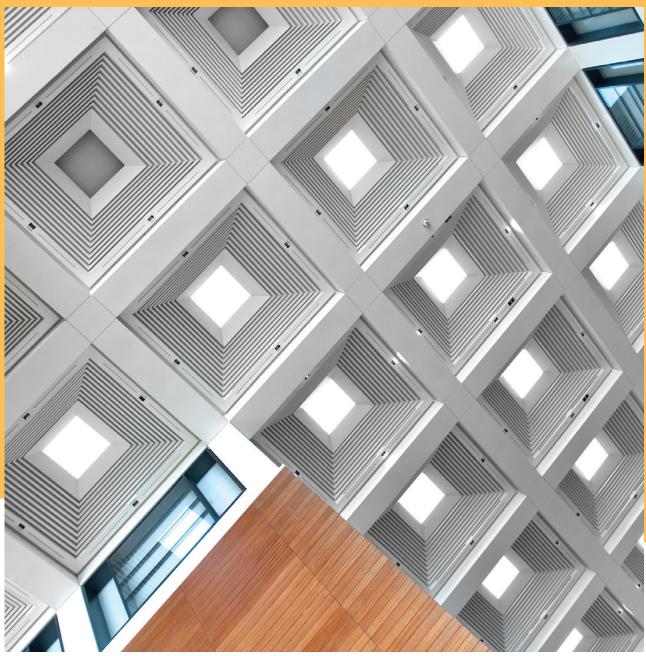

White Paper

Taking Control: 14 Energy-Saving Control Strategies for Commercial Lighting and Beyond

Executive Summary

Lighting Controls have a tremendous capacity for saving energy and money within commercial buildings. About $200B is spent globally on lighting energy each year, around half of which comes from commercial buildings. And yet, much of that energy is still wasted – lights are left on in unoccupied areas and rooms are consistently over-lit, even when technology tools exist to solve these problems.

A common misconception of a "lighting controls solution" is that it is simply an occupancy sensor, turning the lights in a single room on and off. And while this can certainly save energy and money, it's only the simplest one of many controls **strategies** designed to provide more intelligent, sustainable buildings. Today's lighting controls systems have moved beyond the stand-alone occupancy-based products, to provide true system-level control over lighting. If properly applied, the result can be tremendous savings, better occupant comfort, improved building management, and more.

The purpose of this white paper is to describe 14 distinct controls strategies enabled by today's most advanced lighting controls systems, and discuss the technology attributes that are required in order to take advantage of these strategies. Only by utilizing technology that is **intelligent, wireless** and **open** can lighting controls solutions provide the most comprehensive savings and control.

Types of Lighting Controls Systems

There are a myriad of lighting controls technologies, systems, and components on the commercial market. Generally, though, lighting controls can be divided by capability into "simple" or room-based controls, and "advanced" or networked controls. For the purposes of this paper, we can further divide the advanced category into "traditional" advanced systems – wired and proprietary – and the new generation of open, wireless controls. As we will show, these distinctions are more than academic – they represent substantial differences in capabilities and potential savings.

Simple Controls: Most lighting controls installations today still fall into the category of simple, room-based controls. These solutions are not true lighting controls systems, but rather individual components that provide a single lighting control strategy. As an example, an individual occupancy sensor can be connected via low voltage wiring to a set of light fixtures in a room, and this process can be repeated in the next room and so on. The result is to add automated occupancy control to each of those rooms, individually. The same process can be repeated with other controls components.

Centralized Controls: The next step up in capabilities is a centralized control system – for example, a lighting panel or a Digital Addressable Lighting Interface (DALI)-based solution. In these systems, each lighting element (sensors, wall switches, fixtures, etc.) is hard-wired back to a centralized controller, panel or computer. In other words, lighting in these solutions is controlled as a system or network.

These systems typically combine a discrete set of controls capabilities (or "strategies") such as scheduling, occupancy, daylighting, etc., and provide a physical interface for controlling any device hard-wired to the panel. Such systems are often proprietary, with a single vendor providing both the controller and the devices being controlled (which are only compatible with each other).

