US commercial building lighting programs addressing quality design and energy efficiency

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ABSTRACT

This paper surveys current lighting design programs aimed towards energy efficiency in commercial buildings in the US. There is evidence that much of the US market has been transformed toward more efficient linear lamps and ballasts, but there is great potential for further reductions in more efficient and effective lighting design and controls.

Lighting is a significant energy use that affects health, safety, and productivity in commercial and industrial built environments. Energy-efficient lighting practices must consider both technologies and design issues. Recently in the US, energy efficiency programs have recognized this and have been embracing design quality issues in conjunction with technologies. Several utilities and other public benefits providers in the US offer programs. As these programs grow, the need to benchmark, evaluate, and value both the energy and non-energy benefits of lighting design also grows.

INTRODUCTION

There is substantial potential for reducing commercial building lighting energy use in the United States (US) with improvements in the efficiency of the technologies and designs used in these buildings. Commercial buildings, which include office buildings, retail space, schools and other educational facilities, and numerous other business facilities, represent 30 % of US electricity consumption or over 1,035 terawatt-hours (TWh) each year.

There has been tremendous progress in energy savings in recent years due to technology improvements, particularly with electronic ballasts and more efficient lamps, but there is significant remaining potential. There is evidence that much of the US market has been transformed toward more efficient linear lamps and ballasts, but there is great potential for further energy savings through greater use of more efficient and effective lighting design and controls. Several recent studies (Easton 1997, NW Alliance 2000) have documented the potential and suggested program activities to effect the savings.

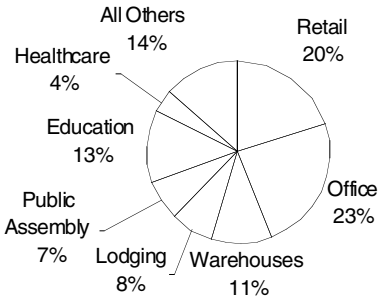
Numerous programs in the US are currently attempting to mine this potential, while maintaining or enhancing the quality of the lit environment. This paper provides an overview of some of these efforts.

Commercial Building Energy Use in the US

In the United States (US), the commercial sector represents 30 % of the country's total electric energy usage, and lighting energy use is approximately 36 % of this, or approximately 350 TWh of electric use in 2000. At the national average commercial electricity price of US$ 0.0722 (0.0828 EURO) per kWh, commercial lighting energy use costs US businesses over US$ 27 billion (31 billion EURO) per year (EIA 2001).

There is a wide range of building types included in the commercial building sector. The three most significant building types are offices, retail, and education. These three building types represent almost 60% of the total

Figure 1.



US Commercial Building Lighting Energy Use by Building Type (Vorsatz et.al. 1997)

Figure 2

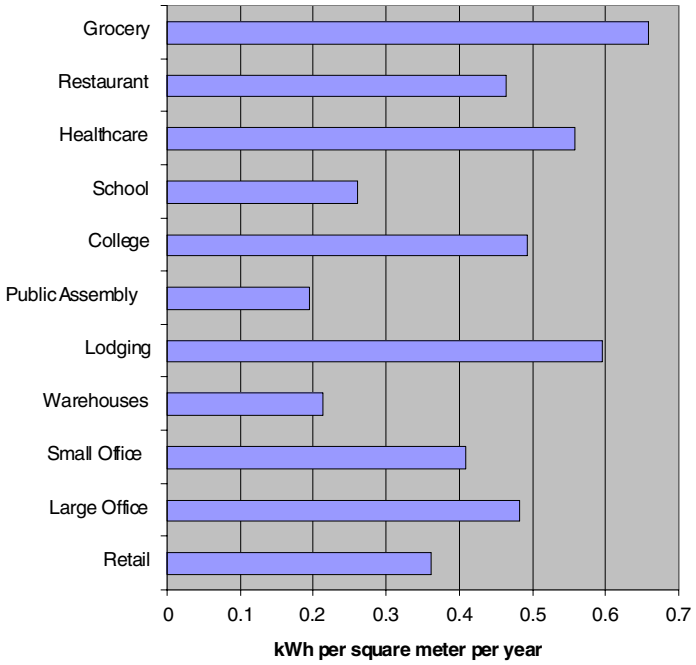


Figure 2. Lighting Energy Intensity by Building Type in kWh/m2/year (Vorsatz et.al. 1997)

commercial sector lighting electricity usage according to an analysis completed by Lawrence Berkeley National Laboratory (Vorsatz et.al. 1997). The distribution of lighting energy usage by building type is presented in Figure 1.

