Efficiency Forward, Inc./DesignLights Consortium
Final Technical Report to the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office

Project Title: Commercial Advanced Lighting Control (ALC) Demonstration and Deployment

U.S. DOE Award Number: DE-EE0006742

Principal Investigator: Gabe Arnold, Technical Director, DesignLights Consortium

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Final Technical Report (FTR) for DOE/EERE

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Recipient: Efficiency Forward (formerly NEEP)

10 High Street

Medford, MA 02155

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Working Partners: Burlington Electric Department, Cape Light Compact, National Grid of Massachusetts, National Grid of Rhode Island, Eversource-Connecticut (formerly Connecticut Light & Power), Efficiency Vermont, Eversource-Massachusetts (formerly NSTAR), New York State Energy Research & Development Authority, PSEG-Long Island, United Illuminating, Northwest Energy Efficiency Alliance

Cost-Sharing Partners: None

PI: Gabe Arnold
Technical Director
Phone: 781-860-9177, ext. 161
Fax: 781-860-9178
Email: garnold@designlights.org

Submitted by: Laura De Angelo
Grants & Contracts Manager
Phone: 781-860-9177, ext. 124
Fax: 781-860-9178
Email: ldeangelo@neep.org

DOE Project Team: Technical Closeout Coordinator – Jonathan Hartman
240-562-1353, Jonathan.Hartman@ee.doe.gov

DOE Project Officer – Charles Llenza
202-586-2192, Charles.Llenza@ee.doe.gov

Project Engineer/Monitor – Andrew Kobusch
720-356-1402, Andrew.Kobusch@ee.doe.gov

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Executive Summary:

This three-year demonstration and deployment project sought to address market barriers to accelerating the adoption of Advanced Lighting Controls (ALCs), an underutilized technology with low market penetration. ALCs are defined as networked, addressable lighting control systems that utilize software or intelligent controllers to combine multiple energy-saving lighting control strategies in a single space (e.g., smart-time scheduling, daylight harvesting, task tuning, occupancy control, personal control, variable load-shedding, and plug-load control). The networked intelligent aspect of these systems allows applicable lighting control strategies to be combined in a single space, layered over one another, maximizing overall energy-savings.

The project included five real building demonstrations of ALCs across the Northeast US region. The demonstrations provided valuable data and experience to support deployment tasks that are necessary to overcome market barriers. These deployment tasks included development of training resources for building designers, installers, and trades, as well as development of new energy efficiency rebates for the technology from Efficiency Forward's utility partners. Educating designers, installers, and trades on ALCs is a critical task for reducing the cost of the technology that is currently inflated due to perceived complexity and unfamiliarity with how to design and install the systems. Further, utility and non-utility energy efficiency programs continue to relegate the technology to custom or ill-suited prescriptive program designs that do not effectively deploy the technology at scale. This project developed new, scalable rebate approaches for the technology. Efficiency Forward utilized their DesignLights Consortium® (DLC) brand and network of 81 DLC member utilities to develop and deploy the results of the project.

The outputs of the project have included five published case studies, a six-hour ALC technology training curriculum that has already been deployed in five US states, and new rebates offered for the technology that have been deployed by a dozen utilities across the US.

Widespread adoption of ALC technology in commercial buildings would provide tremendous benefits. The current market penetration of ALC systems is estimated at <0.1% in commercial buildings[1]. If ALC systems were installed in all commercial buildings, approximately 1,051 TBtu of energy could be saved. This would translate into customer cost savings of approximately $10.7 billion annually[2].

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[1] Adoption of Light-Emitting Diodes in Common Lighting Applications, US Department of Energy, July 2017, https://energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf

[2] DOE CBI Fact Book, Advanced Lighting Controls, 2017

Accomplishments Toward Project Objectives:

- **Objective 1: Overcome market barriers that limit market adoption of Advanced Lighting Controls (ALCs)**
  - The project addressed the following market barriers:
    - Complexity, Awareness, Knowledge, and Experience – The complexity of ALCs, both perceived and real, limits market adoption. This barrier spans from how to design/specify, how to install, how to commission, and how to operate once installed. Many lighting designers and building managers are unfamiliar with the types of ALCs now available.
      - The ALC educational curriculum developed and deployed as part of this project is specifically focused on increasing awareness and knowledge of new ALC systems that reduce cost and complexity. Evaluations for the course, including how well it addressed this barrier, have been outstanding and are included as attachments to this report.
    - Uncertain Savings and Benefits – The lack of data on ALC energy savings or other benefits also limits market uptake. The issue persists without demonstrated evidence or experience that ALCs work reliably and provide cost-effective energy savings.
      - The five ALC demonstration projects and associated case studies developed and deployed as part of this project demonstrate cost-effective energy savings and system performance.
    - Lack of Effective Energy Efficiency Program Designs – Conventional energy efficiency program designs (i.e., prescriptive or customized incentives or rebates per widget, performance above code) are ill-suited to the systems impacts of ALC adoption and use.
      - As part of this project, Efficiency Forward engaged with a working group of utilities to develop new rebate and incentive approaches for the technology. These approaches are currently deployed by ~12 utilities with a growing number being added in 2018. The framework for the approaches are included as attachments to this report.
    - High Costs – The perceived and real high cost of ALCs – including product, installation, and commissioning costs – limits market uptake. However, when the benefits of ALC systems are fully realized, including reduced wiring, ALC systems should cost no more than stand-alone controls and less than conventional low-voltage panel-based controls, yet these benefits are not realized in lighting system pricing due to the other barriers listed above.
      - The ALC educational curriculum developed and deployed as part of this project is specifically focused on increasing

awareness and knowledge of new ALC systems that reduce cost and complexity of installation. Evaluations for the course, including how well it accomplished this objective, have been excellent with average scores above 4 out of 5.

- **Objective 2: Identify and address market barriers that limit owner adoption of ALCs**
    - The project accomplishments towards this objective of addressing market barriers are the same as listed above with Objective 1.
- **Objective 3: Provide real building installation, performance, maintenance and cost data, to improve the use of ALCs by professionals that design, specify, install, commission and operate ALCs**
    - The project produced five case studies that include installation, performance, and cost data. These case studies are deployed nationally by Efficiency Forward via their DLC brand and by DLC utility partners to their customers and trade allies that design, specify, install, commission, and operate ALCs.
- **Objective 4: Reduce the total installed cost of ALCs**
    - The ALC educational curriculum developed and deployed as part of this project is specifically focused on increasing awareness and knowledge of new ALC systems that reduce cost and complexity of installation. Evaluations for the course, including how well it accomplished this objective, have been excellent and are included as attachments to this report.
- **Objective 5: Improve understanding of the benefits of ALCs**
    - The five ALC demonstration projects installed as part of this project demonstrate cost-effective energy savings and system performance. In some cases, the projects provided benefits beyond energy savings including improved lighting quality and maintenance savings as identified in the attached case studies.
- **Objective 6: Develop and deploy case studies to be used in utility and energy efficiency program marketing and outreach activities**
    - The five case studies have been posted to Efficiency Forward’s DLC website and made available for deployment to Efficiency Forward’s 81 DLC Member utilities.
- **Objective 7: Develop and implement a national training program for designers and installers of ALCs**
    - The educational curriculum has already been deployed in five states through Efficiency Forward’s DLC member utilities with trainings in more states under development. Efficiency Forward will continue to offer and deploy this high value, in-person curriculum across the US in 2018.

While not under the scope of this project with DOE, DLC is currently translating this curriculum to an online format that will improve its scalability to reach more participants. This will be deployed in late 2018.

- **Objective 8: Develop and deploy of replicable, system-based utility and energy efficiency program offerings for the ALC technology that can be adopted nationally**
  - As part of this project, Efficiency Forward worked with a working group of utilities to develop new rebate and incentive approaches for the technology. These approaches are currently deployed by ~12 utilities with a growing number being added in 2018. The framework for these approaches is included as an attachment to this report.

Project Activities:

The Project included three primary activities: 1) ALC Demonstration Projects; 2) Development and Deployment of an ALC Educational Curriculum; and 3) Development and Deployment of New ALC Utility Incentive/Rebate Approaches. A summary of each through the duration of the project is provided below.

ALC Demonstration Projects (Tasks 4.0, 8.0, 12.0)

One of the major activities of the project was to find and implement ten demonstration projects utilizing new and promising ALC technology. Each of these demonstration projects was pre- and post-metered and analyzed to assess energy savings, ease of installation and use, and occupant acceptance. A Case Study was produced for each project to deploy results that would serve a dual role of providing valuable data on technology energy savings/benefits, while also providing outreach and marketing tools that could be used by utility energy efficiency programs in encouraging more customers to use the technology.

The demonstration projects activity began by first selecting the specific ALC technologies to be demonstrated. Efficiency Forward utilized an RFQ process with manufacturers to identify the technologies to demonstrate. An RFQ was issued that identified the types of technologies Efficiency Forward was looking to demonstrate and scoring criteria that would be used for selection. Efficiency Forward organized a selection committee of subject matter experts from utilities, national laboratories, and consultants across the US. Each committee member scored the manufacturer RFQ proposals against a set of criteria that assessed how well the technology overcame technology adoption barriers. For example, one criteria involved scoring each RFQ proposal against how well the technology reduced the complexity (and associated cost) of installation. This process worked well, and the output was a ranked list of technologies to demonstrate with the highest ranked technologies being the ones that best addressed market adoption barriers.

The next step was identifying the types of buildings in which to demonstrate the selected technologies. Efficiency Forward analyzed market data to determine: 1) the current market penetration of ALCs by building type; and 2) the types of buildings/facilities with the greatest savings potential. The results of this exercise were compared against the intended building types for each of the selected technologies as some technologies were designed more for industrial applications while others were designed for office. With this information, Efficiency Forward was able to develop Site Selection Criteria for each selected technology that would maximize the potential value of the demonstration. Demonstrations were targeted to building types that provided the greatest opportunity for large-scale savings.

Efficiency Forward then worked with utility partners to identify customers that met the site selection criteria and would be willing to host a demonstration. This was separated into two rounds – first to find sites for the first five projects, and then find sites for the second five projects. The results of this activity were mixed. Some utilities were successful at finding potential sites quickly, while others were not. A further challenge was that once sites were selected, not all followed through with installing the project. Overall, it was helpful to work with utilities in finding potential sites as they have close relationships with many customers.

Once potential sites were selected, Efficiency Forward worked with each potential site host to understand their financial and contracting constraints, before assembling a team to design and propose a project using the selected technology. Each project was to be paid for through a combination of the DOE grant funding, utility rebate/incentives, and a host site customer contribution that was targeted to be 10-30% of the project cost. Once a full proposal was developed including the full project economics and host site contribution, the host site customer was required to make a decision of whether to move forward. The results were mixed in this process with five projects choosing to move forward after the proposal stage, but four deciding not to. A fifth project was dropped after the selected technology manufacturer decided not to participate. There were a variety of reasons potential host site customers decided not to move forward after the proposal. These included:

- The project economics were not good enough or required too much capital.
- The VP of Finance for the host site decided the project needed to go through the capital planning process which would take the project beyond the timelines of the DOE grant.
- The host site customer changed their plans for the building and decided not to invest in a lighting retrofit project because the facility may be gutted or replaced in the next few years.

While Efficiency Forward undertook additional recruitment efforts for more sites after potential hosts decided not to move forward, in the end five demonstration projects moved forward, not the original ten that had been targeted.

The installations at all five sites went well. Pacific Northwest National Laboratory (PNNL) coordinated all pre- and post-metering and site evaluations. Two of the five sites experienced problems several weeks after the installation, but these were eventually traced to manufacturer defects and were resolved with replaced equipment. While the energy savings varied, each project produced significant energy savings. Case Studies were developed for each project and are included as an attachment to this report. While fewer demonstrations were accomplished than originally hoped, the overall demonstration project activity was a success and the Case Studies are a valuable new resource to accelerate the adoption of the technology.

Development and Deployment of an ALC Educational Curriculum (Tasks 3.0, 7.0, 11.0)

A second major project activity involved the development of an educational curriculum for building designers and installers on ALC technology. Educating designers, installers, and trades on ALCs is a critical task for reducing the cost of the technology that is currently inflated due to perceived complexity and unfamiliarity with how to design and install the systems.

To begin this activity, Efficiency Forward formed working groups of manufacturers and utilities to inform the development and deployment of the curriculum. Efficiency Forward had several meetings with the working groups to vet curriculum outlines and deployment models. The input from these working groups was ultimately incorporated into a Training Framework document and then a Training Implementation Plan that was submitted to DOE for review and approval. Once this was approved, DLC recruited a lighting education subject matter expert and worked together to develop and deploy the curriculum.

The course was first piloted in Boise, Id. with Efficiency Forward partners Idaho Power and the Northwest Energy Efficiency Alliance. Each attendee was asked to complete a detailed evaluation on various factors including how well the course met objectives, the relevance or value to their work, and – perhaps most importantly – how likely they were to use ALC technology on future projects. The results of this evaluation were excellent. In almost every category, participants ranked the course near a 4.5 out of 5. Efficiency Forward made some refinements to the course based on the feedback, but overall the course was a great success in fulfilling the intended objectives.

Next, Efficiency Forward began formally offering the course to additional utility partners. Courses were hosted in San Francisco, Ca. with partner Pacific Gas & Electric, at three locations in Michigan with partners NextEnergy, Consumers Energy, and DTE Energy, and in Massachusetts with partners National Grid and Eversource Energy. Additional courses with more utility partners are currently under development.

In developing and offering these courses, Efficiency Forward evaluated different methods to deploy the course and the financial requirements to support them. While the in-person format of the course is high value and has received excellent scores from all attendees and partners, it is difficult and costly to scale. Efficiency Forward will continue to offer the in-person model, but the best way to achieve scale and reach more participants more cost-effectively is in an online format. While outside of the scope of work with DOE, DLC is currently working to transfer the course content into an online format and will offer that through Efficiency Forward's DLC utility partners later in 2018 as a mechanism to reach more participants cost-effectively.

Overall, the course curriculum that was developed and deployed under this grant has been a great success and will be a valuable resource to accelerate the technology adoption for years to come. The course and associated evaluations from participants are included as attachments to this report.

Development and Deployment of New ALC Utility Incentive/Rebate Approaches (Tasks 1.0, 2.0, 5.0, 6.0, 9.0, 10.0)

The third major activity of the project was to develop new, more effective and scalable utility program rebate and incentive approaches for ALC technology. Historically, utility energy efficiency programs have relegated the technology to custom or ill-suited prescriptive program designs that do not effectively support the technology in a scalable way. This project sought to develop new, scalable rebate approaches that would encourage large volumes of customers to participate and use the technology.

To develop these new approaches, Efficiency Forward organized a working group of subject matter experts within Efficiency Forward's DLC utility membership. The working group held several meetings over the course of several months to evaluate different approaches. The output from this effort was a proposed framework for providing rebates/incentives for ALC technology that would support both comprehensiveness and scale. The framework is included as an attachment to this report.

Following the development of the framework, Efficiency Forward began working with several of their DLC utility member partners to deploy it. Efficiency Forward obtained commitments from six utilities to pilot the approach beginning in 2016.

Since that time, several more utilities have launched approaches built upon the original framework. Efficiency Forward and their utility partners continue to learn more about what is working and what is not and new flavors of the recommended framework are being tested. The DOE funding of this original work to develop a framework for ALC rebate/incentive approaches has spurred and accelerated efforts by utilities to develop better approaches to supporting ALC technology.

Products and Technology Transfer:

- **Publications *(Attached)***
  - Case Study: Advanced Lighting Fact Sheet – Cree Smartcast
  - Case Study: Advanced Lighting Fact Sheet – GE Daintree Controlscope
  - Case Study: Advanced Lighting Fact Sheet – Digital Lumens
  - Case Study: Advanced Lighting Fact Sheet – Philips Spacewise
  - Case Study: Advanced Lighting Fact Sheet – Enlighted

- **Website or Other Internet Sites That Reflect the Results of This Project**
  - https://www.designlights.org/lighting-controls/case-studies/
  - https://www.designlights.org/lighting-controls/training-programs/
  - https://www.designlights.org/lighting-controls/reports-tools-resources/

- **Networks or Collaborations Fostered**
  - DLC Utility Members: https://www.designlights.org/about-us/our-members/
  - DLC Training Working Group Members:
    - Acuity Brands Lighting
    - Cree
    - GE Daintree
    - Digital Lumens
    - Eaton
    - Sylvania
    - Enlighted
    - Hubbell
    - Lutron
    - Wattstopper
    - RAB Lighting
    - Efficiency Vermont
    - New York State Energy Research and Development Authority
    - CLEAResult
    - Seattle City Light
    - Northwest Energy Efficiency Alliance
    - National Grid
    - Bonneville Power Administration
  - ALC Utility Rebate/Incentive Approach Working Group Members:
    - Efficiency Vermont
    - Eversource Energy
    - National Grid
    - ICF International
    - Baltimore Gas & Electric
    - Consumers Energy
    - DNV/GL
    - Duke Energy
    - Xcel Energy
    - CLEAResult

- **Technologies/Techniques**
    - N/A

- **Inventions/Patent Applications, Licensing Agreements**
    - N/A

- **Other Products**
    - Training
        - Course Curriculum *(Attached)*
    - Rebate/Incentive Approach
        - Framework *(Attached)*
    - Presentations Given
        - Northeast Advanced Lighting Control Summit, October 9, 2014
            - Presented project overview to manufacturers, energy efficiency programs, and other stakeholders to inform stakeholders and collect input.
        - CSA TC419 Committee, October 28, 2014
            - Presented project overview to Canadian Technical Committee on Performance of Lighting Products to inform industry standards needed to support the project.
        - AESP-NEEC Conference, November 13, 2014
            - Presented project overview and used as example in context of importance of working regionally and nationally to influence emerging technologies.
        - CALC Advisory Committee Meeting, November 20, 2014
            - Presented project status, collected input from stakeholders to guide project.
        - West Coast Utility Lighting Team, December 3, 2014
            - Presented project overview to consortium of lighting energy efficiency program sponsors and stakeholders from California, Idaho, Montana, Oregon, and Washington to inform stakeholders, collect input, and invite future participation.
        - ANSI C.137 Committee – Lighting Standards, December 4-5, 2014
            - Provided brief overview of project to inform industry standards needed to support the project.
        - Midwest Lumen Triennial Meeting, January 27, 2015

    - Presented project overview to Midwest utilities and energy efficiency programs.
- Midwest Energy Solutions Conference, January 30, 2015
    - Presented on “Surfing Advanced Lighting Cutting-Edge” panel on future trends in Advanced Lighting Controls including an overview of the project.
        - http://www.mwalliance.org/conference/sites/default/files/pdf/MES-2015_presentations_Arnold.pdf
- Eaton’s Cooper Lighting, March 11, 2015
    - Presented project overview to large group of Product Managers and VPs at Eaton’s Cooper lighting, one of the largest lighting manufacturers.
- DOE Peer Review, April 14, 2015
    - Presented project overview and progress to DOE Peer Review panel and stakeholders.
        - https://energy.gov/eere/buildings/downloads/northeast-energy-efficiency-partnerships-advanced-lighting-controls
- ACEEE Market Transformation Symposium, April 21, 2015
    - Presented on “Optimizing Lighting Control Performance: The New Frontier” panel including a project overview.
        - http://aceee.org/sites/default/files/pdf/conferences/mt/2015/D1-Arnold.pdf
- NEMA Lighting Systems Technical Forum, April 22, 2015
    - Presented project overview to over 60 representatives from lighting manufacturers.
- Lightfair, May 5, 2015
    - Presented lighting control portion of “Rebates Revolutionized: The Future of Lighting Energy Efficiency Programs” panel including a project overview.
- Better Buildings Summit, May 29, 2015
    - Presented a Poster Session on project to DOE Better Buildings stakeholders.
- New England Energy Efficiency Expo, June 23, 2015
    - Presented “A New Future of Lighting Controls” including a project overview.

