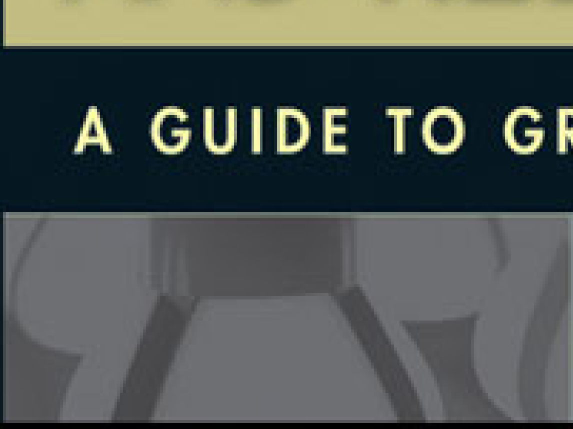
LIGHTING RETROFIT AND RELIGHTING

A GUIDE TO GREEN LIGHTING SOLUTIONS



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Dedicated in memory of Anton A. Leban.

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Introduction

LIGHTING REPRESENTS MORE THAN ONE-THIRD OF ELECTRICITY use in commercial buildings. High efficiency lighting retrofits and relighting have the potential to significantly reduce energy use while enhancing the visual environment and improving lighting quality. The greatest potential for savings is with the existing stock of commercial buildings.

This book aims to encourage the retrofitting and improvement of lighting systems in buildings with energy efficient technologies.

Business and building owners frequently turn to contractors, lighting consultants, energy auditors or utility representatives for information and guidance on energy-efficiency issues, including lighting equipment retrofits. This book is a resource for building owners as well as those they turn to for rational, technical, and financial lighting retrofit information.

In the past several years, lighting retrofit options have expanded, and utilities are no longer the sole driving force behind them. The authors, lighting designer/engineer Jim Benya, and architect/lighting designer Donna Leban, have gained their expertise by performing lighting audits through utility programs, energy service companies, and directly for building owners and design professionals.

Lighting Retrofit and Relighting provides information on the process of auditing a building and evaluating energy efficient lighting technologies and their application to lighting systems.

This handbook is organized into two main parts.

- **Part I** provides a focus on lighting technologies and how they are used in lighting retrofit.
- **Part II** presents details on each step of the lighting retrofit process as well as financial analysis of lighting options.

In addition to the main parts, additional appendices are provided for reference. While a complete database of lighting retrofit technologies is beyond the scope of this book, many recent lighting advances are discussed along with tables assessing their potential energy savings.

This book may be used in various ways, depending on your role in a project:

Facilities managers are a primary focus, and the authors try to answer the type of lighting-related questions often heard from this group of professionals.

The business or building owner may be primarily interested in bottom-line issues and less in the specific lighting technologies utilized. Part II addresses the process and people involved in taking a lighting retrofit from A to Z, and Chapter 9 deals with financial issues of importance.

Electrical contractors should find the entire book of value, even if they are not directly involved in doing a lighting audit or specifying audit measures. Those who do recommend lighting measures for retrofit would do well to review procedures and recommended technologies, as it has become increasingly difficult to keep up with fast paced changes.

Electrical engineers and lighting consultants who perform lighting audits will find the tables in Part I particularly useful. The tables evaluate specific lighting alternatives to existing lighting systems, providing usable energy saving data. Data gathering and analysis tools will also be useful for those who have not already developed tools of their own.

The retrofit process will undoubtedly be different for each project, depending on its size, complexity, and the magnitude of the opportunities. Clearly, not all the tasks will be carried out for every project. At one extreme, a lighting retrofit project might consist of going to the local hardware store and purchasing screw-in compact fluorescent lamps to replace incandescent ones. At the other extreme, it can involve a detailed audit, short-term monitoring of the lighting system, engineering feasibility studies, prototype installations, bidding and negotiations, commissioning, and postconstruction evaluation.

