An Approach to Promoting Smart Lighting for Industry

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ABSTRACT

The paper discusses how industrial lighting design practices can be used to promote energy savings and load reduction/management opportunities. In particular, the paper details the DesignLights™ Consortium's experiences in the development and use of lighting design guides, projects, and the case studies.

Lighting is generally not considered a key target technology for industrial facility energy efficiency improvements, but several new technologies and design practices allow for substantial energy use reductions in providing high quality lit industrial environments. Industrial facility lighting in the US consumes approximately 89 TWh per year, and currently available technology could reduce this consumption by 20-35 percent.

This paper reports on the progress to date of the DesignLights™ Consortium in tackling the industrial facility lighting market, including information about the challenges faced, strategies employed, and early indicators of success in the work. The work of the DesignLights™ Consortium attempts to complement efforts underway by others by providing user friendly, simple to understand tools for use by various practitioners in the lighting and construction industry.

Introduction

Utility (or other public benefit provider) energy efficiency programs typically have targeted specific lighting technologies with incentives or other programmatic approaches. Not much has been done to systematically investigate the opportunities for energy reductions or load management through improved design practices, including broader use of natural sky- or day-lighting. Recently, a number of efficiency services administrators in the Northeast region of the US have banded together to develop lighting design guides, and other follow-on materials such as case studies of well-designed spaces, to encourage energy effective lighting designs in industrial and warehouse spaces. Significantly, the effort seeks to influence design practices, not simply promoting a list of more efficient equipment. The materials developed encourage industrial businesses, and the market channels that support them (including electrical contractors and lighting distributors) to adopt best practices in lighting system design when renovating or building new facilities.

Lighting constitutes a relatively small percentage of total industrial electric use, ranging from 3.5 percent in primary metals to 15 – 17 percent in industries characterized by extensive assembly activities. These latter industries are fairly heavily represented in the Northeast. On average, about 7 percent of industrial electric consumption is used for lighting. It is estimated that lighting energy use in US industrial buildings accounts for approximately 89 TWh annually (Brodrick et al 2002).

While lighting power densities are on average lower for industrial buildings than commercial buildings due to higher efficacy of the light sources used, the generally longer operating hours of industrial facilities results in higher overall lighting energy intensity (kWh/year/sf), as summarized in Table 1 below.

Table 1. Lighting Energy Use per square foot in Commercial and Industrial Buildings

Building Sector	Installed Wattage (w/sq mtr)	Mean Efficacy (lm/w)	Illuminance (fc, CU=0.5)	Operating Hours (hrs/day)	Energy Intensity (kWh/yr/m)
Commercial	17.9	55	45	9.8	62.4
Industrial	14.0	75	48	13.9	71.0

Source: Brodrick et al 2002

Industrial building lighting has a much higher market penetration of more efficient lighting sources, including fluorescent and high intensity discharge (HID) sources, which results in the lower installed wattage as shown above. HID sources account for approximately 29% of the delivered lumens in industrial buildings, more than double the portion for commercial buildings.

Even with this more efficient starting point, substantial savings potential remains. Newer HID technologies, and new fixtures utilizing the latest fluorescent sources that direct the light to where it is most needed, have been demonstrated to dramatically reduce light levels in some buildings. A very significant opportunity also exists to improve the designs of the lighting systems, including more effective fixture layouts, daylighting/skylighting, and use of better controls to optimize lighting energy use.

The DesignLights™ Consortium

The DesignLights™ Consortium (DLC) is a regional collaboration seeking to influence naturally occurring lighting events toward quality, comfort, and efficiency. DLC's mission is to encourage and facilitate the implementation of improved design practices in all parts of the commercial lighting market such that high quality energy-efficient lighting design (or "smart lighting") becomes commonplace. DLC is a market-oriented initiative that focuses more on the practices of the market players rather than the technologies related to commercial lighting (i.e., as typically promoted through ratepayer energy efficiency program offerings). Building market awareness for ***smart lighting*** is the cornerstone of sustainability and success of the DLC to change the practices of the market players. Creating market awareness includes building alliances and developing partnerships with market players involved in the targeted commercial building sectors.

The DLC's mission is to encourage lighting decision-making market players to understand and consider the benefits of ***smart lighting***. The primary beneficiary of better lighting is the owner/occupant of the building. However, to provide the benefits of high quality lighting to this consumer, there are many others in the decision-making chain that need to be better educated. The DLC attempts to address the concerns and needs of the lighting practitioner who interacts with the end user at the time of project transaction.

DesignLights™ Consortium (DLC) was organized in 1998 to establish quality, energy efficient lighting design as a standard practice in the Northeast. In order to carry out its vision, the DLC developed useful tools for use by market actors and decision makers associated with quality lighting installations. For smaller commercial building spaces, electrical contractors, distributors and lighting suppliers are often key players in the selection and design of lighting systems. The tools were developed to help these key market players promote and specify ***smart lighting*** to their customers, helping customers achieve better lighting, lower operating costs, improve tenant retention and higher building value … resulting in a reasonable payback for their investment.