- NEEP/DLC Advanced Lighting Control Summit, October 27, 2015
  - Presented overview and status update of project to manufacturers and energy efficiency programs, sought input to project plans, and participation in demonstration projects.
- DOE Connected Lighting Workshop and SSL Technology Development Workshop, November 15-17, 2015
  - One presentation at each event to provide overview of project to audience of manufacturers, researchers, lighting designers & specifiers, and energy efficiency programs.
    - https://energy.gov/sites/prod/files/2015/11/f27/arnold_whyevolve_portland2015.pdf
    - https://energy.gov/sites/prod/files/2015/11/f27/arnold_optimization_portland2015.pdf
- Strategies in Light Conference, March 3, 2016
  - Presented project overview to large audience of LED lighting and IOT stakeholders.
- ACEEE Market Transformation Symposium, March 21, 2016
  - Presented a project overview and facilitated a panel "Connected Lighting: Assessing the Present, and Envisioning the Future."
- DOE Peer Review, April 6, 2016
  - Presented project overview and progress to DOE Peer Review panel and stakeholders.
    - http://energy.gov/eere/buildings/downloads/northeast-energy-efficiency-partnerships-advanced-lighting-controls
- Eastern Lighting Peer Exchange, April 1, 2016
  - Presented project overview and progress to audience of utility lighting program managers from Eastern US. Sought participation in project activities.
- DOE Better Buildings Summit, May 10, 2016
  - Participated on panel on Interior Lighting Solutions, presented project overview.
    - https://betterbuildingssolutioncenter.energy.gov/sites/default/files/2016-Looking-Inside-for-Better-Lighting-Solutions-High-Impact-Technologies-TUES.pdf

ATTACHMENTS

DLC Advanced Lighting Technology Demonstration: Cree SmartCast(R)

This demonstration is one in a series of advanced lighting demonstration projects being completed through a joint initiative between the DesignLights™ Consortium (DLC) and the U.S. Department of Energy. Additional co-sponsors for this site included Cree Lighting, Con-Serv Inc., Eversource, and EnergizeCT.

Demonstration Site

The medical office facility located at 44 Dale Road in Avon, Connecticut houses multiple healthcare providers in three-stories of mixed-use space including: offices, examination/procedure rooms, and testing laboratories. Constructed in 1985, this 30,500 square-foot building initially had fluorescent lighting and standard on-off wall switch control. The building owner chose the recently completed LED lighting and controls retrofit to harvest extra savings and to improve lighting quality and controls. The new LED lighting and control system provides wireless communication with advanced sensor options that allow for customization of light levels to meet application and occupant needs.

Demonstration Technology

The Cree SmartCast(R) technology, applied at the luminaire level, incorporates wireless controls which support easy one-for-one replacement. The installed system offers onboard occupancy sensing and daylighting control applied to subgroups of fixtures based on room environments. This grouping and control activation was completed wirelessly using Cree's hand-held remote commissioning device. Final commissioning included activation of occupancy sensing for all fixtures and daylighting control for those next to windows. SmartCast(R) technology allows tenants to change light settings as needed with available remotes. For this study access to lighting controls was limited to building managers and lighting installers but light levels were set to meet tenant preferences.

Project Savings

Pacific Northwest National Laboratory managed the measurement and verification component of the demonstration and the Cadmus Company completed the field measurements. Lighting system energy use was measured before and after the upgrade to capture the energy savings provided by the new LED system. In addition, power measurements of existing and retrofit LED fixtures were taken to confirm total savings without the advanced controls. The resultant analysis shows that replacement of older fluorescents with LEDs alone saved over 29% of the estimated annual lighting energy use at this site. Note that a significant portion of this is attributable to the reduction in light levels, correcting previously overlit areas in the building.

With advanced occupancy sensing and daylighting controls, energy savings increased by an additional 33% for a total of 62% savings from baseline conditions. Estimated total annual savings is 69,000 kWh per year. The corresponding reduction in facility energy cost is approximately $12,351 annually. The project cost for the chosen fixtures totaled $92,469, with payback in 2.4 years after EverSource utility rebates of $37,950 are applied.

Installation and Operation

The medical offices operate on a typical 9 AM to 5 PM, 5 days a week schedule. The new lighting controls consist of integrated occupancy and daylight harvesting sensors onboard each fixture. The commissioning process set base light levels to meet occupant needs, set occupancy shut-off controls to match occupant space use, and set up daylighting control in areas with windows to take advantage of sunlight. Some occupants declined to have daylighting control activated in their space.

MEDICAL FACILITY AT 44 DALE ROAD, AVON, CT

The building owner updated the building lighting for energy savings and improved lighting quality. *Photo courtesy of Google Earth.*

Cree ZR Series Troffer with SmartCast(R) Technology

Photo courtesy of Cree, Inc.

Advanced lighting control systems can incorporate a variety of options. The SmartCast system offers the following:

- Occupancy Sensing
- Daylight Harvesting
- High-End Trim / Task Tuning

Occupant Lighting Satisfaction

AFTER THE LED RETROFIT

A staff survey of 28 occupants found the following:

- **79%** Satisfied with new light levels
- **64%** Overall satisfied with lighting controls
- **86%** Overall Satisfaction with new lighting

ENERGY EFFICIENCY STRATEGY

Total Lighting System Savings*	
New LED Fixtures Only	New LED Fixtures **with** Controls
29%	62%

Potential Controls Savings for Typical Lighting Systems**		
Occupancy Sensor Shutoff	Daylight Harvesting	Light Level / Task Tuning***
34%	12%	(~34%)

* Installation of the more energy efficient (LED) fixtures along with reduced light levels in overlit spaces contributed to 29% of the savings. Remaining savings were due to advanced lighting controls.

**The data also shows, that at this site the advanced controls alone, reduced the lighting energy use of the new LED fixtures by up to 80% (34% + 12% + 34%). Note that 34% of this was due to task tuning to meet occupant light level preferences which will vary at other sites.

***Task tuning was performed twice at this site. The final adjustments were made after the energy metering period and resulted in a 34% reduction in basic lighting energy levels for this site. The light level trim was completed to adjust high initial LED fixture levels.

NOTE: Applications with different installed equipment, layouts, and occupant needs could see higher or lower savings.

Application Determines Savings

In most areas, the technology change from fluorescent to LED fixtures provided the majority of savings. Controls offered additional savings when they were not present before. Control savings can vary widely depending upon the space type, activity, and facility function.

It is important when choosing a lighting system and controls to determine the best fit for a given mix of space types and activities.

Facility Acceptance

Con-Serv Inc., the contractor who installed the new fixtures, found the system easy to install, much like a standard fluorescent fixture. The control system programming was new to the installer; however instructions were sufficient to complete the commissioning process. Commissioning this system took approximately 10 minutes per fixture, which included adjusting to the tenant's preferences. Although making the adjustments to meet tenant needs required time, they were relatively easy to make.

Facility operations staff reported that the SmartCast(R) interface and system was fairly easy to set up and operate using the provided remote control. The system was considered more involved, but easier to control than a standard fluorescent system. Staff noted the light quality of the new system was comparable to the old system.

Lighting System Performance

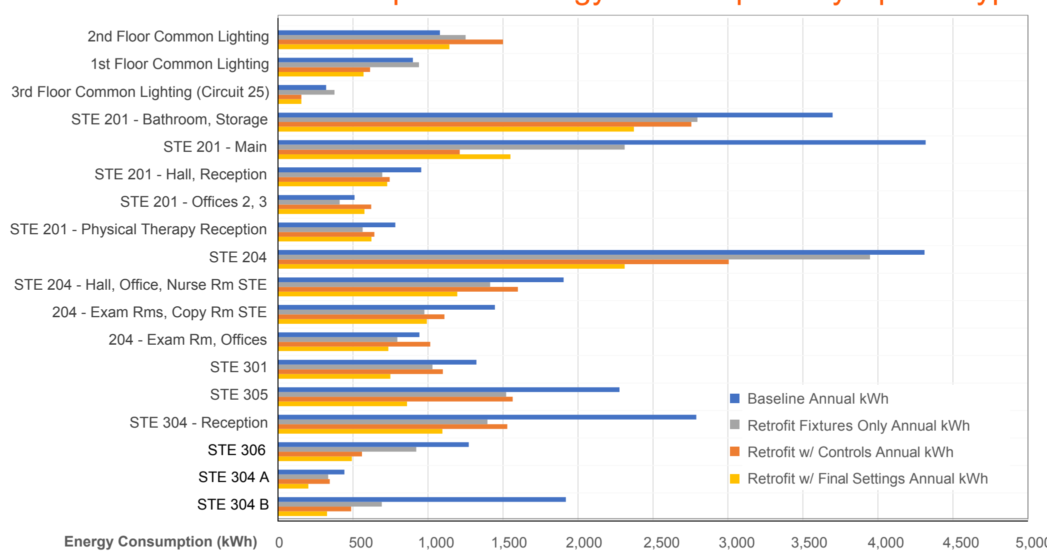
Lighting measurements were taken in selected open hallway areas with lighting layouts that were representative of the majority of the building to compare lighting performance before and after the retrofit.

Location	Before* (fc)	After* (fc)	% Change
Suite 304/ Eye Care	62.7	24.7	-61%
304/303/305/306 Hallway	56.1	14.8	-74%
Suite 204/ Healthcare	49.1	29.4	-40%

*Measurements taken at floor level for consistency, and listed in footcandles (fc).

Light levels before the retrofit were mixed with some higher and some lower than Illuminating Engineering Society (IES) recommendations. The post-retrofit light levels in these areas all generally meet or exceed IES recommendations. This reduction in light levels accounts for a significant portion of the energy savings at this site, which may or may not occur in other site projects.

Annual Extrapolated Energy Consumption by Space Type



Note: These results represent potential savings for one building type with typical space types and activities. Specific space type savings will vary depending on facility type and activities.

This technology demonstration is supported through a partnership of multiple organizations including:

Better Buildings® U.S. DEPARTMENT OF ENERGY
CON-SERV INC YOUR ALL-AMERICAN CONSTRUCTION SOLUTION
CREE
DLC
EVERSOURCE
energize CONNECTICUT
Pacific Northwest NATIONAL LABORATORY Proudly Operated by Battelle Since 1965

DLC Advanced Lighting Technology Demonstration: Daintree ControlScope®

This demonstration is one in a series of advanced lighting demonstration projects being completed through a joint initiative between the Design Lights™ Consortium (DLC) and the U.S. Department of Energy. Additional partners for this site included Opterra Energy Services, GE Current, Eversource, and Stop & Shop New England.

Demonstration Site

The Stop & Shop store in New Bedford, Massachusetts is a 73,000 ft^2 full-service grocery store with offices and a smaller mezzanine area upstairs. Originally, the building had fluorescent lighting and the building owners were interested in the savings potential offered by new LED technology and advanced controls. The task tuning ability was particularly of interest as it ensures quality lighting for the various products, consumers, employees, and tasks in each section.

Demonstration Technology

Current's Daintree ControlScope® Manager (CSM) is a lighting control software solution using Zigbee mesh networking. This networking system can set up fixture groups within the CSM to facilitate localized control. LED luminaires such as the Cooper Corelite™, Cooper Encounter™, and Precision Paragon™ were shipped with pre-installed Zigbee-enabled controls compatible with the Daintree Control System. All luminaires were set up with built-in occupancy and daylight harvesting sensors and can be task tuned with Daintree software.

The CSM software scheduling feature provides for light levels to be tuned to specified levels at specified times. Occupancy sensing was activated in certain areas, task tuning was enabled in fixture groups as suited to location and occupant use, and daylight harvesting was activated in the fixtures by the store front windows.

Project Savings

Pacific Northwest National Laboratory managed the measurement and verification component of the demonstration and the Cadmus Company completed field energy measurements of the lighting system before and after the upgrade to capture the energy savings of the new LED system. The results show that initial replacement of older fluorescents with LEDs saved 30% of the estimated annual lighting energy use.

Energy savings increased by an additional 36% with task tuning and occupancy and daylight sensing controls. Task tuning was used to set operating light levels according to store management requirements for optimum retail sales conditions. This resulted in post-upgrade light levels that were visually brighter to management but measured lower than pre-upgrade levels. Occupancy sensing was used to set reduced light levels rather than fully off in most spaces when not occupied, saving an estimated 18,000 kWh/yr.

Total annual energy savings is estimated to be 439,300 kWh, which is a 66% savings over the baseline energy use at this site. The corresponding reduction in facility energy cost is approximately $65,985 annually and the total project cost, as installed was $583,061. Project payback is calculated to be 7.5 years after the $92,253 EverSource utility rebates are applied.

Installation and Operation

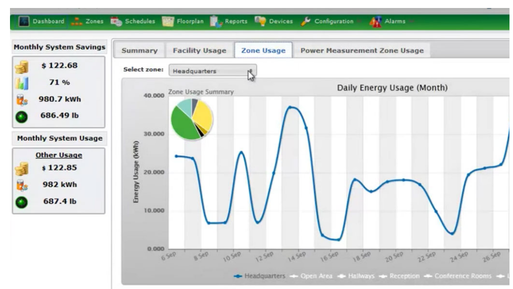
The Stop & Shop store departments operate on varied schedules ranging from 6 AM to 12 AM, Monday through Saturday, and 7 AM to 9 PM on Sunday. The new advanced LED Daintree control applied differing task tuning levels to accommodate the needs of each department.

STOP & SHOP STORE, NEW BEDFORD, MA

The building owner updated the building lighting for energy savings and improved lighting quality. *Photo courtesy of Google Earth 2017.*

Daintree ControlScope Manager Advanced Lighting Control System

Photo courtesy of Current, powered by GE



Advanced lighting control systems can incorporate a variety of options. The CSM system offers the following:

- Occupancy Sensing
- Daylight Harvesting
- High-End Trim/Task-Tuning
- Scheduling On/Off Functionality

Cooper Corelite™

Photo courtesy of Cooper Lighting.

Building managers used the Daintree controls to customize lighting levels, such as setting the main sales floor lighting at 60% of full output from 7:00 AM to 10:30 PM, then at 40% from 10:31 PM until 6:59 AM.

ENERGY EFFICIENCY STRATEGY

Total Lighting System Savings*	
New LED Fixtures Only	New LED Fixtures with Controls
30%	66%

Potential Controls Savings for Typical Lighting Systems**		
Occupancy Sensor Shutoff	Daylight Harvesting	High-End Trim / Task Tuning***
4%	(~)	47%

*The 30% energy savings resulted from installing more efficient LED fixtures. The additional 36% resulted from tuning the new lighting down to preferred operational light levels in addition to occupancy and daylighting controls.
**Data shows, at this site, the advanced controls alone reduced the energy use of the new LED fixtures by 51% (47%+ 4%). This includes significant task tuning with some occupancy-based and scheduled dimming. With few windows onsite, daylight harvesting and related savings were insignificant. ***Task tuning was set as the first control stage after installation of the LED luminaires, and before occupancy sensors and daylight harvesting were activated.
NOTE: Applications with different installed equipment, layouts, and occupant needs could see higher or lower savings.

Application Determines Savings

In most areas, the technology change from fluorescent to LED fixtures provided a significant portion of the savings. A combination of task tuning and the new occupancy-based controls more than doubled the savings. Note that occupancy-based control savings were limited because of the general retail need for consistent light levels throughout sales areas during business hours.

Note: These results represent potential savings for one building type with representative space types and activities. It is important when choosing a lighting system and controls to determine the best fit for a given mix of space types and activities.

Facility Acceptance

The facility operator reported that the Daintree CSM advanced control system was easy to understand, set up, and configure. Once the system was completely commissioned, no further actions were needed. Set up time took about 16 hours to create control zones and configure settings to meet occupant needs.

The facility operator did comment that initially, a few fixtures lost communication once due to external issues, but each fixture was easily reset from full light output back down to the task-tuned level. Challenges such as short sensor delay times were minor and readily resolved. In comparison to the old fluorescent lighting, the facility operator found the new LED lighting improved lighting quality for staff and customers.