Figure I-1 Importance of commercial lighting system retrofits from buildings energy data book 3.1 commercial sector energy consumption. (Buildings Energy Databook, U.S. Department of Energy.)

FOR YEAR 2010 COMMERCIAL ENERGY END-USE SPLITS BY FUEL TYPE (QUADRILLION BTU)

	Site Electric	**Primary Electric**
Lighting	1.12 (35.3%)	3.53 (35.3%)
Space Heating	0.14	0.43
Electronics	0.55	1.73
Space Cooling	0.5	1.56
Water Heating	0.15	0.48
Computers	0.25	0.8
Refrigeration	0.23	0.73
Ventilation	0.19	0.6
Cooking	0.04	0.12
Building related total	3.17	9.98
Other (including service station equipment, ATM′s, telecommunications equipment, medical equipment, pumps, emergency electric generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings)	0.76	2.38
Energy attributable to commercial building sector, but not directly to specific end uses	0.79	2.49
Total	4.72	14.85
Note that as a percentage of identifiable end uses common to commercial buildings		

(not including other and not attributable), 35 percent is for lighting.

One of the tasks that is becoming more common with retrofit projects is the installation of short-term monitoring equipment, such as portable data loggers, to accurately measure hours of lighting operation and determine the magnitude of the savings that are possible with occupant sensors and other types of automatic lighting controls. In the past, it was common just to assume 4,000 hours per year for lighting system operation. Studies have shown that actual hours can vary by 30 percent or more, creating significant errors in the prediction of energy savings. Short-term monitoring used to be a very expensive task; but with modern equipment, good data can be obtained at a very reasonable cost. This makes short-term monitoring a common procedure for an increasing number of lighting retrofit projects.

SIGNIFICANCE OF LIGHTING RETROFITS

Energy efficient lighting retrofits make good economic sense for most commercial buildings. Replacing aged lighting components with advanced energy efficient components can save as much as 50 percent of a building′s lighting energy costs while maintaining or enhancing the visual quality of the workplace. Most lighting retrofits pay for themselves through energy savings in less than five years. When occupant satisfaction and worker productivity are factored into the economic analysis, lighting improvements produce immediate benefits.

Lighting represents a major end use in commercial buildings, accounting for more than one-third of commercial sector electricity consumption. With

American businesses under constant pressure to increase productivity and cut costs, lighting retrofit can be one of the most cost-effective ways of accomplishing these goals.

WHEN LIGHTING RETROFITS MAKE SENSE

Lighting retrofits make economic sense any time lighting energy can be saved while achieving a reasonable rate of return when compared with other uses of capital. This usually results when one or more of the following conditions exist in a building.

- Excessive Illuminance. A majority of spaces in the building are overlighted.
- Inefficient Technology. The lighting equipment is more than 10 years old.
- *Poor Maintenance*. Lamps are beyond their useful life and luminaires are poorly maintained.
- *Excessive Hours of Lighting Operation*. Lighting is operated for more hours than needed.
- *High Electricity and/or Demand Charges*. More money is saved per kWh or kW reduction.
- *Suboptimal Lighting Conditions*. There are inadequate or poorly maintained lighting systems that need to be modified anyway.

Excessive Illuminance

Buildings that are overlighted are always candidates for lighting retrofits. Most unmodified buildings constructed before 1990 are likely to be overlighted for several reasons.

- The wide acceptance of fluorescent lighting during the 1950s and 1960s made it technically possible to design lighting systems with high illumination levels. Customarily, excessive lighting was installed in the belief that more was better.
- Before the 1990s, the lighting levels recommended by the IESNA and other construction guidelines were higher than today′s standards.
- Visual tasks have changed. Since the early 1990s, many workers spend much of their time in front of a computer screen, and paper tasks have improved greatly due to improved printer and copier technology.
- Buildings were often designed without concern for daylighting potential as a source of usable light. Electric lighting is unnecessary when good daylighting is available.