There is also a wide range of energy intensity in lighting energy usage among the various building types. Different building types require different illumination levels, and the prevalent types of lighting systems vary in these buildings. The average lighting intensity for the different building types is presented in Figure 2.

Historical Programs to Effect Commercial Lighting Efficiency

In the past two decades, the large cost of lighting commercial buildings, coupled with dramatic increases in efficient lighting technology, has spurred a lot of interest and investment in lighting efficiency. This activity has been driven largely by electric utility demand-side management (DSM) programs and the US Environmental Protection Agency's (EPA's) Green Lights program.

In the 1980s, utility DSM programs began to evolve as a result of environmental concerns, the need to conserve resources, regulatory initiatives and the desire to defer power plant and distribution system construction. Through these programs, electric utility companies provided their customers significant incentives for the installation of energy efficiency technologies including electronic ballasts, more efficient linear fluorescent lamps, and compact fluorescent lamps. US DSM programs grew dramatically through the early 1990s; a 1992 survey of 666 US utilities by the Electric Power Research Institute (EPRI) showed that over 2,300 programs were available. US lighting rebates alone grew from about US$ 160 million in 1990 to US$ 500 million in 1994 (Johnson 1995).

Beginning in 1991, the US EPA initiated its Green Lights program, which was one of the first and largest of the government's voluntary programs to reduce greenhouse gas emissions. The goal of the Green Lights program, and its successor Energy Star program, was to mitigate greenhouse gas emissions by transforming the markets for energy efficient products, services, and energy management practices. Green Lights was a voluntary public/private partnership that encouraged building owners and operators to adopt energy efficiency products and services. In return for technical assistance and public recognition, Green Lights partners voluntarily committed themselves to installing high efficiency lighting products wherever they could be demonstrated to deliver even a minimum financial return. A recent paper examining the savings impacts estimated that the Green Lights program is responsible for annual savings in 2000 of over 5.6 million metric tons of carbon (Horowitz 2001).

The peak in US DSM expenditures occurred around 1994, when spending reached almost US$ 3 billion. A detailed review of some of these expenditures found that the vast majority of all utility commercial DSM programs addressed lighting technologies, and that commercial lighting programs delivered savings in 1992 of approximately 1,659 GWh, or 70% of the total savings identified (Eto et al 1995).

DSM activity declined dramatically through 1997 as deregulation and electric industry restructuring changed the focus and priority of most utilities and their regulators. By 1999 activity began to ramp back up.

In response to deregulation, in some states regulators established "public benefits funds" to be collected through utility bills, and spent on energy efficiency, renewable en-

ergy development, low income consumer energy programs and other activities deemed to be in the public good. As a result, the delivery and design of DSM programs changed in some cases, moving away from utility administration and utility customers towards programs focused on "market transformation" targeting a broad base including product manufacturers, retailers, and end users. In some states or regions, these programs are administered by state agencies or other public/private partnerships that have been designated as administrators of the funds. Utilities continue to administer public benefits programs in other parts of the country.

Some of the gains in efficient technology market share have been "locked in" through codes and standards. In 2000, fluorescent ballast manufacturers and other groups reached a negotiated minimum efficiency standard that effectively requires electronic ballasts to be used in most applications in the US beginning in 2005.

Overview of Program Activity

New programs face a much more complicated challenge than the simple technology change-outs of lamps or ballast replacement common to earlier program efforts. Instead, much of the potential involves changing design practices, to result in more effective lighting layouts and better use of modern controls. Significant energy savings are possible through additional intervention activities, including: design using lower light levels and task lighting; space design, including increased use of daylighting and improved surface reflectances; and designs incorporating controls such as occupancy sensors, manual switches, dimmers and automated systems for general and modular task lighting. While these design strategies hold great promise for energy savings, there is also a need to be certain that lighting quality is maintained or enhanced.