Lighting System Performance

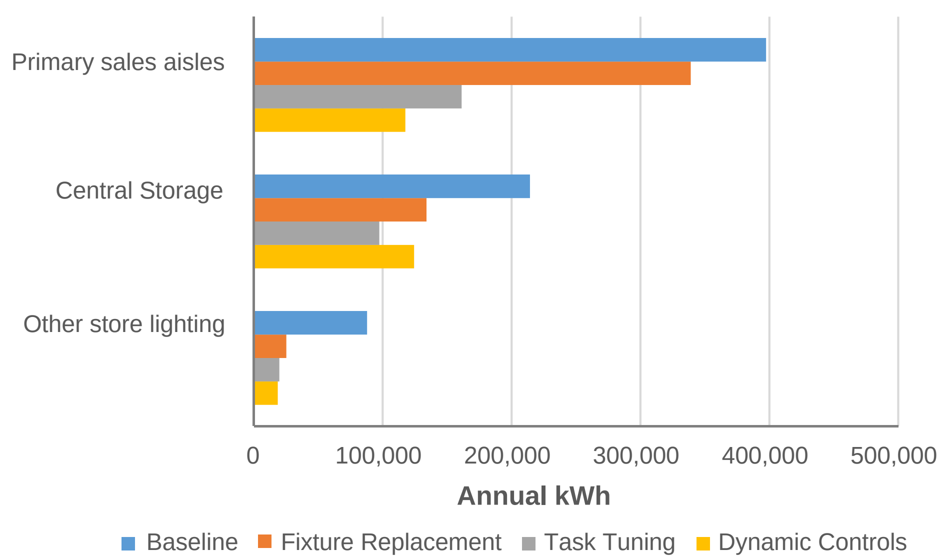
Lighting measurements were taken in selected areas that were representative of the majority of the building. Vertical measurements in a sales isle were also taken to show the critical illumination of the face of products in the aisles.

Location	Before* (fc)	After* (fc)	% Change
Conf Rm /Lunchroom	23.3	17.9	-23
Floral Shop	63.7	32.7	-49
Central Storage	17.6	14.9	-15
Cracker/Juice Aisle	45.5	38.6	-15
Juice Shelves (Vertical)	38.1	40.9	7

* measurements taken at floor level (or at face of product for vertical) for consistency and listed in footcandles (fc)

Final Light levels after the retrofit were based on direction from store management to create optimum retail lighting conditions. Because of the perceived brightness of the new LED technology and some overlighting prior to the retrofit, the resulting measured floor light levels were found to be generally 15% - 49% lower than before. However, the critical vertical measurements were found to be 7% higher than before the retrofit.

Annual Extrapolated Energy Consumption by Space Type



This technology demonstration is supported through a partnership of multiple organizations including:

Better Buildings U.S. DEPARTMENT OF ENERGY | DLC | Stop&Shop | DaintreeNetworks | OPTERRA ENERGY SERVICES | EVERSOURCE | Pacific Northwest NATIONAL LABORATORY Proudly Operated by Battelle Since 1965

DLC Advanced Lighting Technology Demonstration: Digital Lumens

This demonstration is one in a series of advanced lighting demonstration projects being completed through a joint initiative between the DesignLights™ Consortium (DLC) and the U.S. Department of Energy.

Demonstration Site

Two Roads Brewing Company, founded in 2012, is a brewery offering new twists on a variety of craft beers from their Stratford, Connecticut location in a renovated 1911, 103,000 ft^2 building. The 2012 renovation changed the building into an industrial-scale microbrewery with bottling operations, a tasting room, offices, restrooms, shipping / receiving, and storage. Although the 2012 renovation installed efficient fluorescent technology, the evolution in LED lighting and intelligent controls can offer additional savings. The United Illuminating Company (UI), the local utility, recruited Two Roads to participate in this demonstration. New LED control systems can provide modern convenience with wireless communication, and advanced software options that allow for customization of light levels and schedules to meet application and occupant needs.

Demonstration Technology

The Digital Lumens Intelligent LED Lighting System incorporates lighting fixtures with embedded intelligence that includes occupancy and daylight sensing controls integrated or pre-installed in the new light fixtures. The Digital Lumens LED high-bay and low-bay fixtures were installed in the industrial area, and office areas outfitted with Philips Evokit troffers with pre-installed Digital Lumens controls. Although LED lighting alone offers energy and maintenance savings through long product life and energy efficient design, these benefits can be greatly extended through the use of lighting controls.

The Digital Lumens LightRules® software program enables high-end trim / tuning, scheduling, occupancy sensing, and daylight harvesting.

The software allows operations staff to manage energy use, optimize lighting to the application thereby supporting employee safety and comfort. Furthermore, the system has automatic measurement and reporting of energy use along with a suite of additional features for optimizing operations.

The Cadmus company measured the lighting system energy use before and after the upgrade to capture the energy usage with and without lighting controls. Replacement of older fluorescents with LEDs alone saved 50.0% of the estimated annual lighting energy use. With occupancy sensing controls, energy savings increased by 9.8%, and daylighting controls saved another 6.8%. Total energy savings for a year is estimated to be over 95,000 kWh. The corresponding reduction in facility energy cost is over $13,800, or more than $138,000 over ten years. Total installed project cost is $158,489; the retrofit will pay for itself in ~ 7 years with the UI utility incentive reduction of 40.0% applied to project costs.

Installation and Operation

Brewery operations vary with the seasons. Typical operations include 2 production shifts ending at 9 PM, and then limited staff until 7 AM. In production environments, renovation project work must be conducted with minimal disruption and one benefit of embedded, pre-installed sensors and controls is the radically simplified installation process.

Previously, if the facility manager wanted to maximize energy savings with controls they would have to match together different components between light fixtures and controls, determine proper sensor placement, and wire multiple components with potential re-circuiting - effectively adding time and labor costs.

TWO ROADS BREWING

Two Roads Brewing Company located in Stratford, Connecticut modernized their lighting to capture energy savings and convenience. *Photo courtesy of Two Roads Brewing.*

Digital Lumens LED luminaire with on-board controls

Photo courtesy of Digital Lumens.

Advanced lighting control systems can incorporate a variety of options. The Digital Lumens / LightRules® system offers the following options:

- Occupancy Sensing
- Daylight Harvesting
- Scheduling
- Battery backup / Emergency Management
- High-End Trim / Task Tuning*

* Not significantly used at this site

Total Energy Savings: 95,339 kWh

LightRules® Software Screen View

The Digital Lumens System is fully programmable via a software interface for high-end trim / tuning, scheduling control, occupancy sensing, and daylight harvesting. The system also measures its own energy use and offers a range of additional features used to improve productivity such as occupant traffic mapping and testing emergency lighting system compliance. *Photo courtesy of Digital Lumens.*

ENERGY EFFICIENCY STRATEGY

Total Lighting System Savings at Two Roads*

New LED Fixtures Only	New LED Fixtures with Controls
50.0%	66.4%

Control Savings Alone Applied to New LED Fixtures**

Occupancy Sensor Shutoff	Daylighting Reduction	High End Trim / Task Tuning***
19.0%	13.0%	<0.2%

*The 50.0% energy savings came from installing the more efficient LED fixtures. The remainder of this site's savings came from advanced control of these new LED lights.

**The data also shows that at this site, the advanced controls alone reduced the lighting energy use of the new LED fixtures by 32.0% (19.0%+13.0%). NOTE: Applications with a different mix of activities could see higher or lower control savings.

***Tuning only applied to a few fixtures at the site.

Application Determines Savings

In most areas, the simple technology change to LED fixtures provided the majority of savings. Controls offered additional savings in most areas. Control savings can vary widely depending upon the type of activity and facility function.

Facility Acceptance

The installation contractor who installed the new fixtures found the process to be both simple and similar to installing standard fluorescents; system commissioning required only a few hours to complete as much of the process was automated and is provided by the manufacturer as part of the purchase price.

Facility operations staff reported that the software interface and system was easy to set up and operate. Using the LightRules® software, staff developed advanced schedules and control strategies for each area of the facility, optimizing operations. An additional time saving feature of the system is automatic safety testing and reporting of emergency lighting hardware; in older systems this remains a manual and potentially lengthy process.

Prior to the retrofit, a staff survey found 87.0% had a neutral response (satisfaction) with 2 respondents noting conditions being too bright or dim. Post-retrofit found average satisfaction rising to 93.0% with only 1 respondent noting a packing area being too dim.

Lighting System Performance

Pacific Northwest National Laboratory took measurements in selected areas to compare lighting performance before and after the retrofit. Measurements are in footcandles (fc).

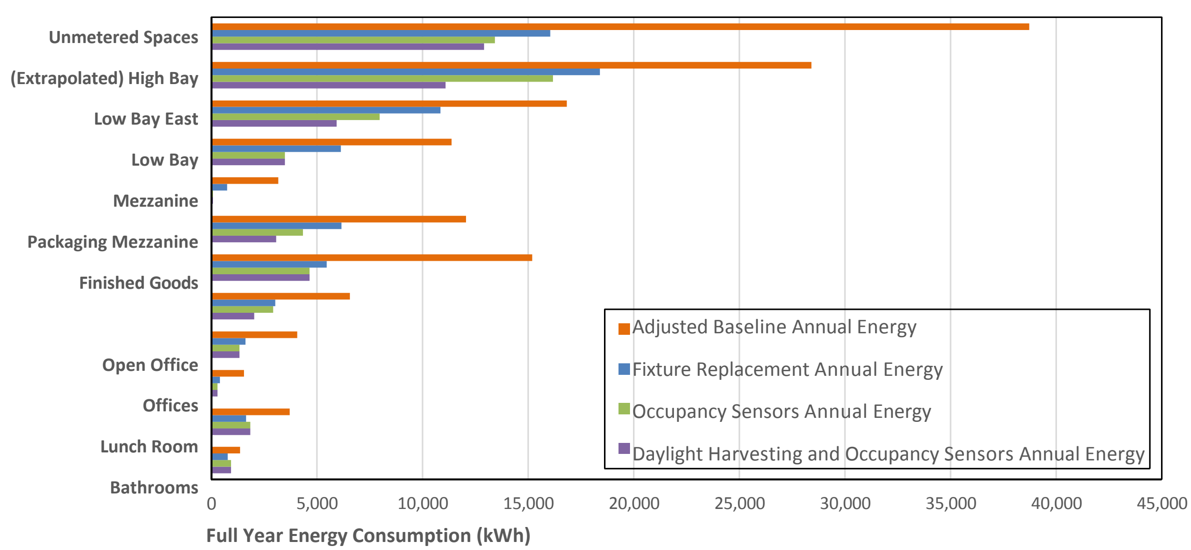
Location	Before (fc)	After (fc)	% Change (+ -)
Waiting Lounge	35.0	56.0	59.0%
Ext. Covered Storage	36.0	21.2	-41.0%
Front Lower Mezz.	9.0	53.4	496.0%
Lunchroom*	41.8	54.8	31.0%
Outer QA Office*	51.2	54.8	7.0%
Rear Lower Mezz.	38.0	55.0	45.0%
HighBay Production	12.9	37.0	188.0%

* measurements taken at desk / table height to represent typical tasks.

All of the post-retrofit LED illuminance levels generally meet Illuminating Engineering Society (IES) guidelines. The system performed as expected or better with most light levels increasing from 7.0% to nearly 500.0%. Where the increases served to correct previously under-lit areas, high-end trim and task tuning was not possible, and did limit energy savings. However, even with the increased light levels, the improved efficacy and added system controls produced significant savings.

These results represent potential savings for one building type with representative space types and activities. It is important when choosing a lighting system and controls to determine the best fit for the given mix of space types and activities.

Annual Energy Consumption by Space Type



This technology demonstration is supported through a partnership of multiple organizations including:

Better Buildings U.S. Department of Energy · DLC · Digital Lumens · Two Roads Brewing Company · energize Connecticut – Empowering you to make smart energy choices · earthlight solar & energy solutions · Pacific Northwest National Laboratory – Proudly Operated by Battelle Since 1965 · UI

DLC Advanced Lighting Technology Demonstration: SpaceWise

This demonstration is one in a series of advanced lighting demonstration projects being completed through a joint initiative between the DesignLights™ Consortium (DLC) and the U.S. Department of Energy.

Demonstration Site

The Rhode Island Public Utility Commission (RIPUC) occupies a multi-story 19,400 ft^2 office building constructed in 1980 in Warwick, Rhode Island. Although the facilities were lighted with standard T8 fluorescent technology, the LED lighting and intelligent controls retrofit completed in 2016 offered additional savings and better quality lighting and control. Working with the local utility National Grid and lighting retrofit contractor Rise Engineering, RI PUC installed the new LED lighting and intelligent control system. The advanced software options allow for customization of light levels to meet application and occupant needs.

Demonstration Technology

The Philips SpaceWise technology is a fully integrated wireless control system applied at the luminaire level that provides plug and play lighting energy savings. It has application modes for open plan offices, private offices, meeting rooms, corridors, and emergency egress; on-board technology provides dimming in response to both occupancy sensing and daylight harvesting. Full light output is delivered only to occupied workstations with background settings typically at only 1/3 of full output. In addition, the system allows for task tuning to adjust lighting to desired levels and daylighting control requires no separate zoning or configuration. For this demonstration, the scope of the project included replacement of the existing luminaires with new Philips DuaLED luminaires with on-board controls.

Project Savings

The Cadmus company measured the lighting system energy use before and after the upgrade with and without lighting controls. The results of the measurements show that replacement of older fluorescents with LEDs alone saved 64% of the estimated annual lighting energy use. Along with this savings was a modest reduction in excessive pre-retrofit light levels in many areas. With advanced occupancy sensing and daylighting controls, an additional 3% of the baseline energy use was saved for a total of 67% estimated to be 39,500 kWh. The corresponding reduction in facility energy cost is approximately $4,700 annually. The total project cost is $110,900 and will pay for itself in just under 15 years after $41,000 in utility rebates from National Grid. A more basic fixture from the manufacturer with similar capabilities could have been applied at $83,300 for a payback of just over 9 years with the rebate.

The low energy savings (3%) from controls at this site are because of limited occupancy sensor savings. This includes enclosed offices and restrooms that already had occupancy sensors. The new embedded occupancy sensors were also set to "automatic-on" and gradually dim to off after the space is unoccupied for 25 minutes. While this configuration may provide occupant satisfaction benefits, it may increase energy use vs. traditional occupancy sensors that automatically turn lights off when unoccupied and use a "vacancy" control strategy requiring a manual switch to turn lights on.

Installation and Operation

RIPUC office hours are from 8 AM to 4 PM, 5 days a week. Pre-retrofit lighting controls were a combination of wall switches and some on-off occupancy sensors. The variety of departments with differing functions in the facility provide some occupancy variance creating energy harvesting opportunities for advanced controls.

RHODE ISLAND PUBLIC UTILITIES COMMISSION

Rhode Island Public Utility Commission building located in Warwick, RI updated their lighting for energy savings and improved lighting quality. *Photo courtesy of Google Earth.*

Philips DuaLED with integrated SpaceWise on-board controls

Photo courtesy of Philips.

Advanced lighting control systems can incorporate a variety of options. The SpaceWise system offers the following:

- Occupancy Sensing
- Daylight Harvesting
- High-End Trim / Task Tuning

Occupant Lighting Satisfaction

BEFORE THE LED RETROFIT*

A staff survey of 38 occupants found the following:

- 89% Between Neutral and Very Satisfied with Overall Lighting Conditions
- 22% Lighting Too Bright At Times
- 78% Occupancy Sensor Control of Lighting is Acceptable or Satisfying

AFTER THE LED RETROFIT*

A staff survey of 13 occupants found the following:

- 100% Very Satisfied or Neutral with Overall Lighting Conditions
- 15% Lighting Too Bright At Times
- 77% Occupancy Sensor Control of Lighting is Acceptable or Satisfying
- 62% Daylighting Controls of Lighting is Acceptable or Satisfying

*Before and after the retrofit 1 respondent found the light too dim.

ENERGY EFFICIENCY STRATEGY

Total Lighting System Savings	
New LED Fixtures Only*	New LED Fixtures **with** Controls
64%	67%

Control Savings Alone Applied to New LED Fixtures**		
Occupancy Sensor Shutoff	Daylighting Reduction**	High End Trim / Task Tuning***
-5%	16%	(~12%)

*The 64% energy savings came from installing the more efficient LED fixtures. The remainder of this site's savings came from advanced control of these new LED lights.

**The data also shows that if the control savings were based only on the lower wattage new LED lighting, the daylighting part of the advanced controls would reduce the lighting energy use by 16%. However, this savings was offset by an increase in energy use due to the new occupancy sensing configuration. The new control system used an auto-on and dim-when-unoccupied approach rather than a manual-on and turn-off-when-unoccupied approach of the previous occupancy controls. NOTE: Applications with a different mix of activities and/or existing controls could see higher or lower overall control savings.

***High End Trim / task tuning was not a part of field adjustments for this system. LED luminaires were shipped to the site with drivers set at 88% of full power to accommodate the specific light level needs at the site. Compared to more common static output products, this could be considered a potential 12% savings.

Facility Acceptance

The installation contractor who installed the LED lighting found the process to be straightforward and generally similar to installing standard fluorescent fixtures. System controls commissioning was provided by the manufacturer and was relatively quick to implement in this mostly standard office facility. Facility operations staff reported that the system software required a learning curve, but found the system made it very easy to check the occupancy sensor operation (typically a cumbersome task). This system when initially installed did experience issues with proper programming and fixture operation. After exploring the issues, the system provider determined there was a manufacturing issue with the LED drivers. After the replacement of the drivers, the system is functioning as designed and operating well to meet the needs of the occupants.

Lighting System Performance

Pacific Northwest National Laboratory took measurements in selected open areas to compare lighting performance before and after the retrofit. These open areas provided clean comparison relative to typical office areas.