Next Generation Controls: The next generation of control systems builds upon the advantages of advanced controls but removes the limitations. Wireless networking enables larger-scale systems with controls that can be accessed from anywhere, and adjusted without physical wiring. Open standards eliminate the restrictions of proprietary systems, enabling a single controls system to utilize control devices from a variety of vendors. Integration with non-lighting products enables savings that go beyond lighting, into areas such as HVAC and plug loads. The result is an even more comprehensive set of energy monitoring and management tools, with centralized control.

Advantages of Advanced Controls

In short, more advanced controls equate to greater financial savings. Each individual controls strategy alone brings savings; when applied together, though, these savings stack. For example, while a room might reduce lighting energy usage by 30% through occupancy sensing, that same room could save 60% by using occupancy sensing, daylighting and scheduling at the same time. And several control strategies can only be implemented with an advanced, networked system, making such systems a requirement in order to realize the greatest savings.

Savings from lighting controls can come from several sources. The primary source is reduction in energy usage. The purpose of the most commonly-adopted control strategies (occupancy sensing, scheduling, etc.) is to eliminate unnecessary lighting, thereby reducing energy usage and saving energy costs. Savings in some advanced systems can also come from other sources as well – for example, by reducing lighting maintenance requirements or reducing the time and labor associated with managing lighting. And of course, government and utility incentives tend to reward greater energy reduction, providing even more savings.

Savings from lighting controls systems are also not static – they change over time. With more basic installations, energy savings tend to shrink over time, as the original design of the solution diverges from the current needs of the building and its occupants. More advanced systems can "self-correct" or adapt to retain value over time. And the most intelligent systems can actually improve their value over time, by automatically recognizing potential areas of energy savings and improvement. Finally, open standard systems offer the ability to add new capabilities in the future that go beyond lighting, for even greater value over time. These applications will be discussed later in this paper.

The intelligence of advanced controls systems provides other benefits that basic controls cannot offer, above and beyond simple financial savings:

- **Greater centralized control:** For many building owners and operators, gaining centralized control and visibility over their lighting and other energy loads is a benefit in itself, offering better management and reporting.
- **Occupant comfort:** The most intelligent lighting controls solutions enable lighting that automatically or manually adapts to each occupant's needs, for greater comfort and productivity. Balancing savings with comfort is a critical function that requires an adaptable system.
- **Green certifications:** Advanced controls systems can provide valuable points and credits towards LEED and other similar programs, above and beyond the credits that basic controls offer.
- **Regulatory compliance:** Regulatory measures such as ASHRAE 90.1 and California's Title 24 are increasingly requiring more advanced lighting controls measures. Over time, basic controls technology will no longer be sufficient to meet building codes.

Controls Strategies

Below, we will detail all of the common energy-saving lighting control strategies available today, as well as several emerging strategies and those that extend beyond lighting. These are organized generally from most common to most innovative.

Common Lighting Controls Strategies: These strategies form the core of most lighting controls systems.

- **Dimming:** Although not always considered a true controls strategy, dimming technology is utilized in several other strategies. Many lighting power supplies (e.g. ballasts, LED drivers) enable fixtures to be dimmed. Dimming the light to a fraction of its brightness will also use a fraction of the energy, allowing for many of the following strategies to reduce energy usage. The exact relationship between the brightness and the power used depends on the unique profile of the power supply. In its simplest form, dimming fixtures are paired with a dimmer switch, for manual dimming control. Dimming capabilities vary widely, from step functions up to full, smooth control over precise light levels.
- **Occupancy sensing:** This is perhaps the most common of all lighting controls strategies. A motion sensor (also known as an occupancy sensor) detects movement within its field of coverage, using Passive Infrared (PIR), ultrasonic, or other sensing technologies. Based on movement detection (or lack thereof) for a pre-defined period of time, lights can be automatically turned on or off. In this way, lights can be automatically turned off when a space is not in use.