In the US, there has been a resurgence in energy efficiency program activity in recent years, driven in part by electric supply constraints and public support for energy efficiency funding. Electric utilities and other public benefits providers are offering a broad range of programs, many based on the concept of "market transformation," where market barriers are identified and programmatic interventions are offered to effectively reduce or eliminate the barriers to adoption of more energy-efficient technology and practices. The US market for electronic ballasts is generally considered to be "transformed;" the market penetration level is still growing and considered sustainable, and regulations are in place to prevent any slide backwards in efficiency.

Earlier programs that promoted efficient lighting and design practices tended to offer off-the-shelf subsidies and more limited technical expertise. The results met with limited success in affecting mainstream design and construction. Currently, there is a broad range of programs being offered as integrated solutions to promote efficient lighting technologies and design practices. While the majority of utility and other public benefits funding for commercial lighting still goes toward equipment incentives and rebates, the level of activity in design-related opportunities is growing.

Programs targeting efficient design can be broken down into two categories. First are those that are independent of manufacturer support, primarily funded by utilities (or other public benefit fund collections) or by the US government. Other innovative initiatives have been developed by manufacturers or their trade associations interested in building markets for more efficient, higher margin products. Some of these programs are summarized in Annex 1, and descriptions of some of the more prominent activities are provided below. All of the programs have websites where the reader can find more details. This is not intended to be an exhaustive list of the activities in the US, but to provide a summary of some of the more active efforts.

DesignLights Consortium (DLC) – The DLC's mission is to help make high quality energy-efficient lighting commonplace in small commercial buildings. Established in 1998, the DLC is a regional collaboration between utilities and other stakeholders. Program activities include market research, customer and contractor education, development of technical guidelines, demonstration projects, and support for improved building energy code requirements.

Lighting design guides have been developed for schools, small retail, office, and warehouse and industrial buildings. They provide models for specifying lighting technologies and design layouts. The guides are intended for practitioners to use as alternatives to their standard layouts that do not adequately consider quality and efficiency issues. The DLC has also produced numerous case studies of built projects that meet the guides. The layouts in the guides all meet or exceed the lighting system efficiency requirements of ASHRAE/IESNA (American Society of Heating, Refrigerating, and Air-Conditioning Engineers/ Illuminating Engineering Society of North America) Standard 90.1-1999, which serves as the basis for the building energy codes in most of the US.

Daylighting Collaborative – The stated objective of this program is to daylight every commercial building. The program was started in late 1998 by the Energy Center of Wisconsin to incorporate daylighting into mainstream design and construction. It brings together many organizations dedicated to promoting the human, environmental and economic benefits of cool daylighting (cool daylighting takes into consideration that daylighting will not be energy efficient if it is not designed to minimize solar heat gain). The program provides training for designers, building owners and builders as well as a design review service and limited design assistance along with demonstration, or "copy," rooms where designers are encouraged to copy the simple demonstrated approaches in their own projects. It has developed cool daylighting performance standards. Since the program's inception it has expanded beyond the original geographic scope of the state of Wisconsin to other parts of the US.

Small Commercial Lighting Program – The objective of this program is to promote effective and efficient lighting solutions that result in better lit spaces, which allow people to see more easily and cost less to operate. The program,

developed by the New York State Energy Research & Development Authority, the public benefits funds administrator in the state, works with lighting contractors, product distributors, and other lighting decision-makers to design and implement these lighting improvements in small commercial spaces. The program offers incentives to participating electrical contractors and lighting distributors for the completion of qualifying products. It also offers training, design and installation competitions and other promotions.

Of particular note, the program has developed quantifiable criteria to define "effective, energy-efficient lighting." The program specifies a range of criteria addressing glare, color rendering, illuminance, and energy intensity among other things. Some criteria vary by building type or design layout. For example, allowed lighting power densities must be at least 10% lower than those prescribed in ASHRAE/IESNA Standard 90.1. Also, to insure illuminance uniformity, fixtures must be spaced within the fixture manufacturers spacing specification listed on fixture photometric/specification sheets with distance between walls and adjacent fixtures not exceeding one-half of the fixture spacing criteria.