Location	Before (fc)	After (fc)	% Change (+ -)
Open Hallway	47	38	-18%
Elevator Lobby	36	30	-18%
Open Hallway	38	32	-16%
Enclosed Hallway	11	26	147%
Lobby	19	36	85%

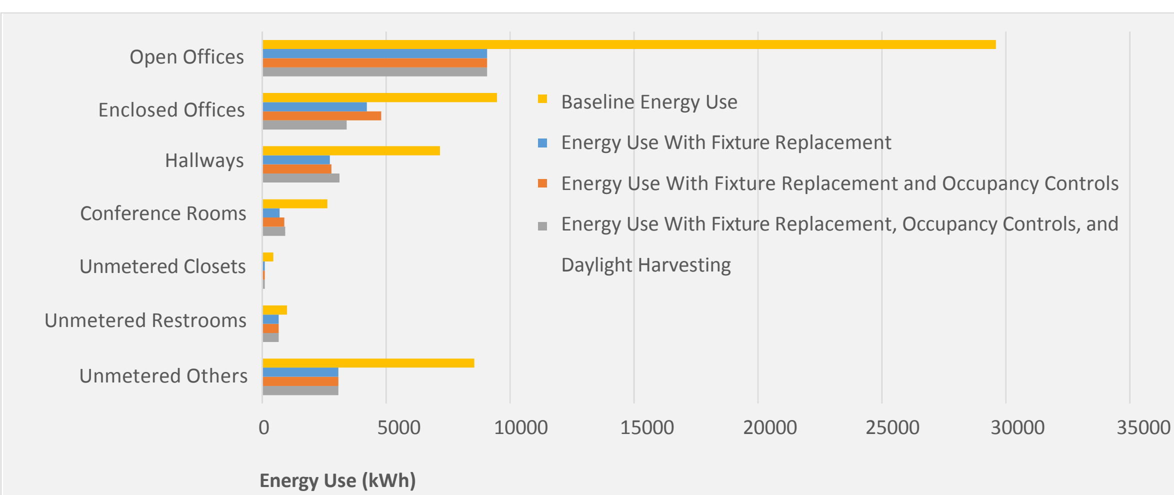
* measurements taken at floor level before and after retrofit

Light levels before the retrofit were mixed with some higher and some lower than Illuminating Engineering Society (IES) recommendations. The post-retrofit light levels in these areas all generally meet or exceed IES recommendations and the changes ranged from approximately 16% lower to almost 150% higher.

Application Determines Savings

In most areas, the technology change from fluorescent to LED fixtures provided the majority of savings. Controls offered additional savings when they were not present before. Control savings can vary widely depending upon the type of activity and facility function.

Annual Energy Consumption by Space Type (extrapolated to full year)



These results represent potential savings for one building type with representative space types and activities. It is important when choosing a lighting system and controls to determine the best fit for the given mix of space types and activities.

This technology demonstration is supported through a partnership of multiple organizations including:

Better Buildings U.S. Department of Energy · DLC · PHILIPS · nationalgrid · Rhode Island Division of Public Utilities · Pacific Northwest National Laboratory, Proudly Operated by Battelle Since 1965 · RISE Engineering

DLC Advanced Lighting Technology Demonstration: Enlighted

This demonstration is one in a series of advanced lighting demonstration projects being completed through a joint initiative between the DesignLights(R) Consortium (DLC) and the U.S. Department of Energy. Additional partners for this site included Wendel Energy, Enlighted, United Illuminating, Energize Connecticut, Beacon Electric, and Yale University.

Demonstration Site

The demonstration site at 221 Whitney Avenue in New Haven, Connecticut is a 75,000 ft^2, 6-story administration building. This demonstration involved floors 5 and 6 with approximately 25,000 ft^2 of office space for the Yale Human Resources department. The space was originally lighted with fluorescent T8 technology. Controls included on/off wall switches and occupancy sensors in perimeter private offices and meeting rooms and only 7 am to 7 pm timeclock control in open cubicle office areas.

Demonstration Technology

The Enlighted Advanced Lighting Control System provides a distributed architecture with a SMART sensor at each fixture. The programming resides locally at the fixture and adjusts (by dimming) the lighting level for each fixture according to that sensor's unique perception from its position in its environment. The sensor is powered by the fixture and collects occupancy and daylight data that combines with schedule and set point data to determine the optimal light level for that fixture. This network of sensors performs fine-grained control of light levels based on measured data through the Enlighted Gateway and Enlighted Energy Manager (EEM). The Enlighted Gateway aggregates wireless communications between the network of Enlighted SMART Sensors and the EEM appliance. The Enlighted system is designed to be easy to install, configure, commission, and service.

Project Savings

Pacific Northwest National Laboratory managed the measurement and verification component of the demonstration and the Cadmus Company completed field energy measurements of the lighting system before and after the upgrade to capture the energy savings of the new LED system. The results show that initial replacement of older fluorescent fixtures with LEDs saved 43% of the estimated annual lighting energy use.

Energy savings increased by an additional 27% with combined task tuning, occupancy sensing, and daylight controls. Savings could have been even higher if occupancy sensors had not already been in place in private office and meeting rooms. Also, some fixtures were initially left on after hours (later corrected) which further reduced the measured savings. Task tuning was used to reduce initial high light levels to more closely match typical office light levels.

Total annual energy savings is estimated to be 34,600 kWh, which is a 70% savings compared to baseline energy use at this site. This equates to an energy cost reduction of approximately $5,190 annually and the total project cost was $116,600. Project payback is calculated to be 13 years after applying a $49,000 incentive provided through United Illuminating from EnergizeCT initiative funds. Part of the relatively high payback for this project is likely due to the limited potential for occupancy sensor savings at the site.

Installation and Operation

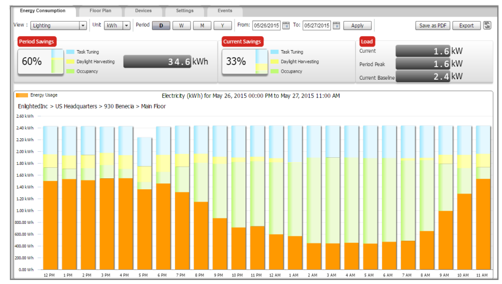
The Human Resources department at Yale operates on an 8 am to 5 pm weekday schedule. The new advanced Enlighted control system manages the lighting in the space automatically with daylight harvesting and granular occupancy-based dimming.

YALE UNIVERSITY, NEW HAVEN, CT

Photo courtesy of Yale University.

Enlighted Energy Manager Advanced Lighting Control System

Photo courtesy of Enlighted



Advanced lighting control systems can incorporate a variety of options. The Enlighted system offers the following:

- Occupancy Sensing
- Daylight Harvesting
- High-End Trim/Task-Tuning
- Scheduling On/Off Functionality

Philips EvoKit LED + Enlighted IoT

Photos courtesy of Philips and Enlighted

Occupant Lighting Satisfaction

BEFORE THE LED RETROFIT*

A staff survey of 21 occupants found the following:

100%	Between Neutral and Very Satisfied with Overall Lighting Conditions
17%	Lighting Too Bright At Times
85%	Occupancy Sensor Control of Lighting is Acceptable or Satisfying

AFTER THE LED RETROFIT*

A staff survey of 18 occupants found the following:

85%	Between Neutral and Very Satisfied with Overall Lighting Conditions
19%	Lighting Too Bright At Times
71%	Occupancy Sensor Control of Lighting is Acceptable or Satisfying

* Before and after the retrofit 2 occupants noted that they thought the lighting was too dim.

PROJECT ENERGY SAVINGS

Total Lighting System Savings*	
New LED Fixtures Only	New LED Fixtures with Controls
43%	70%

Lighting Control Savings**		
Occupancy Sensor Shutoff***	Daylight Harvesting	High-End Trim / Task Tuning
-2%	7%	43%

*The 43% energy savings resulted from installing more efficient LED fixtures. The additional 27% resulted from task tuning the new lighting down to preferred operational light levels plus occupancy sensor and daylighting savings.
**Data shows, at this site, the advanced controls alone would reduce the energy use of the new LED fixtures by 48% (43% + 7% - 2%). This includes significant task tuning with some daylight harvesting.
***This site already had functioning occupancy sensor controls in private offices and conference rooms prior to the retrofit. Building operators also noticed that several fixtures were found to be contunuously operating after the retrofit which further reduces the measured savings shown here.

NOTE: Applications with different installed equipment, layouts, and occupant needs could see higher or lower savings.

Facility Acceptance

The lighting contractor found the process of installing the LED retrofit kits to be straightforward and generally similar in time and effort to installing standard fluorescent fixtures. Instructions were easy to read and understand. One installer indicated he would be able to install the system without any instructions. Another installer commented that the retrofit kits had minor fit issues due to having more components to install. The same installer commented that maintenance and troubleshooting may be harder due to additional parts.

The system took about 26 days to install on both floors working around occupant activity schedules. System commissioning was performed manually and found to be relatively simple. Commissioning was implemented within about one day throughout the two office floors.

Lighting System Performance

Lighting measurements were taken in selected areas on the 6th floor that were typical of the types of spaces in the test area but not necessarily all light levels across the test areas. This included a major conference room and open office areas. Measurements show that the retrofit effectively corrected light levels with slight increase in open office and reduction in conference room to meet a mid-40s level that is often typical of office environments.

Location	Before* (fc)	After* (fc)	% Change
Open Office	32	44	38
Meeting Room	62	45	-27

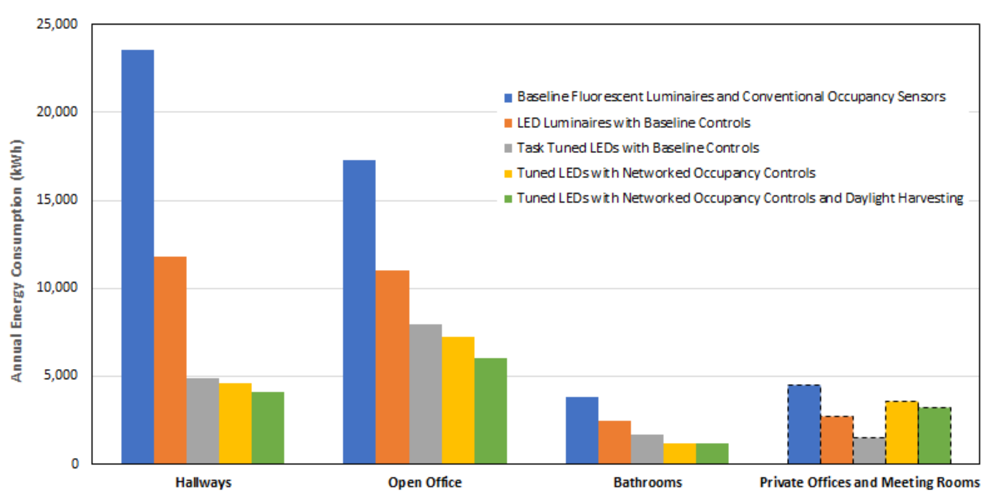
* The measurements shown are for conference room table level and open office desk level. The initial raw measurements were taken at floor level in open office and at both floor and table level for conference room. The office desk level measurements shown were developed using the ratio of floor vs table values taken in the conference room.

Application Determines Savings

In most areas, the technology change from fluorescent to LED fixtures provided a significant portion of the savings. Control savings that included task tuning significantly increased the savings. Note that this site initially had hardwired occupancy sensors and therefore there was no significant additional savings from the new sensors installed as part of the advanced control system.

Note: These results represent potential savings for one building type with representative space types and activities. It is important when choosing a lighting system and controls to determine the best fit for a given mix of space types and activities.

Annual Extrapolated Energy Consumption by Space Type



Note that the "Private Office and Meeting Rooms" group shows a lack of energy savings with the new LED and control system. This was found to be the result of 1) occupancy sensors already existing for these spaces before the retrofit and 2) several fixtures found to be continuously operating after the retrofit and captured in the metered.

This technology demonstration is supported through a partnership of multiple organizations including:

Better Buildings U.S. DEPARTMENT OF ENERGY
DLC
Yale
energize CT CONNECTICUT Empowering you to make smart energy choices
UI
Pacific Northwest NATIONAL LABORATORY Proudly Operated by Battelle Since 1965
wendel
enlighted
BEACON ELECTRIC INCORPORATED

Bringing Efficiency to Light™

Advanced Lighting Control Systems Training

1. Introduction, Background, & Objectives

2

Course developed with gracious support of:

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U.S. DEPARTMENT OF ENERGY

Please complete the sign-in sheet to demonstrate attendance

5

3D18

Material Support

- Thank LSI, Lutron, and the emergency relay company.

6

Slide 6

BD18 drop in slide from older versions here
Bosetti, Damon, 1/29/2018

Learning Objectives

At the end of this course, participants will be able to:

1. Describe the different types of lighting controls available and pros and cons of each.
2. Identify new types of advanced lighting controls that can reduce complexity and cost of installation and commissioning.
3. Identify criteria to guide decisions of the type of advanced lighting controls to use on project.
4. Use a new publicly available tool to understand, evaluate, and compare available networked lighting control systems.
5. Install and commission a new example of a wireless ALCS, and apply this experience to others they will encounter.
6. How to find information about programs from your utility for advanced lighting controls

7

Agenda

1. Introduction, Background, and Objectives
2. Lighting Control Strategies
3. Types of Lighting Controls

\- Break -

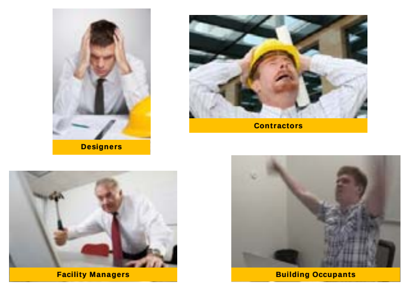
4. Application guidance
5. Networked Lighting Controls
6. Application Workshop

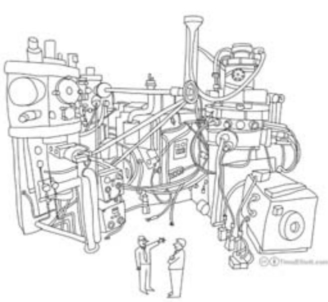
\- Lunch -

7. Hands-On Wiring

8

But first… the past. What's your perception of Advanced Lighting Controls?

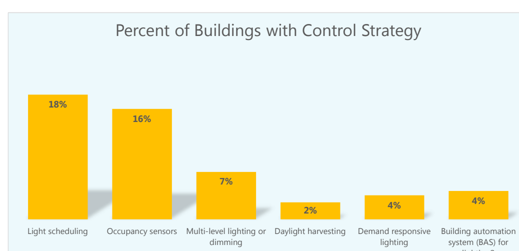




"Well, sure, it looks complicated..."

11

Advanced Lighting Controls have not been widely adopted



Source: 2012 Commercial Buildings Energy Consumption Survey, US Energy Information Administration

12

Advanced Lighting Controls have not been widely adopted

Northwest Region Indoor Lighting Power by Control Type and Building Type

Control Type	All (n=791)	Assembly (n=104)	Food Service (n=43)	Grocery (n=69)	Lodging (n=69)	Office (n=113)	Residential Care (n=68)	Retail (n=129)	School (n=72)	Warehouse (n=43)	Other (n=81)
Manual	2,087 73% ± 2%	279 77% ± 6%	53 87% ± 7%	63 72% ± 8%	121 86% ± 3%	448 68% ± 6%	118 91% ± 3%	447 68% ± 7%	139 61% ± 8%	211 83% ± 7%	208 76% ± 6%
Occupancy Sensor	224 8% ± 1%	27 7% ± 4%	0 0% ± 0%	1 1% ± 1%	1 1% ± 1%	73 11% ± 4%	3 2% ± 2%	12 2% ± 1%	34 15% ± 5%	43 17% ± 7%	32 12% ± 4%
EMS System	256 9% ± 2%	33 9% ± 4%	2 3% ± 4%	6 7% ± 5%	0 0% ± 1%	45 7% ± 4%	1 1% ± 1%	120 18% ± 5%	30 13% ± 6%	0 0% ± 0%	18 7% ± 4%
Dimming	24 1% ± 0%	10 3% ± 2%	4 7% ± 5%	0 0% ± 0%	4 3% ± 1%	1 0% ± 0%	1 0% ± 1%	0 0% ± 0%	1 0% ± 0%	1 0% ± 1%	2 1% ± 1%
Timeclock	74 3% ± 1%	7 2% ± 2%	0 0% ± 0%	2 2% ± 3%	2 1% ± 1%	31 5% ± 3%	1 0% ± 0%	28 4% ± 3%	2 1% ± 1%	0 0% ± 1%	2 1% ± 1%
Photocell	13 0% ± 0%	0 0% ± 0%	0 0% ± 1%	0 0% ± 0%	1 0% ± 0%	4 1% ± 1%	0 0% ± 0%	8 1% ± 1%	0 0% ± 0%	0 0% ± 0%	0 0% ± 0%
Other	126 4% ± 1%	5 1% ± 1%	0 0% ± 0%	5 6% ± 3%	0 0% ± 0%	50 8% ± 4%	0 0% ± 0%	33 5% ± 3%	24 10% ± 5%	0 0% ± 0%	9 3% ± 2%
None (Continuous)	54 2% ± 0%	3 1% ± 0%	1 2% ± 4%	11 12% ± 6%	13 9% ± 3%	6 1% ± 0%	6 5% ± 2%	10 2% ± 1%	0 0% ± 0%	0 0% ± 0%	4 2% ± 1%

13

Barriers to Adoption

- Poor past experiences
- Unfamiliar with technology
- Too complex
- Not standardized
- High costs
- Weak value proposition

Pablo Escudero

14

The Good News

- Technology is changing and improving… FAST!
- Systems designed from the ground up to reduce complexity and cost
- Easier (and less costly) to install, commission, use than ever before
- New system capabilities that provide new value to customers

Staples

15

New Capabilities that go beyond Energy

16

Four Technology Innovations Reduce Install Complexity, Add Value

1. Integrated or “Embedded” Sensors and Controls
2. Wireless
3. Apps or Software-based Tools to Configure the System
4. Integrated Power Meters

17

1. Integrated or Embedded Sensors

Dialight, Digital Lumens, Philips, CREE, Enlighted

18

1. Integrated or Embedded Sensors

- ✓ Pre-installed in fixtures: no on-site installation work
- ✓ Retrofit kits: no on-site part-matching
- ✓ Sensors are pre-configured for out-of-the-box functionality
- ✓ Fewer components
- ✓ Single Warranty
- ✓ No DIY control wiring between components
- ✓ Eliminates task of figuring out where to place sensors

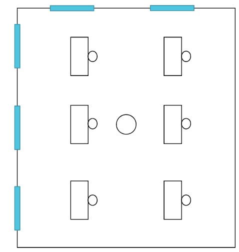
- ✗ May have higher equipment costs
- ✗ May have longer lead time
- ✗ Limited choice of fixtures available

Dialight, Philips

19

Integrated Sensors Allow Luminaire Level Lighting Control (LLLC)

"The capability to have an occupancy sensor and ambient light sensor installed for each luminaire."