  More sophisticated controls solutions allow occupancy settings (such as on/off levels, time delays, etc.) to be dynamically set or changed based on time, location and other inputs. Occupancy sensors can be built as stand-alone devices, or integrated directly into wall switches, light fixtures, furniture and more.
- **Scheduling:** Scheduling is another method of eliminating unnecessary lighting usage when building occupants are not present. Most centralized lighting controls systems provide some form of lighting schedule, the simplest example being a system that automatically turns off the lights after work hours. This is a "brute force" method of reducing energy usage, but can be effective. Some systems allow local user override of the schedule (via a wall switch), and the more sophisticated systems can create more complex schedules that alter other strategies based on time of day, day of week, time of year, etc.

Advanced Lighting Controls Strategies: These strategies are not as commonly used as those above, but are becoming more widely available.

- **Daylight Harvesting:** Also known as Daylighting, this is the practice of automatically reducing artificial light levels when ambient daylight (from windows, skylights, etc.) is available. Daylighting systems typically utilize a photocell sensor (though alternate sensor technologies do exist), which measures ambient light. Based on the reading from the sensor, an algorithm will determine the appropriate level of artificial light, or whether the lights can be turned off altogether, and the control system will take action. A properly-designed daylighting system can provide substantial savings in window-facing areas.

  Daylighting can work effectively with both dimming and non-dimming lighting, and like occupancy sensors, photocell sensors come in a variety of forms and can be integrated into other products. A similar concept is commonly used in outdoor lighting, where integrated photocell sensors automatically switch lights on at dusk and off at dawn.

- **Task Tuning:** This strategy goes under several names. The core concept is to reduce the maximum light output of each individual space to precisely meet occupant needs. Because light levels are often over-designed, or made consistent across a building despite the different needs of occupants, many spaces are over-lit. Some control systems offer the capability to create lighting zones and determine a "tuned" maximum light level that is lower than 100%. As an example, an occupant working with a computer monitor all day may not need the designed light level, and their area could be tuned so that the maximum level is 70%.

  The related concept of Lumen Maintenance stems from the fact that most lighting experiences a slow depreciation of light output over its lifetime. In this scenario, light levels are tuned down initially, but over time the control system slowly tunes levels back up to account for depreciation and maintain a constant output.

- **Demand Response (DR):** This strategy is less about saving money, and more about earning money – by reducing peak energy demand at key times, and being reimbursed by utilities to do so. A major goal of many utility companies is to better distribute their load, reducing the demand for energy at the times of highest demand (such as hot summer days). Lighting controls systems can help by reducing lighting load during those times, in response to a signal from the utility. Some controls systems offer Auto-DR technology: the ability to respond to a DR "event" and reduce light levels automatically. Demand Response utility programs vary widely, but some offer significant reimbursement (such as $300 / kW) for making a building's load available for reduction.

- **Personal Control:** Various studies have proven the positive impact of a worker's environment – and their control over that environment – on their productivity and happiness. It has also been found that when occupants are given personal control over lighting, their energy usage tends to be lower. Advanced lighting controls systems can use various forms of personal dimming to provide this control, ranging from remote controls to desktop dimming switches to "virtual" switches online, on a desktop computer or on a phone.

- **Energy Management:** This strategy typically refers to a software system that enables a building or facilities manager to visualize, report on and adjust their energy usage. It is often said that you cannot manage what you cannot measure – and centralized energy management software tools provide the capability to do both, in order to test and measure the success of lighting controls.

  Energy management saves energy over time by providing ongoing improvements to all of the other controls strategies. As an example, analysis of building energy usage compared with occupancy data over a month might point out that the office's kitchen area sees occupants throughout the day but only for short periods of time. The system could recommend reducing the occupancy-based off-delay in this area from 15 minutes to 5 minutes, and would measure the additional savings of that action. This type of ongoing recommendation and improvement is also known as Continuous Commissioning.

Lighting-Related Controls Strategies: These strategies begin to extend beyond the standard goal of reducing lighting energy usage, and provide other lighting benefits.

- **Automated Maintenance:** By monitoring and measuring energy usage at individual fixtures, some control systems can provide the capability to know when a lamp is out, or a sensor or ballast is malfunctioning. Likewise, similar information can be used to make an educated guess about when maintenance will be required. Finally, some systems can manually or automatically reconfigure in the case of a failure – for example, if an occupancy sensor fails, the lights can be re-associated with a neighboring sensor until maintenance replaces it. Together, all of this information can be used in an energy management system to improve the scheduling of maintenance calls, reducing the frequency (and cost) of lighting maintenance.