LightRight Consortium – The goal of this project is to use research as a basis for market transformation towards high quality energy-efficient and cost-effective lighting. Its interdisciplinary research addresses the physical and psychological needs of people who occupy the lighted space. The LightRight Consortium is a national effort with a diverse membership from both the private and public sectors, aimed at market transformation toward "ergonomic lighting." Ergonomic lighting, as defined by the LightRight Consortium, is designed and installed in a way that considers the physical and psychological needs of people in buildings, such that it is high quality, energy efficient, and economical.

Advanced Lighting Guidelines – The objective of the 2001 Edition of the Advanced Lighting Guidelines is to be the definitive source on how to achieve good lighting. First developed by the California Energy Commission in 1991, these guidelines are intended for use by all decision-makers about commercial and industrial lighting design. The New Buildings Institute recently completed a major update of the Guidelines (New Buildings Institute 2001). The guidelines identify the lighting design criteria relevant to various types of buildings and uses and describe measurement techniques for a wide range of criteria, addressing glare, flicker, shadows, and "modeling of faces and objects" among other things.

The Lighting Controls Association (LCA) – The goal of this trade association is to educate facility executives, lighting designers, architects, and others in the building services industry about the role of lighting controls in energy-efficient, high quality lighting design. Member companies include manufacturers of occupancy sensors, dimming controls, lighting management systems, dimming ballasts, and other products involved in lighting control strategies. The LCA, formed in 2001, distributes materials that demonstrate the energy and non-energy benefits of lighting controls including case studies to showcase successful applications of lighting controls and an interactive CD-ROM. The CD-ROM provides a tutorial on the use of controls in different building types, an estimator tool that gives the user a detailed analysis of the energy savings, costs, environmental benefits, and worker productivity enhancements from installation of a lighting control system, and a catalog of products and components. The LCA is exploring opportunities to partner with utilities, market transformation programs, ESCOs, and others to offer education and training, demonstration projects, product labeling efforts, and other activities to increase the use of efficient lighting design and lighting control systems.

DISCUSSION/CONCLUSIONS

Why Establish Lighting Design Programs?

Recent studies of existing utility programs that encourage commercial and industrial lighting retrofits suggest that these activities have had a profound effect on lighting sales and practices. Many energy-efficient technologies have permeated the new construction market. New energy-efficient technologies and concepts continue to emerge. Lighting design now addresses plans that are based on lower light levels, space design that incorporates daylighting and improved surface reflections, and use of lighting controls such as occupancy sensors, dimmers, and automated systems, for example. Studies suggest that significant additional energy savings opportunities are possible through intervention activities relating to design. Recent evaluations of current construction have found potential energy savings from better design on the order of 5% to 40% (NW Alliance 2000, Easton 1997). Knowledge and technologies exist in the market place, but the key to increasing quality energy-efficient lighting design lies in overcoming market barriers.

Lighting design programs can play a crucial role in capturing the savings potential in existing commercial buildings. Various barriers to energy-efficient lighting design in existing facilities have limited the deployment of a number of simple, well-established design practices and technologies.

Utility rebate programs are still an important component of many lighting programs because they remove the most significant barrier, first cost. Without that incentive, many lighting designers design to minimum requirements exclusively. In addition, there is a strong need to involve end-users in understanding the benefits of high quality energy-efficient lighting. While many lighting design programs have a strong training and education component directed at designers and installers, lack of awareness by end-users remains a barrier to increased demand for and acceptance of high quality energy-efficient design (PA Consulting Group 2001).

In many respects, including quality and design in the objectives of efficiency programs is a natural extension of existing efforts. Utilities have experience with technologies, an established infrastructure, and they already work

with many of the market actors. Influencing lighting design is an activity that is in tune with the philosophy of "market transformation" and public benefits programs. As found in New England, "many of the utility program results achieved reflect the importance of market effects on market actors other than customers. The most important market effects include: stimulation of increased sales efforts; the development of new services by existing market actors; and the appearance of new types of market actors" (Easton 1997, p. 7).

Outstanding Challenges for Lighting Design Programs

New program activities face a number of challenges:

Ensuring that the design process is comprehensive

Lighting quality issues should be considered for the whole space and every visual task within the environment. The designer should then identify all of the criteria relevant to those conditions. Design may affect both the built structure and the internal layout of furniture, equipment, surface finishes and lighting technologies.