- ✓ Either factory- or field-installed, these give the control system maximum flexibility for current and future uses.

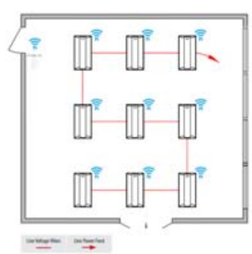
- ✗ Upfront part and commissioning costs

20

2. Wireless

- ✓ Reduces or eliminates control wiring and terminations
- ✓ More flexibility in how devices are connected and configured

- ✗ Distance limitations
- ✗ May experience interference with some systems in some applications
- ✗ May require wider coordination for security or bandwidth concerns



Acuity

21

3. App or Software Tools to Configure

Acuity

See fixtures and devices in room by signal strength. Flash to identify.

Click to select or drag and drop into group

Configure settings

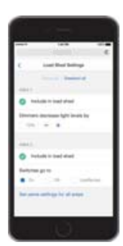
22

3. App or Software Tools to Configure

Lutron

See Light Fixtures and Devices in Room by Signal Strength. Flash to identify.

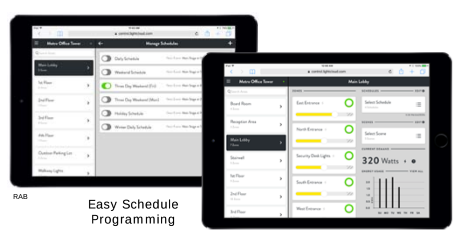
Timeclock/Schedules are much easier to set up



Configure Load Shed Settings

23

3. App or Software Tools to Configure



RAB

Easy Schedule Programming

Intuitive Dashboards

Easily identify and tune lights

24

Remote Controls?

CREE, Philips, Eaton

✓ Point at the light you are configuring

✗ No 2-way communication
✗ What setting have you chosen?
✗ What setting are the lights at?
✗ Where's the remote?

25

4: Integrated Power Meters in Drivers, Sensors, and Controllers

New metering microchips embedded directly into lighting equip.

- Wireless Smart Sensor with built-in meter

- Wireless Fixture Controller with built-in meter

- LED Driver with built-in meter

Enlighted, Lutron, Philips

Microchip Technology, Inc.

26

Limitations of the Past		Possibilities of the Future
Sensor Layout	→	Sensor per Luminaire
Grouping/Zoning	→	Auto-Grouping/Zoning
Driver / Controller / Sensor Compatibility	→	Pre-Installed, Pre-Wired, Compatible
Control Strategy Design	→	Pre-Programmed, Out-of-the-box
Low Voltage Control Wiring	→	Wireless / PoE
Complex Commissioning	→	Simple Configuration w/ Commissioning Assistance

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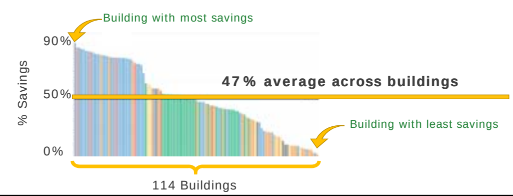
Significant Energy Savings

- Average savings in lighting energy from lighting controls: 47%
- Data from voluntary contributions
- Individual buildings: lighting control savings from 2% to 90%
- Search "DLC Energy Savings Report" online to download the full report and webinar



28

Case Studies

- ALCS are new, and some people may need help to believe the claims they make about saving energy.
- There have been lots of case studies carried out around the country you can use!

Name	Subject	Link
Lawrence Berkley National Lab	Combining advanced lighting and window shades in an office building.	https://facades.lbl.gov/nyclivinglab
DLC and DOE	Effects of ALCS usage in five different building types, from manufacturing to offices.	https://www.designlights.org/lighting-controls/case-studies/
GSA	Retrofit of federal buildings with wireless controls and LED, leading to 78% energy savings.	https://www.gsa.gov/portal/content/227563

29

2. Lighting Control Basics and Strategies

30

Lighting Control System Basics

- **Functions** – in order to unlock the full power of a lighting control system, it must be able to do two main things:
  - ✓ **Switching** – turning lights on and off
  - ✓ **Dimming** – reducing the amount of light output
- **Control strategies** – the strategies shown on subsequent slides are some of the methods used to switch and dim lights based on different types of input.

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Lighting Control System Basics

- **Addressability** – If every single fixture, switch and sensor has its own "address", this provides ultimate flexibility for commissioning and programming the system.
- **Grouping / Zoning** – With traditional controls, groups/zones of fixtures are determined at the design or installation phase. They are "locked-in" and can't be changed without re-wiring. Conversely, addressable systems allow you to program and change groups/zones at any time.
- **DLC Qualified Systems are Addressable** - All DLC qualified control systems are required to have the capability to be addressable.

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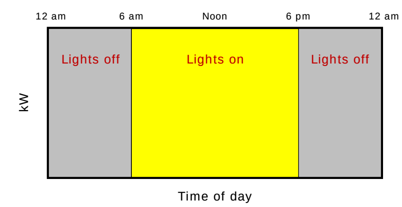
Lighting Control Strategies

- **Time scheduling** – turn off lights "after hours" or when a space is not normally used
- **High-End Trim / Task Tuning** – reduce the maximum light level for a space or building at the time of installation/commissioning
- **Daylight harvesting** – dim or turn off lights based on available natural light
- **Occupancy (& vacancy) sensing** – turn off lights when the space is unoccupied (vacant)
- **Personal control** – dim or turn off lights based on personal preference or needs
- **Variable load shedding ("demand response")** – dim or turn off lights during periods of peak demand

33

Time Scheduling

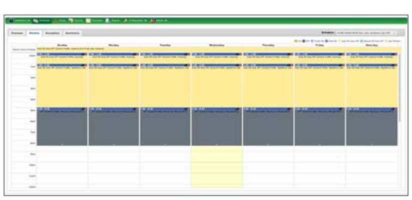
Energy Savings: 10-30%



Turn off lights after hours or when a space is not normally used.

34

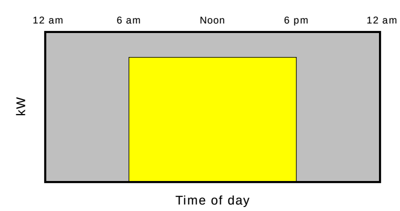
Time Scheduling



35

High-End Trim / Task Tuning

Energy Savings: 5-20%

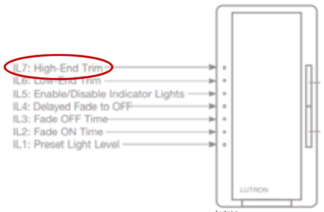


Reduce the maximum light level for an entire space or building during normal occupied hours.

36

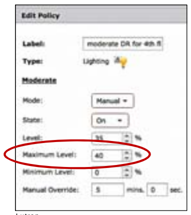
High-End Trim / Task Tuning

Advanced Dimmer with High-End Trim Capability



Lutron

Software-based High-End Trim

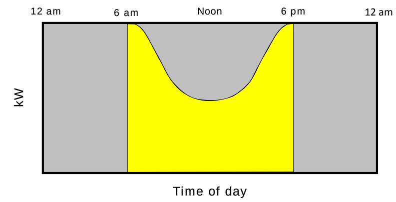


Lutron

37

Daylight Harvesting

Energy Savings: 10-60%



Dim or turn off lights based on available natural light.

38

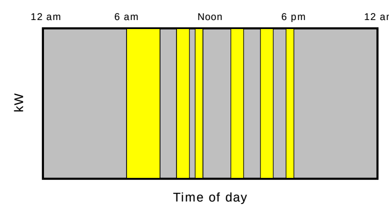
Daylight Harvesting

Acuity, Lutron, RAKO, Philips,

39

Occupancy / Vacancy Sensing

Energy Savings: 15-90%



Turn off lights when the space is unoccupied (vacant).

40

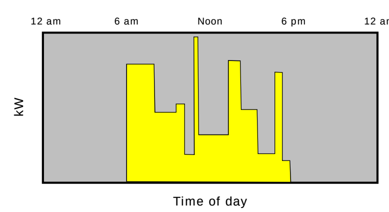
Occupancy / Vacancy Sensing

Enlighted, Gerrie Distributors

41

Personal Control

Energy Savings: 10-30%



Dim or turn off lights based on personal preference or needs.

42

Personal Control

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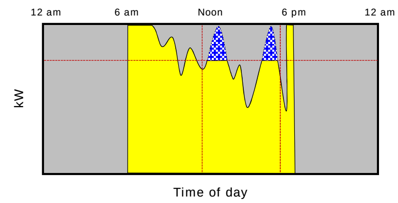
Variable Load Shedding ("Demand Response")

Reduces Peak Power

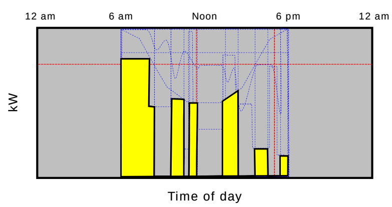


Dim or turn off lights during periods of peak demand.

44

Aggregate Strategies for a Given Space

Energy Savings: 40-90%



Aggregate strategies for that space, and the resulting energy use.

45

3. Types of Lighting Controls

46

Traditional Lighting Controls

- Stand-Alone Controls
- Low-Voltage Relay Panel Systems

New Types of Lighting Controls

- Stand-Alone Fixture-Integrated Sensors
- Room-Based Controls (Room Controllers)
- Simplified Networked Systems
- Comprehensive Networked Systems

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Stand-Alone Controls

Grainger, Gerrie Distributors

48

Stand-Alone Controls

Descriptions

- **Toggle switch** – turns lights on and off
- **Occupancy sensor** – turns lights on upon occupancy or off upon vacancy (or both)
- **Hotel key-card switch** – prevents use of lights in guest room if no one is present (serves as a "master" power switch)
- **Timer ("countdown") switch** – turns lights off after specified period of time
- **Dimmer** – allows occupants to dim or increase light levels
- **Photosensor** – switches or dims lights based on availability of daylight

49 Grainger, Gerrie Distributors

Stand-Alone Controls

Benefits

- ✓ No control wiring or wireless connectivity required
- ✓ Easy to install (familiar wiring methods)

Challenges

- ✗ Limited to controlling specific branches or switch legs
- ✗ Combining multiple controls/strategies is difficult
- ✗ Difficult to meet energy code requirements
- ✗ No central way to program; settings are on each device
- ✗ Typically result in less overall energy savings

50 Grainger, Gerrie Distributors

Traditional Lighting Controls

Stand-Alone Controls

Low-Voltage Relay Panel Systems

New Types of Lighting Controls

Stand-Alone Fixture-Integrated Sensors

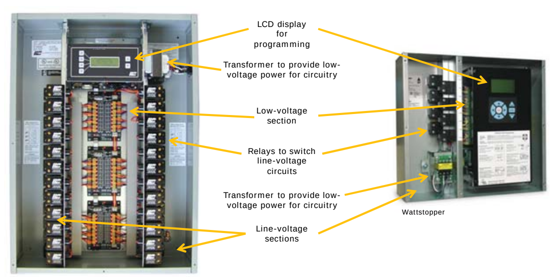
Room-Based Controls (Room Controllers)

Simplified Networked Systems

Comprehensive Networked Systems

51

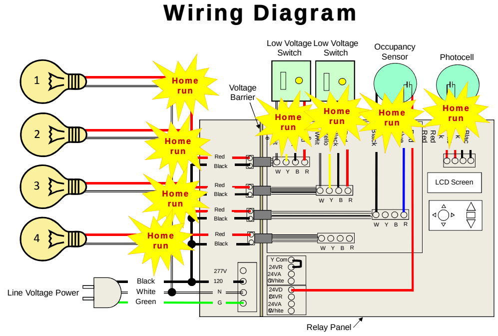
Low-Voltage Relay Panel Systems



52 Wattstopper

Low-Voltage Relay Panel Systems

Wiring Diagram



53

Low-Voltage Relay Panel Systems

Wattstopper

Benefits

- ✓ Centralized control and programming of *some* settings
- ✓ Capable of more advanced control strategies than stand-alone controls

Challenges

- ✗ Requires low-voltage wiring and associated home runs
- ✗ Limited number of inputs to do multiple control strategies (e.g. limited sensor inputs)
- ✗ Loads are controlled in groups based on physical circuitry (branches or switch legs) – individual addressability is difficult
- ✗ Small LCD displays can make it harder to program and troubleshoot

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Traditional Lighting Controls

- Stand-Alone Controls
- Low-Voltage Relay Panel Systems

New Types of Lighting Controls

- ▶ Stand-Alone Fixture-Integrated Sensors ◀
- Room-Based Controls (Room Controllers)
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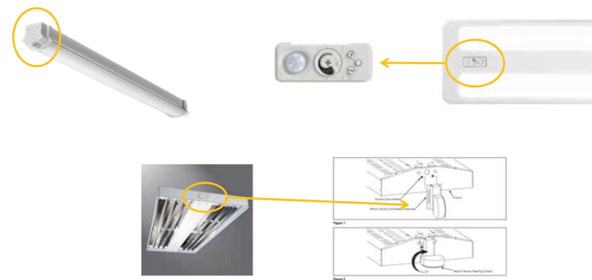
- Comprehensive Networked Systems

Stand-Alone Fixture-Integrated Sensors



56 Acuity, Eaton

Stand-Alone Fixture-Integrated Sensors

Benefits

- ✓ Factory Installed; no control wiring
- ✓ Easy to specify
- ✓ Granular control → greater energy savings

Challenges

- ✗ Controls only the fixture it is installed in – can't link together sensors or form groups
- ✗ May result in patchwork appearance in space
- ✗ Each sensor/fixture must be programmed individually

57 Acuity

Traditional Lighting Controls

- Stand-Alone Controls
- Low-Voltage Relay Panel Systems

New Types of Lighting Controls

- Stand-Alone Fixture-Integrated Sensors
- ▶ Room-Based Controls (Room Controllers) ◀
- Simplified Networked Systems
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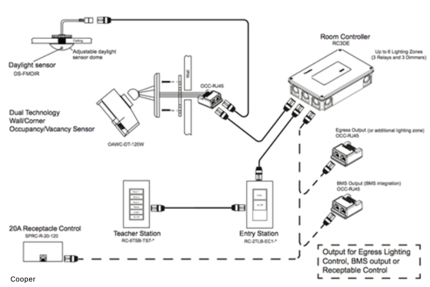
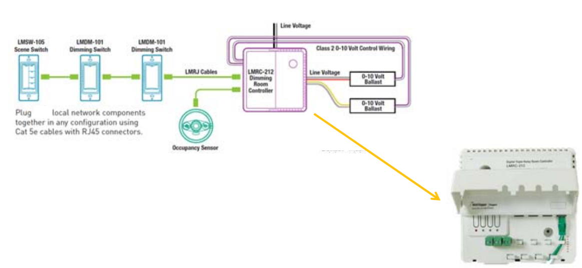
Room-Based Controls (Room Controllers)



Room-Based Controls (Room Controllers)



60 Leviton, Wattstopper

Room-Based Controls (Room Controllers)

Benefits

- ✓ Many with out-of-the-box, pre-programmed functionality
- ✓ Designed for easy code compliance of single room
- ✓ Simplified CAT5 connections

Challenges

- ✗ No fixture addressability
- ✗ Can only control loads in groups based on physical circuitry (branches or switch legs)

61 Wattstopper, Eaton

Traditional Lighting Controls

- Stand-Alone Controls
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New Types of Lighting Controls

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- Comprehensive Networked Systems

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What do we mean by Simplified vs. Comprehensive?

63

DLC Qualified Networked Systems

All DLC Qualified Networked Systems have the following capabilities:

1. **Networked** – All devices networked together to enable advanced control capabilities
2. **Three Minimum Control Strategies**:
   1. Occupancy Sensing
   2. Daylight Harvesting
   3. High-End Trim
3. **Addressable / Programmable** – Program your zones rather than wiring them

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DLC Qualified Networked Systems

Two categories or "buckets" of Networked Systems

- Simpler/Easier to install and use
- Fewer features and capabilities

- More difficult to install and use
- Advanced features and capabilities

65

Characteristics

Simplified Systems

- Out-of-the-box functionality
- No computer server, central gateway, or cloud internet connection required
- Simple commissioning by contractor
- Does not require sophisticated Facility Manager or 3rd party to manage system
- Basic control strategies (occupancy, daylight, high-end trim)
- Single room or building
- More likely to be wireless
- May have integrated sensors to reduce complexity

Comprehensive Systems

- Customized by application
- May require computer server or cloud internet connection
- Commissioning by or with support of manufacturer or rep
- Requires capable Facility Manager or 3rd party to manage system
- Basic + Advanced control strategies (scheduling, demand response)
- Building, Campus, or Enterprise
- Advanced Capabilities (energy monitoring, remote diagnostics, shade controls, and more…)

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Examples of Available Systems

Simplified Systems

- Lutron Vive
- Philips SpaceWise DT
- Acuity nLight Air
- Cree SmartCast Wireless
- Eaton WaveLinx
- LG Electronics Sensor Connect

Comprehensive Systems

- Lutron Quantum
- Philips Dynalite
- Acuity nLight
- Cree SmartCast PoE
- Digital Lumens LightRules
- Enlighted IoT System

The lines between the two types of systems are starting to blur – this is good!