- **BMS Integration:** Some advanced lighting controls systems enable integration to a facility's Building Management System (BMS), typically via BACnet or another open protocol. Through this integration, the user interface of the BMS can provide integrated control and management functions. Although this strategy doesn't save additional energy in itself, it does offer reduced management overhead (and the associated lower cost) for buildings that want to manage HVAC, lighting and other functions from a single console.

Beyond Lighting: These strategies extend a single control system beyond lighting, to control (and reduce) other common energy loads.

- **Plug load Control:** Plug loads are an area of energy usage that is rarely controlled, but represents a significant amount of energy waste. Under this strategy, devices that would be plugged into a standard plug strip or outlet (such as monitors or desktop lamps) are instead plugged into a specialized "plug load controller". These loads can then be managed according to a schedule or associated with an occupancy sensor. For example, a plug load controller can be set to automatically turn off a desk lamp at the end of the day and whenever the user leaves his desk. This reduces both wasted usage and the "vampire power" that some devices draw even when off. Generally, wireless plug load controllers that are part of a centralized solution offer more sophisticated control options than standalone controllers.
- **Temperature, Humidity, CO2, and other Environmental Monitoring:** One of the advantages of a centralized control system (especially wireless and standards-based systems) is the ability to add applications onto an existing network without the need to build out a new dedicated infrastructure. Several emerging applications take advantage of environmental monitoring sensors, to report on conditions in a facility and trigger alerts if those conditions exceed a threshold. For example, some data centers closely track temperature and humidity to avoid unplanned outages. In a lighting controls solution that supports this application, temperature and humidity sensors can be added to the network and report real-time data.
- **Wireless Thermostats:** Building Management Systems typically manage the thermostats and other HVAC devices within the building. As those devices have begun to roll out with wireless communications capabilities, though, buildings have balked at the requirement to build a dedicated wireless network just for thermostats. A wireless lighting controls network can be used to avoid this requirement, routing wireless control messages to and from the thermostats via the lights. The benefit is a single building control network, eliminating the cost of building separate parallel networks. Lighting serves as an especially robust "base application" for this network, due to the large number of lighting nodes (e.g. fixtures), and their even, distributed coverage throughout the building.
- **Other Independent Building Systems:** As with the environmental sensors above, some standards-based controls systems have the capability to add control over a variety of other devices. Some examples include automated window blinds, industrial fans, and security systems. By providing centralized control over these devices in addition to lighting, these advanced building networks can provide greater control from a single integrated solution and interface.

How to Take Advantage of the Most Advanced Control Strategies

As detailed at the start of this paper, not every controls system enables all of the above strategies. While most systems offer a subset, many are constrained due to their choice of technology, making some of the most valuable strategies impossible to implement. For example, a lighting controls system that isn't networked will not be able to provide a centralized control interface – it is a basic limitation of the technology architecture.

In order to get the most out of a potential controls system purchase, and enable all of the above strategies, here are some of the key attributes to look for:

Networked: A networked architecture is what separates basic "room-level" controls from true control systems. Without some form of networking (wired or wireless), it is impossible to take central control over lighting and therefore impossible to take advantage of energy management, demand response, and many other controls capabilities. Non-networked controls are also extremely difficult to manage, maintain and upgrade.

Intelligent: Many controls solutions tout "intelligence" as a feature – and it is a critical one, but difficult to define precisely. In practice, intelligence in a controls system typically means a combination of multiple related attributes:

- Flexible configuration, allowing facilities managers and other users to more accurately adapt to conditions and occupant needs. In other words, an intelligent controls system usually includes a powerful and feature-rich user interface for setting or changing controls.
- Automated controls algorithms that make decisions based on multiple inputs. For example, an intelligent controls system could combine ambient light readings with time of day, day of week, location, user preference and more to determine (and set) the appropriate light level.
- The ability to measure results, and the means to use that information to improve results.