The primary tools developed by the DLC were seven technical design guides, called the *knowhow*™ Series, for common space types: office, retail, classroom, highbay industrial, lowbay industrial, warehouse with skylighting and retail with skylighting. These lighting design guides are intended to provide an alternative to the standard designs that many contractors and/or building owners may currently be using (the guides can be downloaded from www.designlights.org or can be requested from the Northeast Energy Efficiency Partnerships or one of the DLC sponsors). The goal was to influence the identification, specification and installation of lighting projects such that efficient lighting products with efficient lighting design are achieved, resulting in ***smart lighting***. High quality energy efficient lighting (or "smart lighting") is defined as that which is aesthetically and visually superior in meeting the needs of occupants, while being more energy efficient than the typical lighting practices for similar applications.

To promote the installation of energy efficient lighting and design, the DesignLights™ Consortium has developed a series of case studies highlighting good lighting design practices in real-world applications. These case studies (currently, over 23 in publication) illustrate how the *knowhow*™ Series can be put into practice. Training of over 1,000 lighting practitioners and lighting distributors was provided in the Northeast Region, New York and New Jersey to educate and build awareness about the benefits of ***smart lighting***.

The *knowhow*™ guides and case studies are primarily distributed to the marketplace by the DLC sponsors through their energy efficiency programs. In the first three years of the initiative, an intensive training and outreach program was conducted across the Northeast. One sponsor, the New York State Energy Research and Development Authority (NYSERDA) has also had success using lighting equipment distributors and installation contractors to employ the material in their day to day business activities through the **New York Energy $mart^sm^** Small Commercial Lighting Program.

The work of the DesignLights™ Consortium attempts to complement efforts underway by others, including the Lighting Research Center of the Rensselaer Polytechnic Institute. LRC has done a lot of research on the subject of industrial lighting which would require a separate paper so won't be discussed here. More information in the work of the Lighting Research center can be found at http://www.lrc.rpi.edu

Identifying the Need for Warehouse/Small Industrial Lighting

The goals behind developing a lighting guide for small industrial facilities were two fold: 1) To develop a defensible baseline of current practice; and 2) To develop a single guide for generic space types in small industrial facilities less than 50,000 square feet undergoing new construction, remodeling/major renovation or major retrofit lighting activity. Based upon these two principles, it was important to develop a tool that would continue to serve the long term goal of DLC, to foster the widespread adoption of design practices that encourage ***smart lighting*** design. Additionally, it was important to establish a benchmark for practices and energy efficiency which could be used to assess progress in changing or "transforming" market practices as they pertain to the specification, design and installation of energy efficient lighting components and systems for the commercial market, including industrial facilities.

The development of the small industrial lighting guide was based on focus group results (Atlantic Marketing Research 2000) and a survey administered to various market actors involved in the design and installation of lighting in industrial facilities in the Northeast Region and New York and lighting data on industrial facilities taken from industrial energy audits (Xenergy 2001). The objective of the survey was to develop a preliminary characterization of efficient lighting design opportunities for the small industrial market sector.

The focus group and survey results indicated that most of the projects in the small industrial market involve new construction or major renovation instead of retrofit and that the facility owner or manager has greatest influence over equipment selection. As expected, high initial cost is the primary customer objection to purchasing energy efficient lighting technologies (including lighting controls). The customer needs to be convinced that there is a reasonable payback period to specify an energy efficient lighting upgrade.

Overview/Summary of the Industrial Design Guides

The challenge, at the onset, was to develop a guide (or a set of "rule of thumb" guidelines) that would address the fact that there are a variety of industrial spaces that have different ceiling heights and space dimensions, and different types of tasks requiring different levels of light, which would utilize different lighting technologies, yet conform to the template for the existing *knowhow*™ Series publications.

Survey results and energy audits provided a set of many variables that needed to be considered when designing lighting for industrial spaces. Two common industrial activities illustrating the range of lighting needs are active storage areas and detailed task work. Active storage space is affected by many variables that include: level of activity, ceiling height, aisle layout, size of items stored, the need to distinguish color, and rack heights. Various technologies are specified depending on ceiling height. Metal halide fixtures are typically specified for high bay applications (common size 250 – 400 Watts). Whereas low bay fixtures (i.e., using T12, T8 and T5 fluorescent technologies) are specified for the lower ceiling heights because they tend to be smaller, have closer spacing requirements, and use lenses that spread the light at greater angles.