We will see a spectrum of capabilities that lets users get as sophisticated as they need, while keeping future flexibility open.

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Summarizing Simplified Systems

- Easier to install, commission, and use
- Basic feature set to deliver energy savings and code compliance
- Appropriate for wider range of customers
  - Less Sophisticated
  - Small Business
  - Tenant Leased Space

68

Summarizing Comprehensive Systems

- More Savings, More Flexibility, More Options
- Advanced features deliver more than energy savings
- Get energy data and more…

…for the right customer

69

Luminaire Level Lighting Controls (LLLC)

70

Luminaire Level Lighting Controls (LLLCs)

Luminaire Level Lighting Controls (LLLCs)

Some utilities offer specialized rebates for a specific type of Networked Lighting Controls called Luminaire Level Lighting Controls or LLLCs.

LLLC Characteristics:

- **Controller per luminaire**
- **Occupancy, Daylight Sensor per luminaire** (some utilities require sensor to be "embedded" or "integrated directly into luminaire"
- **Control Persistence**– controls, sensors, etc. can continue to operate *at the luminaire* without connection to central processor

71

Luminaire Level Lighting Controls (LLLCs)

72 Dialight, Digital Lumens, Philips, CREE

Luminaire Level Lighting Controls (LLLCs)

Find LLCs on the DLC Qualified Products List

Traditional Lighting Controls

- Stand-Alone Controls
- Low-Voltage Relay Panel Systems

New Types of Lighting Controls

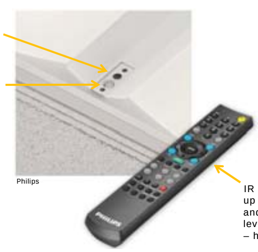
- Stand-Alone Fixture-Integrated Sensors
- Room-Based Controls (Room Controllers)
- Simplified Networked Systems
- Comprehensive Networked Systems

Simplified Networked Systems

Wireless, Integrated Sensors

Photosensor

Occupancy sensor

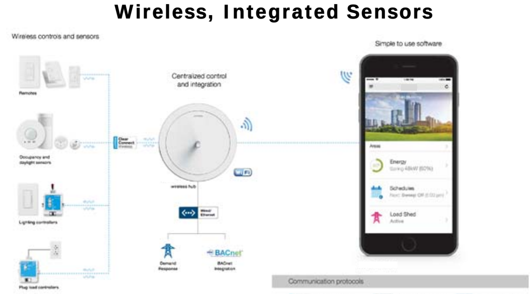


Philips

IR remote for setting up "groups" (zones) and occupied ambient level (low – medium – high)

Simplified Networked Systems

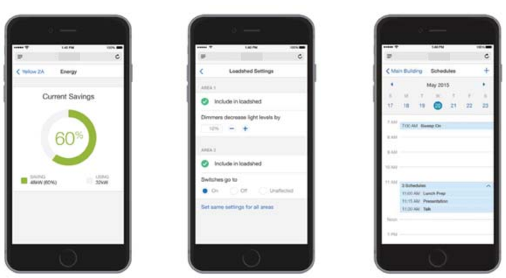
Wireless, Integrated Sensors



Lutron

Simplified Networked Systems

Wireless, Integrated Sensors



Lutron

Simplified Networked Systems

Wireless, Integrated Sensors

Philips, Lutron, Cree

Benefits

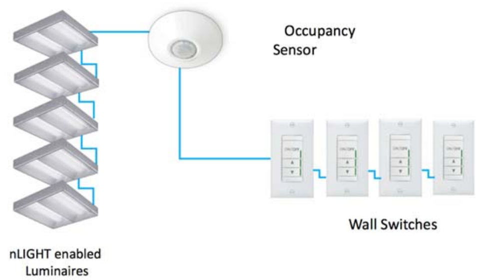
- ✓ Easy to install and commission
- ✓ No control wiring – great for existing buildings
- ✓ Factory installed sensors/controllers eliminate compatibility problems
- ✓ Commission with Smartphone or Remote Control
- ✓ Program and reprogram zones without re-wiring

Challenges

- ✗ Wireless may require clearance from IT
- ✗ New tech contractors may be unfamiliar with
- ✗ Responsibility for smartphone/remote?

Simplified Networked Systems

Wired, No Integrated Sensor



Acuity

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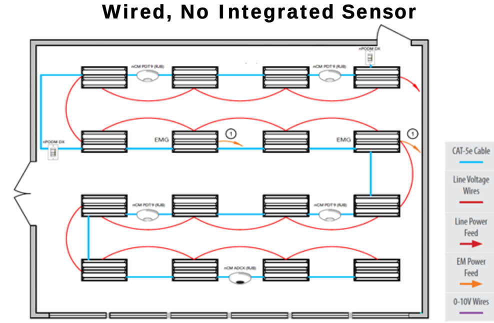
Simplified Networked Systems

Wired, No Integrated Sensor



80

Simplified Networked Systems

Wired, No Integrated Sensor

Wattstopper

Benefits

- ✓ Easier to install and commission than comprehensive system
- ✓ Out-of-the-box functionality
- ✓ Wired connections
- ✓ Program and reprogram zones without re-wiring

Challenges

- ✗ Requires low-voltage control wiring between devices and fixtures – not great for existing buildings
- ✗ Non-integrated sensors require careful sensor placement and may require more complex commissioning

81

Traditional Lighting Controls

- Stand-Alone Controls
- Low-Voltage Relay Panel Systems

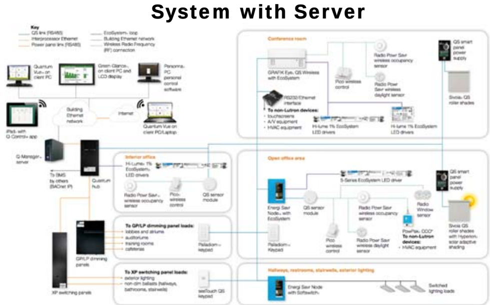
New Types of Lighting Controls

- Stand-Alone Fixture-Integrated Sensors
- Room-Based Controls (Room Controllers)
- Simplified Networked Systems
- ▶ Comprehensive Networked Systems

82

Comprehensive Networked Systems

System with Server

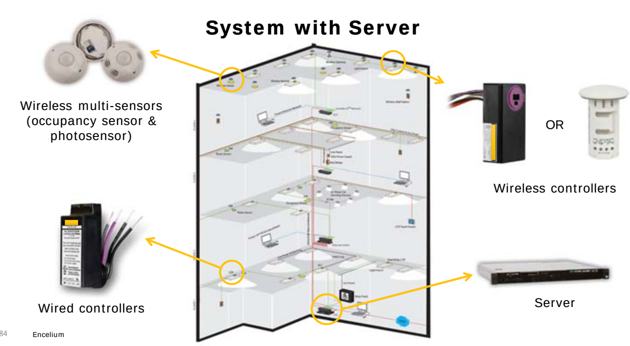


Lutron

83

Comprehensive Networked Systems

System with Server

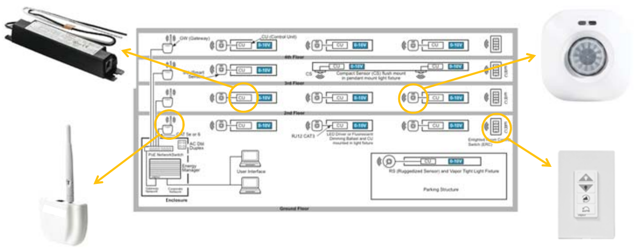


Encelium

84

Comprehensive Networked Systems

System with Server



85 Enlighted

Comprehensive Networked Systems

System with Server

Wattstopper

Benefits

- ✓ Addressability allows for unlimited flexibility in zoning and rezoning
- ✓ Many programmable options – such as time delays, target set points, schedules, etc.
- ✓ Ability to interface with BMS, Demand Response, etc.
- ✓ Monitor and report energy use and savings

Challenges

- ✗ Higher equipment and installation cost
- ✗ More complicated to specify, install, commission, and use
- ✗ Requires relatively sophisticated customer or 3rd party to manage system

86

4. Application Guidance: Choosing a Networked Control System for your project

87

DLC Networked Lighting Controls QPL

88

How to find the DLC Networked Lighting Controls QPL

89

What can you filter for on the NLC QPL?

What can the system do?	
Networked	Scheduling
Wired, Wireless, or Both	Personal control
Occupancy-sensing	Demand Response
Daylight-harvesting	Non-lighting plug-load control
Adjustable for high-end trim	Zoning
Address individual luminaires	Luminaire-level control (field)
Luminaire-level lighting control	Continuous (100+ steps) dimming
Local processing	Energy monitoring
BMS/HVAC/etc integration	Remote diagnostics
Emergency lighting integration	

90

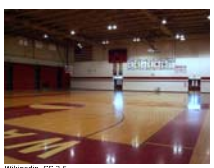
Use DLC QPL to identify systems based on particular capabilities or characteristics

Wired or Wireless?	Server Required, Local or Cloud?	Start-Up and Configuration Party?	Occupancy Sensing?	Traffic Sensing?	Daylight Harvesting (Interior)?	Photocell Control (Exterior)?	High-End Trim?	Scheduling?	Personal Control?	Load Shed (DR)	Plug Load Control?	Zoning?	Individual Luminaire Addressable?	Luminaire Level Lighting Control (LLLC)?	Continuous Dimming?	Color Change / Tune?	Control Persistence?	Energy Monitor?	Building Systems Integration?	Remote Diagnostics?	Emergency Lighting [illegible]
Wired	Local Server	Factory representative on-site	Yes	NA	Yes	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wireless	No Server Required	Installation contractor with less than 1 day of training	Yes	NA	Yes	NA	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes
Wired, Wireless	Local Server	Factory representative on-site	Yes	NA	Yes	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wired, Wireless	No Server Required	Installation contractor with less than 1 day of training, working with remote personnel at factory	Yes	NA	Yes	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No

General criteria to consider when selecting a system

Selection Criteria

- **Is the space to be controlled large or small?**
  - ✓ Large space – may require a large, comprehensive networked system with central server because of the total load, number of circuits or switch legs, etc.
  - ✓ Small space – a simplified networked system without a central server may suffice.



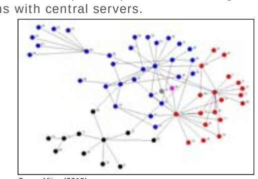
Wikipedia, CC 2.5

Wikipedia, CC4.0

Selection Criteria

- **Specification or installation complexity**
  - ✓ Specifiers and ontractors working with the most comprehensive networked systems with central servers will benefit from continued education and training for ALCS to ensure proper function and realized energy savings
  - ✓ Most simplified systems can be easily specified and installed even if the specifier or installing contractor has not had prior experience with large comprehensive networked systems with central servers.

A → B



Sunny Mitra (2013)

Selection Criteria

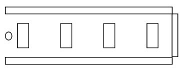
- **Sophistication and resources of the owner:**
  - ✓ Comprehensive networked systems have the most benefit for customers with the largest energy spending.
  - ✓ They need to be invested in the system, keeping staff trained on how to use, operate, and maintain it (unless they pay others via a service contract to do that).
  - ✓ For customers that do not have energy bills of this size, or the ability to invest in a sophisticated system's continuing operation, a simplified networked system may be a better choice.
- **New construction vs. retrofit**
  - ✓ Certain systems may be significantly better suited for a retrofit project, such as wireless systems that reduce or eliminate the need to run additional wiring through the plenum.
  - ✓ In new construction, running additional cables for control wiring may be a very insignificant factor.

Selection Criteria

- **Cost**
  - ✓ As the number of features increase, so does the cost of the ALCS. This isn't bad, but be sure to understand the cost and benefit of each feature for each specific customer to be sure they're getting what's best for them.
  - ✓ If the owner's budget is restrictive, then it may be necessary to use a simplified control system that minimally meets code requirements.

Selection Criteria

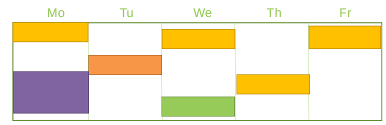
- **Individual fixture addressability**
  - ✓ Many currently available systems can be installed with either (1) individual fixture addressability, or (2) one controller per zone. The first approach will always provide the maximum flexibility for zoning and rezoning.
  - ✓ If the owner is certain that rezoning will never be required, selecting and installing a system with one controller per zone may potentially reduce the equipment and installation cost on a given project.
    - ✓ For example, all fixtures within the same aisle in a warehouse project may have to turn on based on code requirements. If so, then using one controller for all fixtures in that aisle, upstream of the fixtures themselves, may be a viable solution, and may potentially reduce equipment and installation cost.



97

Selection Criteria

- **Scheduling**
  - ✓ Using a "scheduling" strategy is not strictly required in every space type based on current code requirements. Often, the use of occupancy sensors suffices to meet the "automatic shutoff" requirements.
  - ✓ Certain simplified systems do not have a "scheduling" or "time clock" function (to reduce system cost). However, it's common to employ scheduling in addition to other strategies to maximize the energy savings from a control system.



98

Selection Criteria

- **Demand response**
  - ✓ Most large comprehensive networked systems have options for pre-programming "demand response" scenes or profiles, for manual activation when necessary.
    - ✓ However, in certain systems, "Auto-DR" can only be accomplished by interconnecting with another system such as a BMS, usually via BACnet protocol.
  - ✓ Some simplified networked systems do not have DR capability
  - ✓ A small but growing number of jurisdictions is beginning to require lighting control systems that are "demand response capable", specifically for "Auto-DR" functionality. Relying on human users to manually activate "pre-programmed" DR strategies does not meet code.

99

Selection Criteria

- **Integrated Sensors – LLLC on DLC QPL**
  - ✓ Installing controllers and sensors in the field can cost much more (in time and money) than having the equipment arrive integrated in the fixture or retrofit kit.
  - ✓ This LLLC or fixture-integrated product may have longer lead times, since this affects manufacturers' warehouse stocking decisions. Ask your rep!

100

Selection Criteria

- **Emergency lighting**
  - ✓ Every commercial project requires some method of providing emergency egress lighting.
  - ✓ Lighting control systems may work seamlessly with fixtures that contain integral batteries and transfer circuitry. However, integrating a lighting control system with EM fixtures supplied by an external EM power source is typically more complex.
    - In every single case, you need to ensure that, when transferring to EM power, any occupancy sensor or other light-limiting commands are locked out. The system is now in emergency mode, not energy-saving mode!
  - ✓ It is ***extremely*** important to pre-determine what method of EM lighting is used. Then, it is essential to consult with the control vendor to understand how their system works with that method of EM lighting, and if additional equipment or labor will be required to install a fully code-compliant system.

101

Selection Criteria

- **Security**
  - ✓ Every computerized system has strengths and weaknesses.
  - ✓ Understand what the customer's appetite for risk is:
    - ✓ Government, utility, financial, or medical facilities probably have stricter security requirements than general office space
    - ✓ Are WiFi-based systems banned, but other wireless protocols allowed?
    - ✓ How should users be granted access to the software controls?
  - ✓ Manufacturers understand these concerns, and are answering questions about them every day. Ask them!
  - ✓ Check the DLC QPL, where manufacturers have the option of providing information about system security.

102

Budgeting Your Selected System

- How much am I spending right now?
- What could I potentially save for a given space?
- How much would it cost me to get those savings?
- How much of a utility incentive can I receive?

	Benefits				Costs				
Space Type	Yearly lighting energy spending	Networked Control Type	Potential savings	Yearly savings	Equipment	Labor	Incentive	Total	Payback, years
Office	$10,000	Simplified, non-integrated	43%	$4,300	$8,000	$5,000	$3,000	$10,000	2.3
		Simplified, integrated retrofit	63%	$6,300	$12,000	$3,500	$4,000	$11,500	1.8
		Comprehensive	82%	$8,200	$20,000	$9,000	$5,000	$24,000	2.9

Potential savings drawn from "Energy Savings From NLC Systems", DLC, 2017

103

5. Application Examples

104

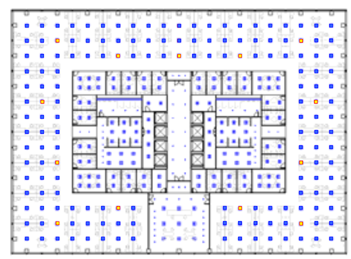
Welcome slide to be completed

- Wow! There sure are a lot of different ways to light an office. We're going to look at six different ways to do an office. Work on this intro tbd

		#1	#2	#3	#4	#5	#6
Complexity	Simplified	✓	✓	✓			
	Comprehensive				✓	✓	✓
Network to lights	Wired			✓			✓
	Wireless	✓	✓		✓	✓	
Sensor integration	LLLC	✓	✓		✓	✓	
	Standalone			✓			✓

105

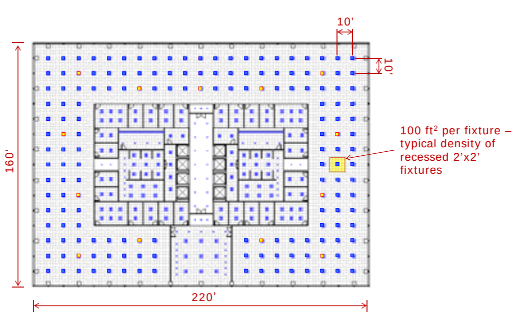
Office Plan – Showing Furniture and Recessed 2'x2' LED Fixtures



22,302 ft² total open office area – 35,200 ft² floor plate including core

106

Office Plan – Showing Recessed 2'x2' LED Fixtures and 2'x2' Ceiling Grid



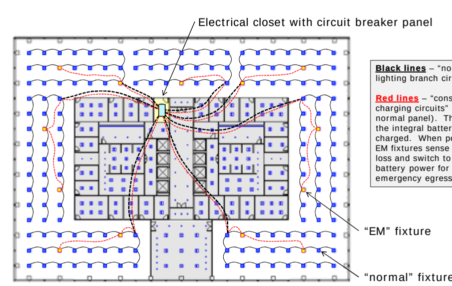
107

3D2 animated

Typical existing circuitry – EM fixtures with integral batteries

22,302 ft² total open office area

2'x2' LED fixtures located 10' x 10' O.C.