Simply having access to multiple controls strategies does not necessarily make a system intelligent –sophisticated software is required in order to determine how those strategies should interact. It is important to look in-depth at a system's capabilities and how it logically makes decisions, in order to determine if it meets your needs.

Wireless: As the number of end points in a building control system has proliferated – lights, various sensors, wall switches, remote controls, computers, plug load devices, and more – so has the complexity of reaching and communicating with each of these devices. In order to effectively control a device, the central system must be able to communicate with it. Wired systems bridge this gap with dedicated control wiring (or specialized power-line control wiring), but the more devices in a system, the more complex and inflexible this becomes.

Wireless networking is an effective solution, eliminating limitations of which devices can be controlled, where they can be placed, and so on. This is especially critical in order to realize the most advanced control strategies, and those that extend beyond lighting. Most wired systems, for example, were not designed to connect to plug load controllers or environmental sensors, so there is physically no way to add that capability. Wireless systems can connect to such devices easily, as long as they speak the same language.

Open: As noted above, communications is a requirement of any controls system – the system must be able to receive data from devices and issue commands to fixtures. But what "language" is used for these control messages? It can take many forms, though most frequently the communications language is proprietary, and created by the manufacturer of the controls system. For example, a controls manufacturer could create a sensor, a ballast and a control panel, and write the language they use to communicate with each other. If a customer tried to use another vendor's sensor with that panel, they would not be able to understand each other and would be unlikely to work together.

Proprietary systems have limited the growth of new and innovative control strategies, because each vendor essentially starts from scratch in developing their own system, and has the added overhead of upkeep on their proprietary communications protocol. This is changing with the introduction of "open" systems to the lighting controls market, based on well-accepted industry standards. In an open system, a manufacturer chooses an existing communications language, and their products can communicate directly with other manufacturers' products.

There are many positive results of open systems – choice, trust, lower cost – but perhaps the most important is their impact on innovation. Unlike proprietary systems, a standards-based control system can use any standards-compliant device. When multiple companies develop products based on the same open industry standard, customers can take advantage of all their combined innovations. This is how lighting controls systems have begun to take advantage of energy savings beyond lighting (for example, connecting to environmental sensors or wireless thermostats) and will define the future of how new integrated energy strategies will be developed.

Common Lighting Controls Strategies	
Dimming: Enable fixtures to dim, for use in other strategies below	Variable
Occupancy Sensing: Adjust lights based on occupancy detection	Up to 40%
Scheduling: Dim and turn off lights according to a pre-set schedule	Up to 40%
Advanced Lighting Controls Strategies	
Daylight Harvesting: Adjust electric light levels to take natural light into account, using photosensors	Up to 20%
Task Tuning: Reduce maximum light levels based on requirements for each space	Up to 20%
Demand Response: Reduce light levels at peak times based on automated signals from electric utilities	Variable
Personal Control: Enable individuals to set light levels to suit personal preferences	Up to 10%
Energy Management: Software for ongoing improvement in controls settings and strategies	Variable
Combined Lighting Energy Cost Savings	**Up to 70% of Lighting Energy Costs**

Additional Lighting-Related Strategies	
Automated Maintenance: Monitor lamp & ballast life to reduce ongoing maintenance costs	Up to 10% of total lighting costs
BMS Integration: Integrate lighting with a BMS for simplified building management	Variable
Additional Strategies Beyond Lighting	
Plug Load Control: Manage and schedule additional plugged-in devices through the controls network	Up to 20% of plug load energy costs
Environmental Monitoring: Measure and manage environmental data through the controls network	Variable
Wireless Thermostats: Control wireless thermostat usage through the controls network	Variable
Other Independent Controls: Add & control other uncontrolled load through the controls network	Variable

Conclusion

Today's lighting controls systems provide a more comprehensive solution with greater savings potential than ever before. The key to taking advantage of this potential is to go beyond the basic control strategies – using multiple strategies in tandem. We have described 14 strategies being used today, but there are countless emerging strategies waiting to be used and innovations yet to be discovered. Controls systems that are primed to use these new innovations are more likely to last the lifetime of your building, and continue to provide value far into the future.

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