Lighting for detailed tasks needs to consider the level and variety of activities, the sizes of the items being worked on, the amounts of time available to see them, and the ages of the workers performing the tasks. A 40-year-old person generally requires twice as much light to perform a task as a 20-year old. Relying on the general lighting system to provide adequate light for detailed tasks can result in high energy costs and overly bright ambient lighting. Locating light close to the task can provide higher light levels where it is needed, and eliminate shadows created by machinery or the workers themselves, while keeping overall lighting and energy costs down. It also allows for more control over lighting giving workers the ability to adjust lighting to meet specific task requirements.

Two important findings from the focus groups and surveys were that almost every respondent reported using some type of guideline for selecting equipment in industrial projects (i.e., IES standards), and that sample fixture layouts in the design guides were most useful in assisting lighting specifiers in the design of quality and energy efficient lighting.

In order to create a document that was not visually crowded, large layouts were needed, and more detailed information was needed to explain the different space types and task functions that have different illumination requirements. Also, the document needed to explain the various quality issues or derivation assumptions for the many variables that affect ***smart lighting*** design of the different space types and the tasks performed in an industrial facility. This led to a logical choice of either constructing a separate guide to address spaces with lower ceilings (less than 25 feet) requiring higher task illuminance, or to add to the high bay guide to provide information on these spaces.

First cost, a major market barrier, needed to be addressed and compared to quality, performance and energy savings for each lighting layout. It was decided that a table addressing all of these attributes together for each lighting layout would make a better tool for the user of the guide. This had been done for the first three *knowhow*™ guides published in 1999.

Thus, it was decided to develop two lighting design guides to address the small industrial lighting design: one for high bay ceilings (ceiling heights 25 feet or higher); and one for low bay ceilings (ceiling heights less than 25 feet), with the understanding that metal halide is the fixture of choice for coarse and storage activities and that fluorescent technologies dominate fine activities and task lighting typical of low bay industrial spaces (although new technologies in fluorescent high bay lighting are becoming more commonplace). The two guides were designed to be a companion to the first three lighting *knowhow*™ Series design guides for office, classroom and retail that were published in 1999.

Overview of Warehouse Skylighting Guide

At the time that the DLC was developing the highbay *knowhow*™ guide, an opportunity arose to piggyback on some work that was being done by a DLC sponsor, the NYSERDA. NYSERDA was considering a project to customize a skylighting design tool, SkyCalc™, which had initially been developed for use on the West coast. NYSERDA and the DLC decided to work together to both make the SkyCalc™ tools relevant for the Northeast, as well as develop additional *knowhow*™ guides to highlight the energy savings potential, and demonstrate appropriate uses of skylighting in two space types: warehouses and retail applications.

The warehouse skylighting design guide, like others in the *knowhow*™ series, includes general information, including skylighting design principles, information on efficient light sources and control strategies, and sample lighting and skylight layouts for effective design. It also includes results of SkyCalc™ software runs for these typical layouts, as well as information on how to use and access the design software.

Case Study Projects in Development

A number of case studies are under development by the DLC for release during the second quarter of 2003 highlighting industrial lighting applications. Two of the case studies are summarized here.

Gillette World Shaving Headquarter, Andover, Mass.

Gillette manufactures toiletries and shaving products for world markets. Gillette has a large plant in Andover, Massachusetts. DLC sponsor National Grid, examined the possibility of replacing the existing high pressure sodium (HPS) and metal halide fixtures with "high intensity fluorescent" high bay fixtures (so-called T-5 fixtures) in three of the primary warehouse areas. The fluorescent technology also afforded the opportunity to install occupancy sensors in the spaces. The layout closely follows "active highbay storage" layouts 4 or 5 in the Highbay Industrial Lighting *knowhow*™ guide which recommends high performance fluorescent lighting for warehouse aisles.

The warehouses consist of open spaces for staging raw materials and finished product and high, multilevel storage racks. In the case of the HPS, poor color rendering made tasks more difficult (reading labels and documentation). In addition, either of the high intensity discharge fixtures did not lend themselves to optimal lighting of the storage racks. Some light was being lost on the top of the racks and not fully illuminating the sides of the racks. The high intensity fluorescent fixtures focused light down the sides of the stacks more efficiently allowing product labeling be read more easily. In addition, the fluorescent lighting provided better color rendering properties, making the environment more comfortable for employees.

Occupancy controls were installed in various locations in the warehouse where there was opportunity to shut off lighting in areas with limited activity. Although not discussed in the Highbay Industrial Lighting *knowhow*™ guide, this is something that will likely be included in a future revision of it.

The area treated by the new lighting system was 375,000 sq. ft. A total of 510 HID fixtures were replaced with "high intensity fluorescent" fixtures. Of these, 267 of the fluorescent fixtures are controlled by occupancy sensors. Lighting power density decreased from 0.6 watts per square foot to 0.35 watts per square ft with an annual energy savings of nearly 1.12 million kWh[1]. Illuminance increased from 24 foot-candles to 48 fc with the new fluorescent system (measurements were taken at 30 inches above the floor). The CRI increased from as low as 65 to 85 with the new system.