Black lines – "normal" lighting branch circuits

Red lines – "constant charging circuits" (from normal panel). These keep the integral batteries charged. When power fails, EM fixtures sense the power loss and switch to integral battery power for emergency egress lighting.

108

Slide 108

BD2 I want to shave some time from this section and hide EM topics, to focus on the things that came up most at the NGLS installation competition this January.

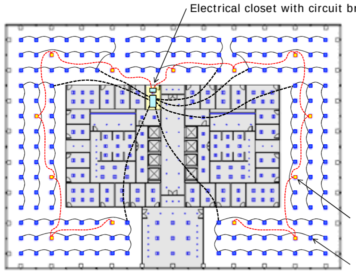
Bosetti, Damon, 1/24/2018

animated

Typical existing circuitry – EM fixtures powered by separate EM circuit and power supply

22,302 ft² total open office area

2'x2' LED fixtures located 10' x 10' O.C.



Black lines – "normal" lighting branch circuits

Red lines – "EM" lighting branch circuits. EM fixtures can operate normally (depending on the system), but have to bypass any controls in an emergency condition. Automatic transfer to an EM power source happens at the panel.

109

Simplified Networked System, Wireless, LLLC

		#1	#2	#3	#4	#5	#6
Complexity	Simplified	✓					
	Comprehensive						
Network to lights	Wired						
	Wireless	✓					
Sensor integration	LLLC	✓					
	Standalone						

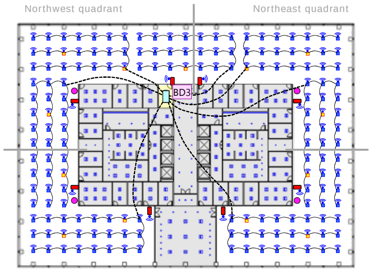
110

animated

Simplified Networked System, wireless, with Fixture-Integrated Sensors

LEGEND:

- Existing circuit breaker panel
- 2x2 fixture (normal power) with wireless controller, integrated occupancy sensor and photosensor
- EM fixture (integral battery) with wireless controller, integrated occupancy sensor and photosensor
- Wireless gateway
- Wireless wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)



111

Simplified Networked System, Wireless, LLLC, and BMS connection

		#1	#2	#3	#4	#5	#6
Complexity	Simplified		✓				
	Comprehensive						
Network to lights	Wired						
	Wireless		✓				
Sensor integration	LLLC		✓				
	Standalone						

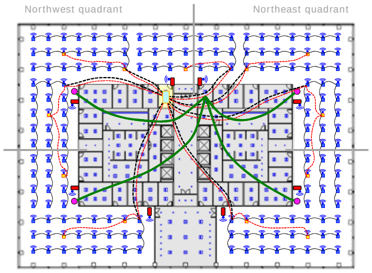
112

animated

Simplified Networked System, Wireless, LLLC, and BMS connection

LEGEND:

- Existing circuit breaker panel
- 2x2 fixture (normal power) with wireless controller, integrated occupancy sensor and photosensor
- EM fixture (integral battery) with wireless controller, integrated occupancy sensor and photosensor
- Wireless gateway
- Wireless wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- Cat 5 Ethernet network cable to BMS (communicates via BACnet)



113

Simplified Networked Systems, Wired, Standalone Sensors

		#1	#2	#3	#4	#5	#6
Complexity	Simplified			✓			
	Comprehensive						
Network to lights	Wired			✓			
	Wireless						
Sensor integration	LLLC						
	Standalone			✓			

114

Slide 111

BD3 See the slide as a template. I've removed the EM power lines, but left the EM fixtures. This lets us simplify the visual appearance, while still delivering the basic message of "each EM layout will be unique. Be sure you understand what it is, and what the manufacturer recommends you do to accommodate it."
Bosetti, Damon, 1/24/2018

Slide 112

BD5 This next system straddles the line between "Simplified" and "Comprehensive" and is built on the system we just looked at.
Bosetti, Damon, 1/24/2018

Slide 113

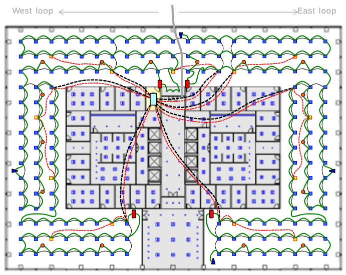
BD4 Remove constant-charging circuit, keep EM-designated lights. The big thing here is to show that the simple zones can be stitched together into a simple BMS connection. I changed this from BACnet to reduce the jargon level.
Bosetti, Damon, 1/24/2018

BD6 BD7 animated

Simplified Networked System, Wired, Standalone Sensors

LEGEND:

- Existing circuit breaker panel
- 2x2 fixture (normal power) with integral controller
- EM fixture (integral battery) with integral controller
- Occupancy sensor
- Photosensor (open-loop)
- Local wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- Cat 5 Ethernet network cable



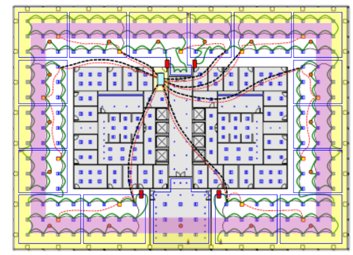
115

BD8 BD9

Simplified Networked System, Wired, with Zone-based Sensors (meeting code requirements)

LEGEND:

- Primary daylight zone
- Secondary daylight zone
- Occupancy zones (for "automatic shutoff"



116

Comprehensive Networked System, Wireless, LLLC

		#1	#2	#3	#4	#5	#6
Complexity	Simplified						
	Comprehensive				✓		
Network to lights	Wired						
	Wireless				✓		
Sensor integration	LLLC				✓		
	Standalone						

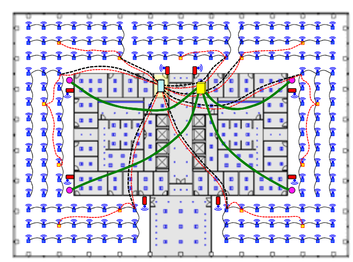
117

BD10 animated

Comprehensive Networked System, Wireless, LLLC

LEGEND:

- Existing circuit breaker panel
- Server (in IT room)
- 2x2 fixture (normal power) with wireless controller, integrated occupancy sensor and photosensor
- EM fixture (integral battery) with wireless controller, integrated occupancy sensor and photosensor
- Wireless gateway
- Wireless wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- Cat 5 Ethernet cable



118

Comprehensive Networked System, Wireless, LLLC: With Cloud Server

BD11

		#1	#2	#3	#4	#5	#6
Complexity	Simplified						
	Comprehensive					✓	
Network to lights	Wired						
	Wireless					✓	
Sensor integration	LLLC					✓	
	Standalone						

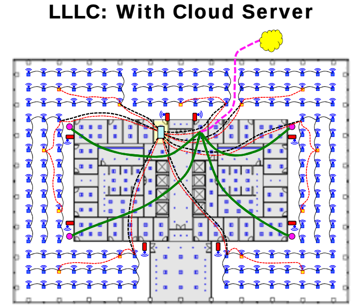
119

BD12 BD13 animated

Comprehensive Networked System, Wireless, LLLC: With Cloud Server

LEGEND:

- Existing circuit breaker panel
- Connection to cloud (via owner's IT infrastructure)
- Cloud-based server
- 2x2 fixture (normal power) with wireless controller, integrated occupancy sensor and photosensor
- EM fixture (integral battery) with wireless controller, integrated occupancy sensor and photosensor
- Wireless gateway
- Wireless wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- Cat 5 Ethernet cable



120

Slide 115

BD6 Remove constant-charging circuit, keep EM-designated fixtures.
Bosetti, Damon, 1/24/2018

BD7 I changed from "zoned" to "standalone" on feedback from Levin. Even LLLC can be zoned, whereas "standalone" sensors that are not LLLC need to be zone-assigned in the software.
Bosetti, Damon, 1/24/2018

Slide 116

BD8 We need to lighten up on specific code callouts in this general course. "More aggressive building codes" is fine, but CA or specific ASHRAE callouts hurt our ability to localize for specific users.
Bosetti, Damon, 1/24/2018

BD9 Remove EM wiring from diagram. Otherwise maintain and keep the discussion of how software-zoned sensors can be used to give feedback to lights in multiple zones.
Bosetti, Damon, 1/24/2018

Slide 118

BD10 Remove constant charging circuit. Keep EM-designated lights.
Bosetti, Damon, 1/24/2018

Slide 119

BD11 This is the same layout we just worked on, but with one major difference: the control server, or hub, is not on site. It's in the cloud.
Bosetti, Damon, 1/24/2018

Slide 120

BD12 Remove constant-charging circuit. Keep EM-designated fixtures.
Bosetti, Damon, 1/24/2018

BD13 What if we pulled out the branch circuit wiring in all diagrams too? What didactic purpose does it serve? We aren't showing how to do switched-leg relay control. And, the lack of branch circuit wiring will emphasize how much more wiring POE, say, adds to a project.
Bosetti, Damon, 1/24/2018

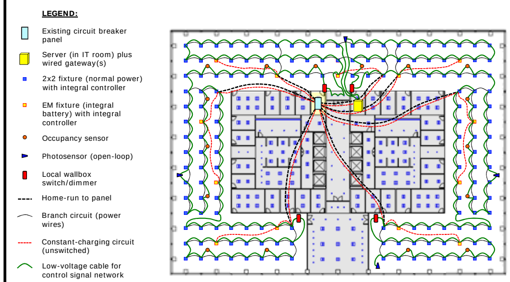
Comprehensive Networked System, Wired, Standalone Sensors

		#1	#2	#3	#4	#5	#6
Complexity	Simplified						
	Comprehensive						✓
Network to lights	Wired						✓
	Wireless						
Sensor integration	LLLC						
	Standalone						✓

3D14

animated

Comprehensive Networked System, Wired, Standalone Sensors



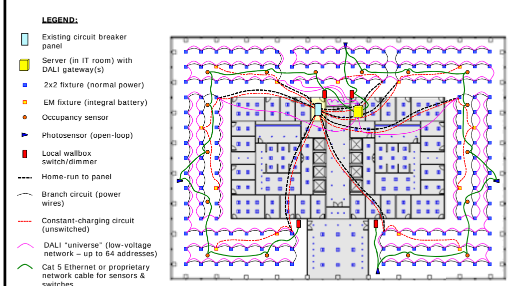
3D15

Comprehensive Networked Systems with Server – wired, with Zone-based Sensors

(using DALI protocol for communication to fixtures; with separate proprietary network for sensors and switches)

animated

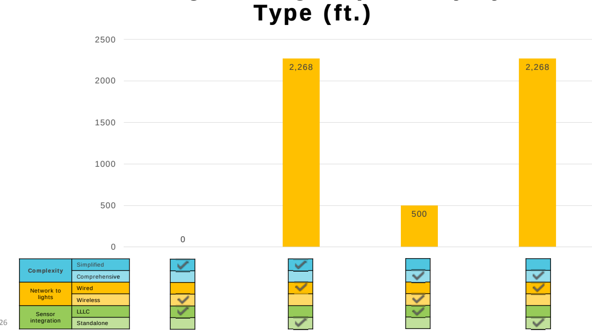
Comprehensive Networked System with Server – wired with zone-based sensors – DALI



Comparing Wiring and Termination Requirements of Each System

3D16

Low-Voltage Wiring Required by System Type (ft.)



Slide 122

BD14 Remove constant-charging circuit, keep EM-designated lights
Bosetti, Damon, 1/24/2018

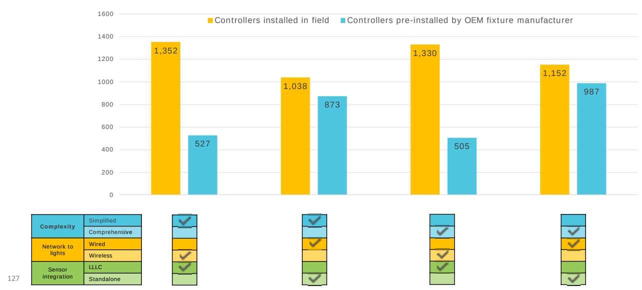
Slide 123

BD15 Given that this is an intro-level class for the trades, should we focus this much on DALI specifics? Plug-and-play, simplified wireless systems are the desired outcome for most of our students. Consider hiding these slides.
Bosetti, Damon, 1/24/2018

Slide 126

BD16 Cleaned up the labels for easier at-a-glance understanding.
Bosetti, Damon, 1/24/2018

of Required Wiring Terminations by System Type



127

Application Workshop

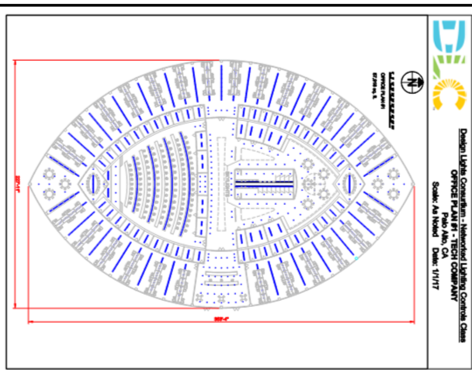
128

Considerations in the selection process

- Would you use a simplified or comprehensive system? Why or why not?
- Wired or Wireless?
- Replace fixtures or not?
- Integrated per-fixture sensors (LLLC) or not?
- Individually addressable fixtures or not?
- What control strategies would you use? (scheduling, occupancy, daylight, high-end trim, plug load control, demand response)
- Energy Monitoring or not?
- Tie into other Building Systems?
- What other capabilities might be important?

Office plan #1

- Single-story standalone building on a multi-building campus of a large tech company in Silicon Valley (Palo Alto, California). This space is used for offices as shown, but also for training both for staff as well as customers.
- Owner occupied.
- New construction; building designed by full design team including all appropriate consultants. (Not design/build.)
- Proposed light fixtures – 4' linear LED uplight/downlights mounted in continuous rows as shown. Each 4' segment has two LED drivers – one for the uplight component and one for the downlight component (so uplight and downlight can be separately controlled). Light distribution is 50% uplight/50% downlight. Maximum input power for each 4' segment is 50 watts.
- Window walls have automated shading systems.
- Ceiling heights are 10'-0" AFF throughout.
- Light finishes throughout (ceiling, walls, furniture, etc.).

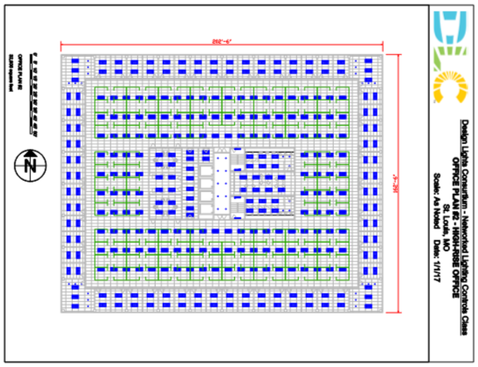


Office plan #2

- High-rise building in downtown St. Louis (Missouri). This space is used exclusively for offices as shown.
- Tenant occupied (single tenant occupies 8 floors of the 20-story tower). Tenant has negotiated a lease extension including a provision for the owner to retrofit 4 floors/year over two years with new lighting and control systems.
- All building systems are maintained, operated and serviced by the owner's staff.
- Existing (retrofit).
- Light fixtures – 2'x4' 3-lamp 18-cell fluorescent parabolic troffers. Maximum input power for each fixture is 96 watts.
- Window walls have manual shading systems.
- Ceiling heights are 9'-0" AFF throughout.
- Light finishes throughout (ceiling, walls, furniture, etc.).

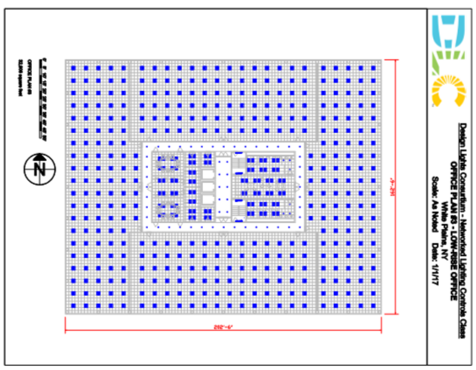
Slide 127

BD17 Cleaned up the labels for easier at-a-glance understanding.
Bosetti, Damon, 1/24/2018



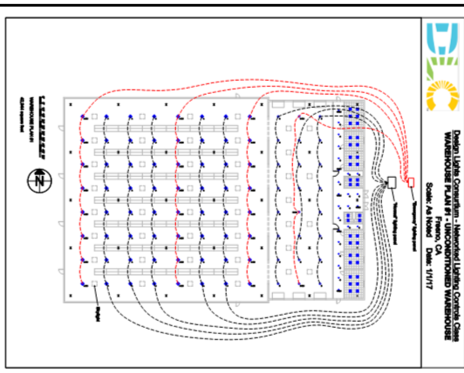
Office plan #3

- 3-story speculative office building in White Plains, NY (suburban NYC). The ground floor is used for parking. This plan shows the layout for the 2nd and 3rd floors which will be rented out to a variety of tenants. Tentatively, each floor will be split into 4 separate units as shown.
- Tenant occupied.
- New construction.
- Light fixtures – 2' x 2' LED troffers. Maximum input power for each fixture is 45 watts.
- Window walls have manual shading systems.
- Ceiling heights are 9'-0" AFF throughout.
- Light finishes throughout (ceiling, walls, furniture, etc.).



