Lighting Control Systems
New Construction & Retrofit

Presenters-

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Lighting Controls Systems:

- Reasons for Controls
- Components and Strategies
- System Design
- New Utility Controls Initiatives
- Case Studies
Reasons for Lighting Controls

The following are user-defined, architectural response and energy reduction purposes for advanced lighting control:

- **Required by Energy Code** - local, state and national energy code require some form of lighting control devices or system

- **Energy Savings** – reducing overall energy use and grid demand

- **Visual Comfort** – intuitive and easy to manipulate controls increase user flexibility and comfort

- **Load Shedding** – the capability to give load back. Shedding entails a reduction in non-critical power loads across a building including reduced lighting power consumption.
  - *Demand Response* is an automated or manual response to a utility request to reduce load at critical times.
Purpose and Goals

Successful Lighting Control Systems:

• Satisfies the design intent
• Meets user’s operational and visual needs
• Minimizing energy consumption
• Provides the appropriate amount of light where and when it is needed

Visual Comfort
Can respond to changes based on lighting task requirements as well as daylight contribution, and personal preferences.

Energy Consumption

\[ \text{ENERGY (kWh)} = \text{POWER (W or kW)} \times \text{TIME (hours)} \]

• Demand (Power) - is reduced when lighting is dimmed or shut OFF
• Energy Savings - is a reduction of power over time
### Barriers

- Initial cost
- Overly complex (not fully utilized)
- Lack of training for installers
- Lack of certification for specifiers and installers
- Lack of education for facility managers
- Lack of commissioning
Lighting has the largest estimated technical potential for energy savings of any U.S. building end-use. A significant fraction of that potential is believed to lie in lighting system controls.

### Current Controls Saturation (NCI 2012)

- Timer
- EMS
- Motion Detector
- Light Sensor
- Dimmer
- None

0% 20% 40% 60% 80%
## Savings by Strategy – Meta Study 2012

<table>
<thead>
<tr>
<th>Definition</th>
<th>Examples</th>
<th>Average Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Occupancy</strong></td>
<td>Lighting status changes automatically based on presence of people</td>
<td>24%</td>
</tr>
<tr>
<td></td>
<td>Occupancy sensors, timeclocks, energy management system</td>
<td></td>
</tr>
<tr>
<td><strong>Personal Tuning</strong></td>
<td>Occupant control of light levels</td>
<td>31%</td>
</tr>
<tr>
<td></td>
<td>Dimmers, wireless switches, workstation-specific control, preset scene control</td>
<td></td>
</tr>
<tr>
<td><strong>Daylight Harvesting</strong></td>
<td>Lighting status changes automatically based on daylight levels</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>Photosensors</td>
<td></td>
</tr>
<tr>
<td><strong>Institutional Tuning</strong></td>
<td>Light levels tuned to space needs by application, ballast tuning (reduction of ballast factor), task tuning, lumen maintenance, group controls</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>Dimmable ballasts, and dimmers and switches used to control group lighting</td>
<td></td>
</tr>
<tr>
<td><strong>Multiple Strategies</strong></td>
<td>Any combination of the above</td>
<td>38%</td>
</tr>
</tbody>
</table>
Lighting Controls Mandated By Code

IECC 2012 contain mandatory lighting provisions for the following:

- Indoor automatic lighting shutoff
- Light reduction controls - must allow the occupants to select a lighting level that is 30% and 70% of full power (Step or Dimming)
- Occupancy sensor or timer switch controls – within a open or closed space
- Time Switch Controls
- Daylight control zones - with daylight sensors
- Display/Accent lighting control
- Outdoor lighting control
- Separate Task lighting control
Components, Systems & Strategies

- **Lighting Control Components:**
  Occupancy sensors, daylight sensors, that control a fixture or a lighting circuit.

- **Localized Lighting Controls:**
  Space confined network of sensors and lighting to a local relay controlled by a keypad.

- **Intelligent Lighting:**
  Lighting fixtures with integral sensors that are networkable, addressable and programmable.

- **Networked Lighting Controls:**
  Programmable, addressable, lighting, sensors and controls that is controlled and networked to a central server.

- **Integrated Lighting Controls:**
  Network lighting controls system that is integrated with the whole building automation system.
Control Zones

A Control Zone is a logical grouping of luminaires that are controlled together.