Cost-effectiveness is difficult to measure

To be implemented, high quality energy efficient design must also be cost-effective. Costs of design and equipment should be compared to energy and non-energy benefits. This sounds simple, but the non-energy benefits are very difficult to quantify, so demonstrating cost-effectiveness can be a significant challenge. Developing tools and benchmarks for the costs and benefits, especially non-energy benefits, can help to demonstrate and compare the cost-effectiveness of competing design options.

Evaluating lighting design and quality involves subjective and objective criteria

Many indicators of high quality energy-efficient design can be measured. Energy savings and physical measurements such as those describing illuminance, glare, and color appearance are very useful indicators. They can be quantified and are free of personal bias. However, they do not adequately embrace all of the issues in lighting design. A more thorough evaluation must also assess the more subjective issues of users' perceptions and satisfaction. However, it is difficult to assess subjective criteria, since one person's judgment can vary from another's. Ideally an evaluation would ask the same person to compare designs or to judge before and after conditions, but this is not always practical or cost-effective. It is also difficult to attribute behavioral benefits such as well-being or productivity to lighting design.

In summary, energy efficient commercial lighting technologies and practices continue to emerge, creating growing potential for savings. At the same time, new programmatic approaches that point toward methods for harvesting these savings are developing. Several examples of the new programs are presented in this paper. Many of these programs are still in their infancy. As the ideas and programs mature, so will our understanding of the large potential for quality energy-efficient lighting. This topic will provide a wealth of new information over the next few years.

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Annex 1. Commercial Lighting Design Related Market Transformation Activities/Programs

Organization/ Website	Mission	Primary Audience
Independent/Utility or Public Funded:		
Design Lights Consortium (DLC) www.designlights.org	A regional collaboration seeking to influence naturally occurring lighting events toward efficient, high quality lighting design	Commercial lighting specifiers, decision-makers
The Daylighting Collaborative www.daylighting.org	To make successful daylighting part of mainstream construction	Designers, building owners
Small Commercial Lighting Program www.nyserda.org/sclp	To promote effective and efficient lighting solutions that result in better lit spaces in small commercial buildings	Electrical contractors, distributors and other decision-makers
Northwest Lighting Design Lab www.lightingdesignlab.com	Works to transform the Northwest lighting market by promoting quality design and energy-efficient technologies.	Designers
The LightRight Consortium www.lightright.org	To quantify ancillary benefits of quality energy-efficient lighting, thereby providing significant incentive for its implementation, and to deliver this information in a form which is easily useable by the sponsors	Lighting decision-makers
National Council for Quality in the Lighting Professions www.ncqlp.org	To certify lighting professionals, thereby promoting the general well-being of the public through effective and efficient lighting practice	Lighting professionals
Advanced Lighting Guidelines www.newbuildings.org	Develop guidelines to describe state-of-the-art lighting technologies and design principles	Lighting decision-makers, designers, policy-makers, educators
Pacific Gas & Electric's Daylighting Initiative www.pge.com/pec/daylight	PG&E seeks to lower barriers to the implementation of daylighting strategies in new construction and building renovation	Architects/ Lighting designers
Lighting Research Center (affiliated with Rensselaer Polytechnic Institute) www.lrc.rpi.edu	Conducts and disseminates applied research, development and demonstration projects to encourage the use of more efficient lighting systems and strategies	Lighting professionals, policy-makers, manufacturers, end-users
Manufacturer Supported:		
Lighting Controls Association www.aboutlightingcontrols.org	To raise end-user occupant awareness regarding lighting controls benefits, and to simplify the selection process for the engineering community	End-users, lighting designers, electrical engineers
National Lighting Bureau www.nlb.org	To educate lighting decision-makers about the bottom-line benefits they can derive for their organizations--whether industrial, commercial, retail, or institutional--by specifying high-benefit lighting	Lighting decision-makers
Energy Efficient Lighting Association www.eela.com	To promote the purchase and installation of energy-efficient lighting products through education and networking across these channels (manufacturers, distributors, contractors, ESCOs, and end-users)	Lighting industry