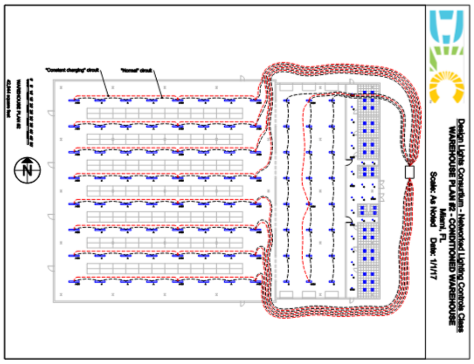
Warehouse plan #1

- Single-story standalone warehouse/shipping facility in Fresno (California).
- Owner occupied.
- Existing (retrofit).
- Light fixtures – 250-watt metal halide high-bays. Light distribution is 20% uplight/80% downlight. Maximum input power for each fixture is 300 watts.
- Existing 4' x 4' skylights as shown over each aisle provide diffuse daylight.
- Ceiling heights are 30'-0" AFF in the warehouse area, 20'-0" AFF in the shipping area, and 10'-0" AFF in the entry/office area.
- Medium finishes throughout (ceiling, walls, etc.).
- "Emergency" fixtures are indicated by connection to the EM Lighting Panel – with circuitry shown as dashed red lines. "Normal" fixtures are indicated by connection to the Normal Lighting Panel – with circuitry shown as dashed black lines. Upon loss of normal power, an Automatic Transfer Switch provides power from an emergency generator to the "EM" fixtures. (EM fixtures are provided with special equipment that maintains the arc in the lamp until emergency power is provided by the generator.)



Warehouse plan #2

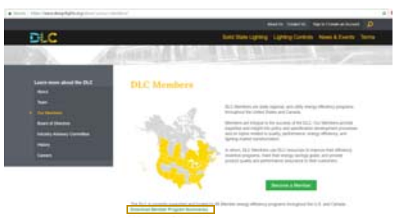
- Single-story standalone warehouse/shipping facility in Miami (Florida). This facility is used for storing and shipping cold/frozen foods.
- Owner occupied.
- New construction.
- Proposed light fixtures – 8' linear LED uplight/downlights in the warehouse area; 4' linear LED uplight/downlights in the shipping area. Light distribution is 10% uplight/90% downlight. Maximum input power for each fixture is 200 watts for the 8' fixtures and 100 watts for the 4' fixtures.
- Since the facility is used for storing cold/frozen foods, no skylights will be incorporated into the roof.
- Ceiling heights are 30'-0" AFF in the warehouse area, 20'-0" AFF in the shipping area, and 10'-0" AFF in the entry/office area.
- Medium finishes throughout (ceiling, walls, etc.).
- "Emergency" fixtures are indicated by connection to the Normal Lighting Panel with circuitry shown as dashed red lines. This is in addition to the normal circuits shown as dashed black lines. All "EM" fixtures have integral batteries that provide sufficient light output in an emergency egress situation. Upon loss of normal power, the integral battery provides power for up to 90 minutes as required by code.



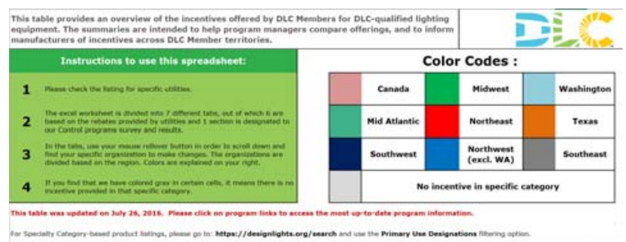
6. How to find information about programs from your utility for advanced lighting controls

DLC Member Program Summaries

- What programs exist to give rebates for ALCS products?
- DLC has surveyed and summarized its utility members' programs for you!
- Go to https://www.designlights.org/about-us/our-members/ and click on "Download Member Program Summaries".



Program Summary Spreadsheet



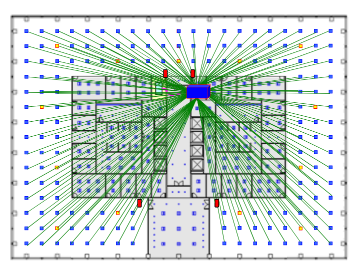
Comprehensive Networked Systems with Server – PoE

animated

Comprehensive Networked System with Server – PoE

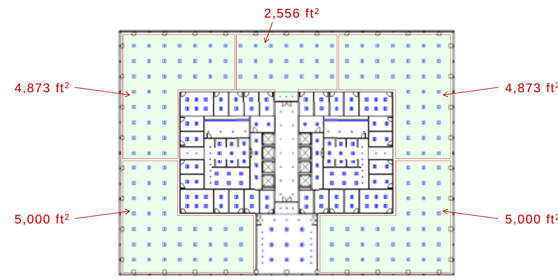
LEGEND:

- Existing circuit breaker panel
- Network switch (in IT room)
- 2x2 PoE-enabled fixture (normal power)
- PoE-enabled EM fixture (with integral battery)
- Local wallbox switch/dimmer (PoE)
- Power to Network switch
- Cat 5 Ethernet cable for fixtures & switches



Room-Based Controls (Room Controllers)

Control Zones for "Automatic Full OFF" & "Manual Override" (5,000 ft² max.)

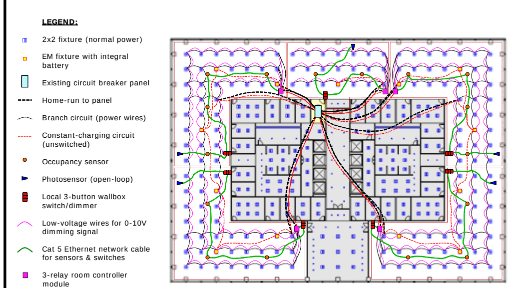


22,302 ft² total open office area

Daylighting Zones

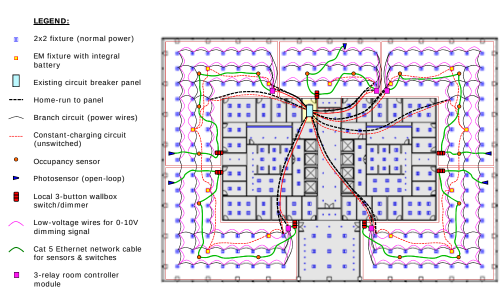
Room-Based System (Room Controllers)

animated



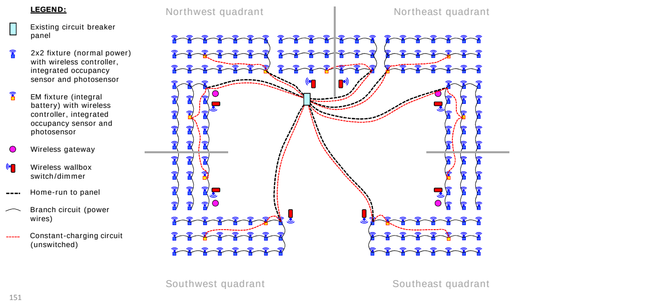
Room-Based System (Room Controllers)

animated



Control System Schematics without Base Floor Plans

Simplified Networked System with Fixture-Integrated Sensors



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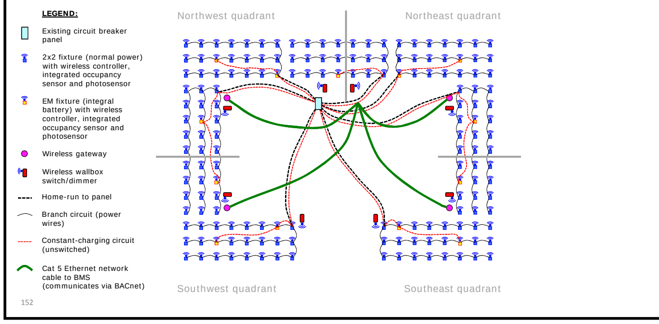
Simplified Networked System with Fixture-Integrated Sensors & BACnet connection



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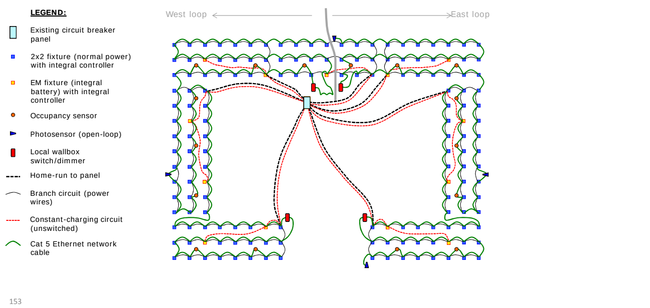
Simplified Networked System without Fixture-Integrated Sensors



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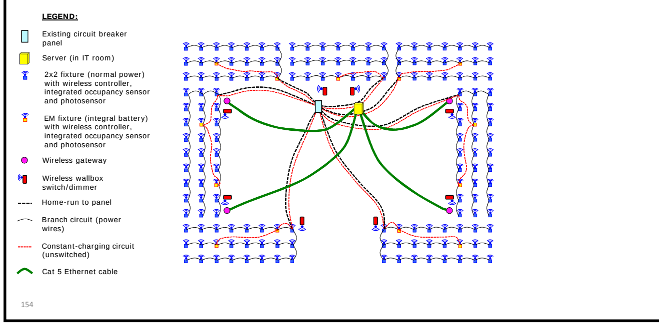
Comprehensive Networked System with Server – wireless with integrated sensors



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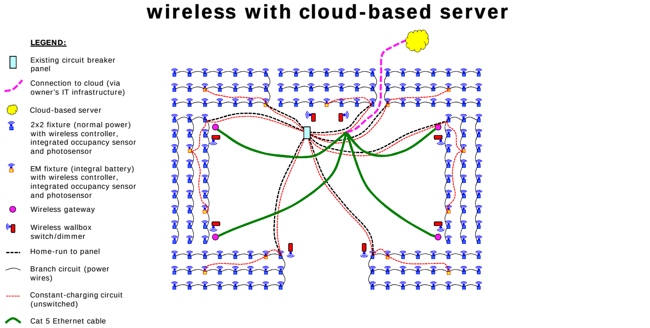
Comprehensive Networked System with Server – wireless with cloud-based server



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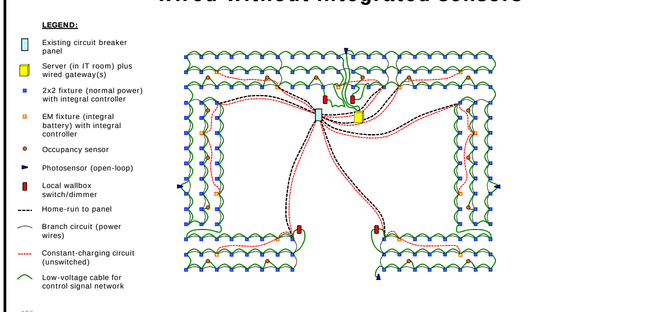
Comprehensive Networked System with Server – wired without integrated sensors



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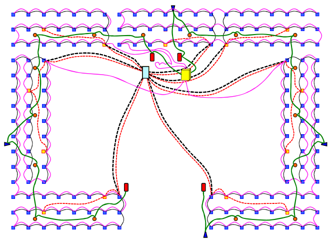
Comprehensive Networked System with Server – wired without integrated sensors – DALI

LEGEND:

- Existing circuit breaker panel
- Server (in IT room) with DALI gateway(s)
- 2x2 fixture (normal power)
- EM fixture (integral battery)
- Occupancy sensor
- Photosensor (open-loop)
- Local wallbox switch/dimmer
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- DALI "universe" (low-voltage network – up to 64 addresses)
- Cat 5 Ethernet or proprietary network cable for sensors & switches



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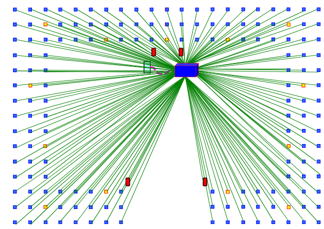
Comprehensive Networked System with Server – PoE

LEGEND:

- Existing circuit breaker panel
- Network switch (in IT room)
- 2x2 PoE-enabled fixture (normal power)
- PoE-enabled EM fixture (with integral battery)
- Local wallbox switch/dimmer (PoE)
- Power to Network switch
- Cat 5 Ethernet cable for fixtures & switches



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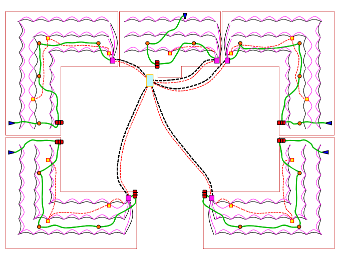
Room-Based System (Room Controllers)

LEGEND:

- 2x2 fixture (normal power)
- EM fixture with integral battery
- Existing circuit breaker panel
- Home-run to panel
- Branch circuit (power wires)
- Constant-charging circuit (unswitched)
- Occupancy sensor
- Photosensor (open-loop)
- Local 3-button wallbox switch/dimmer
- Low-voltage wires for 0-10V dimming signal
- Cat 5 Ethernet network cable for sensors & switches
- 3-relay room controller module



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Unified Incentive Structure for Advanced Lighting Control Systems (ALCs)

Traditional efficiency program incentive structures for ALCs (prescriptive/deemed and custom) are highly variable from program to program, making it difficult for manufacturers, vendors, national accounts, and end users to participate. This lack of consistency among efficiency programs prevents a significant leveraging and partnership opportunity with the lighting market to accelerate widespread adoption of ALCs. Further, the traditional program offerings that have been deployed for ALCs are not market-friendly. Utility incentives are unpredictable and utility processes are complex and time-consuming. DLC is working with member utilities and the lighting industry to develop new market-friendly, unified incentive approaches for ALCs. When combined with the DLC Advanced Lighting Control Specification and Qualified Products List (QPL), this new unified approach by efficiency programs will provide the framework necessary to enable at-scale partnerships with the lighting market to achieve widespread adoption. This document outlines two complimentary unified, market friendly incentive structures developed in partnership with DLC member utilities to support the widespread adoption of ALCs.

Approach 1: Prescriptive Incentive for Luminaires PLUS Additional Incentive for Integrated Sensors with Networking

The simple structure of a set prescriptive incentive that is provided for each product installed is a market-friendly incentive approach that supports high volume application. Market actors can easily predict what the incentive will be based on the products they are proposing to install and the simple structure and repeatability of this method allows utility energy efficiency programs to develop processes to support high volume participation. To best support high volume participation and adoption of ALCs within energy efficiency programs, it is important that utilities develop a prescriptive incentive approach for them.

DLC proposes a prescriptive incentive structure targeted to simpler, self-contained ALC systems, specifically, luminaires with integral sensors that are networked to one another, but has the flexibility to work with systems that use a central control system in addition to embedded sensors. These systems will provide at a minimum energy savings capabilities including occupancy sensing, daylight harvesting, and task tuning with the capability to zone and layer control strategies.

The prescriptive approach would consist of an incentive for a DLC qualified luminaire with integrated sensor PLUS an additional incentive if controlled by a qualified system.

Considerations

- <u>Targeting:</u> The approach will be targeted to simpler integrated systems and predictable room use types such as commercial office spaces (Corporate office, tenant fit-outs) or Warehouse/storage that see high-volume, predictable application.

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- Eligible Products: The forthcoming DLC QPL for ALCs will provide the capability to filter the list to products that qualify for this prescriptive incentive.
- Savings: Set deemed savings amounts will be determined for the measure. DLC will provide assistance to members on determining this amount.
- Application of Incentive: The prescriptive incentive can be provided downstream to the end-user in through a traditional approach or through a midstream incentive paid directly to the distributor. A midstream incentive approach should be considered to motivate distributors to stock and actively sell qualified products.
- Scalability: DLC will define the structure, but individual programs should scale or set the incentive to their specific program budget.

Approach 2: Custom Approach with Predictable Incentive using $/Sq. Ft. Incentive Metric

The Custom Approach with Predictable Incentive combines the ability to capture savings accurately through a custom savings methodology with a predictable incentive metric: dollars per square foot ($/SF). Building owners and managers are familiar with pricing using $/SF for comparing costs for building materials and construction costs. This predictable metric allows lighting market actors and customers to easily determine, cost justify, and prioritize ALCs projects as well. The predictable $/SF incentive metric works well for implementing broadly across different programs and markets, and can be scaled to fit each program's incentive budget.

Considerations

- Targeting: Targeted to larger building types (retail distribution, warehouse, corporate real estate) and/or more complex control systems that may include monitoring and reporting capabilities and other advanced features.
- Eligible Products: The forthcoming DLC QPL for ALCs will provide a list of eligible products. Members may filter the DLC QPL list if desired to identify systems with specific capabilities such as energy monitoring.
- Savings: While this approach utilizes a "prescriptive" incentive dollar amount based on the square footage affected, the project review and savings analysis will follow a typical custom process as specified by the member efficiency program. Savings assumptions will either use the forthcoming DLC ALCS Energy Estimator Tool, or be based on data from multiple sources for targeted applications to correlate the $/SF amount to average kWh savings/square foot. This information will be made available to programs to forecast program savings estimates. Risk mitigation strategies for custom savings estimates will be implemented at the program level and may include:
    - M&V results used to normalize claimed savings after project completion
    - Holdback/retainer on incentive provided after project completion based on modeling or pre-meter data versus actual measurement reported after completion.
    - Use of gateway requirements for participation such as: minimum project/building size, building level control, or targeted space use type characterized by end use)

    - Verification of the affected square footage using site plans and drawings with additional documentation for control schedule and order of operations (control narrative) for project analysis to determine layering savings.
- Scalability to individual programs: This predictive incentive model is customizable at the program level to individual incentive budgets, deemed values, and evaluation requirements.
    - DLC will provide programs with estimated savings in $/kWh to correspond with $/SF. Programs can scale the suggested $/SF number up or down based on individual program budgets.
    - The DLC will maintain a list of actual $/SF incentives for all utilities that adopt the strategy. The DLC will make this incentive list available to manufacturers and vendors to easily determine what $/SF incentives are offered by each DLC Member utility.

For Additional information regarding either of these approaches or other information contained in this memo, please contact Liesel Whitney-Schulte lschulte@neep.org or Gabe Arnold garnold@neep.org.

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