- May be the same grouping as the power circuit
- May be independent from the power circuit
- Zoning should be for “like type” luminaires in continuous areas.
- Consider Daylight areas when choosing control zones
- Generally, the more control zones, the more flexible the system will be

Poor Zoning is one of the most common mistakes in lighting control design
Multiple Control Networking Methods

- **Powerline carrier**
  - Digital modulation of AC power
  - Coincident AC power and control signal

- **Wireless**
  - Digital open spectrum communication
  - Separate AC power and control signal

- **Centralized power supply or LED driver**
  - Low-voltage (CV or CC) wiring to LED source
  - Coincident or separate AC power and control signal
Localized Controls System

1. Stand-alone, self-contained lighting controls system.
2. Large Room /Space or Area control
3. Requires multiple sensors, dimming, scheduling and relays
4. Can be digitally programmed

Source: Redwood Systems Controls
Networked (Global) Controls System

1. Multi-Room /Space or Area control
2. Networked sensors, dimming modules, and digital relays
3. Networked to building wide lighting controls server.
4. Can be digitally programmed.
5. Graphical interface showing devices and power consumption
1. Flexibility. Wireless control devices can be placed where they are needed without limitation imposed by wiring.
2. Labor savings due to reduced wiring and conduit.
3. Scalable to fit various spaces
4. Some devices are self-powered, further simplifying installation

Wireless protocols for systems include:
- Z-wave
- Zigbee
- Enocean
- Miro
- Aurora
- Synapse

Courtesy of Leviton & Enocean
Six Control Strategies

64% average energy savings attaining through six strategies, synergies and deep commissioning

Source: Osram Sylvania – Enselium Controls
Smart Time Scheduling

- Can be done as stand alone strategy or part of system
- Light scheduling configurable by floor, department, room, zone or even a light fixture
- Lighting schedules are automatically extended in the event that after hours occupancy is detected via the “virtual occupancy sensor” feature (detects PC activity)
- Office occupancy can override to keep hallways lit at night
- Easy to use drag & drop calendar
- Built on Microsoft Outlook platform
Occupancy Control

- Can be done as stand alone strategy or as part of a system
- Lights are automatically turned on or off based on occupancy detection (independent of electrical circuiting)
- Association of sensors to fixtures via software
  - Allows for overlapping and support zones
  - Reconfigure without rewiring
- Occupancy signal can switch or dim lights – bi-level for stairs and corridors
- Share real time occupancy data with HVAC systems
- Can program profiles based on time and space use
Daylight Harvesting

- Can be done as stand alone strategy or part of system
- Lighting levels are automatically adjusted to take into account ambient natural sunlight through windows or skylights
- Level of daylight harvesting varies based on proximity of fixture to window
- Association of sensors to fixtures via software
- Reconfigure without rewiring.
- Adjust aggressiveness with software
- Create building orientation based profiles for different daylight responses
Personal Control

- Can be done as stand alone strategy or part of system
- Occupants can control light levels in their workspace from their PC, create personal presets for reading, computer work, meetings, etc.
- Each light fixture can be dimmed or turned off individually allowing users ultimate flexibility in setting preferred light levels
- PC is used as secondary form of occupancy sensor
- Significant contributor to energy savings as most users dim lights below default light levels
Scene Based Keypads

- Programmable keypad
- Multiple scenes per zone,
- ON/OFF functionality and manual dimming
Personal Control Software

- Workstation based personal control
- Allows dimming, on/off control and pre-set scene selection
- Can be configured as PC based software application or via web browser interface
Task Tuning

- Requires dimming & advanced control system
- Set light levels to suit the area or task to the “new 100%”
- Light levels are “tuned” by individual fixture throughout a facility (through dimming or addressable switching) to meet required light levels
Variable Load Shedding

- Requires dimming AND advanced control system
- Reduces peak demand charges
- System automatically executes load shedding to reduce demand peaks or to meet specific demand response goals
- Lights are dimmed selectively by lowest priority areas first
- Sheds load in a manner that is transparent to occupants (i.e., configurable fade rate)
- Responds to a demand meter, a utility demand response (DR) signal, or a signal from building or energy management systems
Demand Response

**Peak Demand** is the period of time when energy demands are the highest. Because it is the most expensive power to produce, the high costs are often passed along to customers.