Advanced DC Motors, Syracuse, NY

Advanced DC Motors designs and manufactures special purpose low voltage traction and pump motors, and markets them throughout the world. A 55,000 square foot industrial facility in Syracuse is their headquarters. City Electric Company Inc. (Ally Distributor) and CRI Electrical Contractors, Inc. (Ally Contractor), both Allies in the **New York Energy $mart**[SM] Small Commercial Lighting Program, worked together to design an energy

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[1] Energy savings includes savings from the occupancy controls and is based on 8,760 annual operating hours.

efficient lighting system that would resolve the lighting problems in the development lab. The principles and concepts used in their solution follow those presented in the Lowbay Industrial Lighting *knowhow*™ *Series* guide.

The development lab consists of a general area plus test and inspection areas where higher light levels are needed. The lab previously had a combination of indirect metal halide luminaires, strip fixtures, and recessed prismatic troffers. At 25 to 30 footcandles, the light level was well below Illuminating Engineering Society recommendations for "performance of tasks of high contrast or small size" (50 fc or higher), the lighting was uneven, and caused glare (this requirement is found in IESNA/ANSI Standard RP-7). Employees had a difficult time accurately completing their tasks.

The new lighting system uses a recessed 2X2 luminaire with two 40-watt, high color-rendering compact-fluorescent lamps. The high color rendering was important because the employees are performing tasks that require differentiating between similar colors. Its indirect feature provides an additional benefit in reducing glare. The 12 foot high ceiling with 2X2 grids lent itself to the luminaire selected. The even spacing of the luminaires (8 foot centers across and 6 foot centers along) provides even lighting. The new lighting uses less than 1.7 watts per square foot which is about half of the previous system. In the general lab space, the lighting power density is nearer to 1.24 watts per square foot. The space now has about 50 footcandles average, with the test and inspection areas at higher light levels of over 70 footcandles. The employees unanimously reported that the new lighting is more comfortable, more uniform, and easier to read under.

A complete cost analysis of this case study is being finalized as of this writing. For updated information, please refer to the DesignLights™ Consortium web site.

Conclusions

Smart lighting can contribute to the comfort of warehouse and manufacturing personnel by minimizing glare. Recent Studies done for schools and offices have shown that improved lighting also increases productivity. It may also contribute to their safety, especially around moving machinery. Glare control, balanced brightness ratios and reduced lamp flicker or strobe effect must be taken into account to increase safety and security in the work space.

Industrial lighting is generally fairly simple, but good practice is often forgotten. In most cases, people install lighting and don't consider changes that are made in the space or visual comfort of the occupants. Lighting is often installed without thought about how the tasks in the space will be conducted.

Attention to proper luminance and selection of light source can help worker productivity and morale. Recent studies done for schools and offices have shown that improved lighting quality also increases productivity of the occupants of the space, although to the best of the authors' knowledge, no similar study has been done for industrial space.

The colors of interior spaces, which can help with reflectivity, often make a very big difference. Besides lighting system, lighter color walls and ceiling/roof areas can help a great deal. When lighting meets both quantity and quality needs, it adds measurably to worker performance and productivity.

The types of fixtures used in industrial spaces are limited compared to the vast array of equipment available for other work places. Appropriately applied, however, they can help to create a comfortable and energy effective environment. First cost almost always rules in the minds of the building owner. The *knowhow*™ series attempts to overcome this barrier by giving people selling and specifying lighting an understanding of incremental costs and the benefits of ***smart lighting*** design.

References

Atlantic Marketing Research. October 2000. Focus Group Report for Energy-Efficient Lighting in Small Industrial Facilities.

Brodrick, Petrow and Scholand. 2002. Lighting Energy Consumption Trends and Conservation Opportunities in U.S. Buildings. Proceedings of RightLight 5, May 2002, Nice France.

DesignLights™ Consortium. 2000. Highbay Industrial Lighting *knowhow*™.

DesignLights™ Consortium. 2000. Warehouse Skylighting *knowhow*™.

Xenergy, Inc. March 2001. Final Report of the DesignLights™ Consortium Industrial Lighting Project.

Illuminating Engineering Society or North America, American National Standards Institute, *StandardRP-7, Recommended Practice for Lighting Industrial Facilities,* Table 1b, *Determination of Illuminance Categories*

Heschong Mahone Group for the Pacific Gas and Electric Company on behalf of the California Board of Energy Efficiency Third Party Program1999 and Re-analysis on behalf of the New Buildings Institute 2002 *Daylighting in Schools, an Investigation into the Relationship between Daylighting and Human Performance*"

Light Right Consortium, ongoing multi phase study that will address, among other things, the effects of lighting on productivity