDY

10.1 Report Scope

For purposes of this report, Pike Research is defining an "intelligent" control as requiring some type of reaction to the actual conditions in the space, such as the people using it and/or light levels that are present.

10.1.1 Building Industry Categories

This report covers the use of the various strategies and technologies for the intelligent control of lighting in the complete range of commercial buildings, plus the common areas of multi-family residential buildings. This report uses Pike Research's standard segmentation of the Commercial building sector. These eight categories are: Office, Retail, Education, Healthcare, Hotels & Restaurants, Institutional/Assembly, Warehouse, and Transport.

10.1.2 Geography

For geographic forecasting, Pike Research uses a standardized list of 224 countries, territories and other geographic divisions. These are divided into five global regions: Asia Pacific, Europe, Middle East/Africa, North America, and Latin America.

The baseline data for the forecasts in this report is Pike Research's Global Building Stock Database. The forecasts cover all five regions of the world.

10.1.3 Products

This report focuses on lighting control sensors, controllers, dimming ballasts, and lighting management systems.

Pike Research did NOT include the following types of controls, products, and other costs these forecasts:

- Manual dimmers
- Theatrical lighting – programmed lighting used in spaces specifically for entertainment.
- Non-dimming ballasts
- Labor of any type (installation, commissioning)
- Wiring, conduit, etc. used in the installation of lighting controls.

SOURCES AND METHODOLOGY

Pike Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Pike Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Pike Research's analysts and the firm's staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Pike Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Pike Research is an independent market research firm whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. The firm is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2011 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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