Utilities have created several incentives to reduce peak demand, including:

- Time-of-day rate scheduling that increases utility rates as demand increases to peak
- Providing financial incentives for customers to upgrade their energy efficiency
Poll Question: 1

"And the dim fluorescent lighting is meant to emphasize the general absence of hope."
Typical Sequence of Controls

1. Scheduling
2. Occupancy
3. Task Tuning
4. Daylight Harvesting
5. Personal Control
6. Demand Response
No Controls Installed

Lighting Electricity Usage

100% to 0% at different times of the day:
- 12am: 100%
- 6am: 100%
- Noon: 100%
- 6pm: 100%
- 12am: 100%
Implement Basic Scheduling

Basic Scheduling

Lighting Electricity Usage

12am 6am Noon 6pm 12am
Implement Smart Scheduling

Lighting Electricity Usage

12am 6am Noon 6pm 12am

100% 0%
Implement Occupancy Controls

Lighting Electricity Usage

- Basic Scheduling
- Smart Scheduling
- Occupancy

12am 6am Noon 6pm 12am
Implement Task Tuning

Lighting Electricity Usage

12am 6am Noon 6pm 12am

100% 0%
Implement Daylight Harvesting

Lighting Electricity Usage

100%

0%

12am  6am  Noon  6pm  12am

Basic Scheduling  Smart Scheduling  Occupancy  Task Tuning  Daylight Harvesting  Task Tuning  Occupancy  Smart Scheduling  Basic Scheduling
Implement Personal Control

Lighting Electricity Usage

- Basic Scheduling
- Smart Scheduling
- Occupancy
- Task Tuning
- Daylight Harvesting
- Pers. Ctl

12am 6am Noon 6pm 12am
Implement Personal Control

100% 0%

12am 6am Noon 6pm 12am

Lighting Electricity Usage

Basic Scheduling Smart Scheduling Occupancy Task Tuning Daylight Harvesting Pers. Ctl Remaining Energy Use

Basic Scheduling Smart Scheduling Occupancy Task Tuning Daylight Harvesting Pers. Ctl Remaining Energy Use

Lighting Electricity Usage

12am 6am Noon 6pm 12am
Integrated Controls Yield >50% savings

Source: Osram Sylvania – Enselium Controls
Commissioning involves ensuring that a system operates according to the specified design intent.

Calibration entails tuning the settings of sensors, such as occupancy sensors and photosensors, so that they operate properly within actual field conditions.

The process involves:
- A written sequence of operation
- Specification of design **illuminance levels**
- System **activation** and verification
- Field **calibration** of sensors (at representative times throughout the day)
- Field **verification** and performance testing
- Controls and schedule **programming**
- Owner **notification** of the system's operation and intent
Lighting Commissioning Saves Energy

Avg. 23% Additional Savings
Poll Question: 2

"Maybe we should have listened when he complained about the fluorescent lighting."
Utility – Lighting Controls Rebates

“rebates and other incentives covering lighting controls are available in 47 out of the 50 states. The most popular control rebate is for occupancy sensors”…
-Leendert Jan Enthoven, president of BriteSwitch
Control Strategies Beyond Code

- Multi-scene programmable dimming
- Multi-scene programmable time scheduling
- Multi-scene programmable occupancy sensors
- Task or direct lighting programmable dimming control with occupancy sensor – separate from the ambient light
- Automatic continuous daylight dimming control of primary perimeter lighting when effective aperture is 0.15 and area is less than 250 ft²
- Automatic continuous daylight dimming control of secondary perimeter lighting when effective aperture is 0.30
- Automatic continuous daylight dimming control under skylights when the area is greater than 900 ft² and the effective aperture is greater than 0.01
Space/Room based control solutions incorporating multiple sensors and programmed energy savings strategies without the need for a server.

- Large spaces - minimum 2,500 SF
- Multi-functional spaces
- Addressable & Dimmable Ballast
- Addressable & Dimmable Drivers
- Addressable Photocell
- Low voltage power supply
- Programmable Relay/Contactors
- Wall mount Controller
Project Incentives

- Qualifying projects will receive an incentive of $0.50 per sq/ft.
- Project incentives are subject to Custom Application guidelines:
  - Up to a maximum of $200,000 per project
- 80% initial payment, 20% after commissioning (3 months)

Project Qualifications

- >20,000 sq/ft or greater
- Pre-Qualified Lighting Control Systems required.
- Projects must achieve 40% kWh savings below energy code (ComCheck)
- Requires the involvement of qualified lighting professional
  - Lighting Certified LC or IALD Specifiers to participate
Challenges of Dimming LED’s

LED drivers and dimming controls systems incompatibility can result in:

- Flicker
- Non-dim or Drop-out (dims only to 60%)
- Pop-on (reverts to 100% on instead of dim on)
- Poor Power Quality
- Perceptible buzz or hum

Dimming controls designed for LED sources

- Forward or Reverse Phase
- Dimmer load requirements
LED Driver & Dimmer Compatibility
NEMA SSL-7 2013 (An Upcoming Standard)


- The reliability of the dimmer and LLE are not affected by combining them.
- Dimming behavior meets or exceeds the behavior specified in the standard.
- Defines design specification for SSL lamps/fixtures and phase-cut controls
- Defines compliance test procedures for SSL lamps/fixtures and phase-cut controls
Poll Question: 3
ENCELLIUM® Energy Management System

Overview

- **Supplier agnostic control system**, compatible with third-party ballasts and sensors
- Can integrate to non-dimming, 0-10V dimming ballasts/LED drivers, or DALI-based systems
- Accommodates upgrades to new, more efficient lighting technologies (LED)
- **Software-based** in hardware-centric industry
- 360°, 3-D building navigation with multi-floor views
- Graphically display lighting energy savings in formats ranging from kWh to dollars
- Retrofit or new construction projects ≥ 10,000ft²
Baseline vs. New Lighting System

In this view the baseline lighting system and actual new system wattages are entered for future reporting and analysis.
ENCELIUM® EMS
ENCELIUM Polaris 3D® Software

Advanced Energy Reports you can easily understand

Easy to understand charts/graphs
Reports down to a fixture!

Report by strategy to show:
• Energy Savings
• Tons of carbon reduction
• Monetary savings
• Report whole building or per fixture
Eastern Connecticut State Univ.
J. Eugene Smith Library

Strategies Used

- Integrated lighting with library HVAC system to turn both ON/OFF based on occupancy detection and time scheduling
- Networked photo sensors dim electric light based on natural daylight
- Set maximum light levels to eliminate over-lighting
Results

- Estimated annual energy cost savings of $114,000
- Estimated annual 607,500 kWh savings equivalent of approximately 856,575 lbs of carbon dioxide emissions averted annually

Potential Incentive $65,224.50
Goshow Architects

Strategies Used

- Set time schedules based on office hours while networked occupancy sensors turn lights ON/OFF or dim based on occupancy
- Employees recall pre-set lighting scenes in their immediate workspace from their computer with the ENCELUM Personal Control Software
- Set maximum light levels to eliminate over-lighting
Results

- Estimated annual energy cost savings of $5,650
- Estimated annual energy savings: 27,880 kWh
- Approximately 39,493 lbs of carbon dioxide emissions averted annually
Toronto General Hospital

Strategies Used

- Set time schedules based on circadian rhythms while maintaining light at IES recommended light levels
- Employees recall pre-set lighting scenes in their immediate workspace from their computer with the ENCELUM Personal Control Software
- Networked photo sensors dim electric light based on natural daylight
Toronto General Hospital

Results

- Annual energy cost reduction of $47,000 or $4.50/sq. m.
- Estimated 588,000 kWh annual savings
- Approximately 832,923 lbs of carbon dioxide emissions averted annually

Potential Incentive

$47,500.00
## Six Energy Management Strategies Savings

<table>
<thead>
<tr>
<th>Energy Management Strategies</th>
<th>Lighting energy savings due to Addressable Lighting Controls</th>
<th>Average Savings by Strategy *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multi-Tenant office bldg 300K ft(^2)</td>
<td>HQ of Fortune 100 firm 400K ft(^2)</td>
</tr>
<tr>
<td>Smart Time scheduling</td>
<td>13.91%</td>
<td>8.91%</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>0.60%</td>
<td>3.96%</td>
</tr>
<tr>
<td>Task Tuning</td>
<td>9.0%</td>
<td>10.95%</td>
</tr>
<tr>
<td>Occupancy Control</td>
<td>31.3%</td>
<td>24.94%</td>
</tr>
<tr>
<td>Personal Control</td>
<td>6.12%</td>
<td>10.64%</td>
</tr>
<tr>
<td>Variable Load Control</td>
<td>0.03%</td>
<td>4.65%</td>
</tr>
<tr>
<td>Cumulative Savings due to Addressable Lighting Controls</td>
<td><strong>60.96%</strong></td>
<td><strong>64.05%</strong></td>
</tr>
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**Energy Consumption**

\[
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\]

- **Demand (Power)** - is reduced when lighting is **dimmed** or shut **OFF**
- **Energy Savings** - is a reduction of power over time
Thank you

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Poll Question: Final

CATBERT: EVIL DIRECTOR OF HUMAN RESOURCES

I'VE WORKED IN A WINDOWLESS CUBE FOR 25 YEARS. CAN I MOVE TO THE VACANT CUBE BY THE WINDOW?

SURE.

GAAA!!! IT BURNS!

TOO FAST.
Resources

- Lighting Controls Association
  http://lightingcontrolsassociation.org/

- Advance Lighting Guidelines (ALG)

- Lighting Research Center
  http://www.lrc.rpi.edu/researchAreas/controls.asp

- Daylighting Pattern Guide
  http://patternguide.advancedbuildings.net/
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