Inefficient Technology

The efficiency of lighting equipment has markedly improved since the first energy crisis of the mid-1970s. Much of this improvement has been accompanied by improvements in lighting quality as well. For instance, electronic ballasts eliminate fluorescent flicker and newer T-8 and T-5 fluorescent lamps have better color rendering properties. However, older inefficient equipment is still in common use, and its replacement is a primary strategy in lighting retrofits.

Poor Maintenance

Poor or infrequent maintenance results in dust and dirt accumulation on lamps and fixtures. This interferes with light delivery and reduces the efficiency of luminaires.

Poor maintenance also results in the use of lamps that are beyond their rated lives. Old lamps use the same or more power as new ones but produce significantly less light.

Long Hours of Operation

Even a small improvement in lighting efficiency (power reduction) can save a considerable amount of energy when the lighting system is operated almost continuously. Long hours of lighting operation typical of hospitals, police stations, correctional facilities, and so forth make many lighting retrofits easy to justify financially.

Long hours of operation also point out the need for automatic lighting controls such as programmable lighting control panels, occupancy sensors, and other devices. One of the most needless—and common—wastes of energy is the operation of lights in unoccupied spaces. While efficient equipment can reduce lighting energy use by as much as 50 percent, turning lights off saves 100 percent.

Regardless of the control devices employed, providing pertinent information on use of lighting controls for the building users is important.

High Electricity and/or Demand Charges

Higher electric rates make it easier to justify investments in efficient lighting. While the cost of the retrofit remains the same, the energy cost savings are greater.

Because utilities must base their power delivery potential on anticipated peak use, they attempt to reduce the magnitude of those peaks through demand charges and differential billing rates, in which the price charged for electricity is substantially higher during peak-demand periods than during off-peak hours. Strategies that minimize electric lighting during peak hours—such as daylighting controls, task lighting, and occupancy controls—will return proportionally greater savings than those that reduce electricity use during off-peak hours.

As utilities and governments invest in system improvements to the electric grid, new lighting retrofit opportunities will also develop. “Smart meters” capable of real-time pricing will enable utilities to price electricity by the hour. This may significantly increase mid-day rates on hot, sunny days, when daylight lighting control systems are most effective. Other clever methods of reducing consumption, and generating and storing electricity from alternate energy sources will likely occur with the widespread development of the smart grid.

Suboptimal Lighting Conditions (Deferred Capital Reinvestment)

Although a major focus of this guidebook is on retrofitting lighting systems to save energy, it is important not to lose sight of the connection between a high-quality visual environment and the well-being and productivity of the occupants. Buildings that have inadequate lighting systems already need improvement. Through the use of efficient lighting technologies, lighting energy use can remain constant or be reduced as a building′s lighting systems are improved. Capital reinvestment may be minimized through state, federal, or utility incentives as well as other benefits of new lighting systems.

OTHER BENEFITS FROM LIGHTING IMPROVEMENTS

Lighting retrofits have many benefits for the building owner and the building users. The direct benefits are reduced electricity demand, energy savings, and lower building operating costs. Less quantifiable benefits, such as improved lighting quality and potential increases in productivity when existing lighting is poor or inadequate, may be just as important in some facilities. These are discussed in detail in Chapter 7, Lighting Engineering and Evaluation.

Reduced Energy Costs

The most obvious and immediate benefit of retrofitting an outdated lighting system is reduced lighting energy and related operating expenses. This is often the only benefit considered in assessing the cost-effectiveness of lighting retrofits. Lighting retrofits reduce both electricity use and demand. The savings include direct reductions in lighting power and hours of lighting operation as well as indirect air-conditioning energy savings (there is less heat generated by electric lights to remove from the building). A retrofit can sometimes achieve a 50 percent reduction in the lighting share of the electric bill. The total electric bill for a typical office building can often be reduced by 20 to 25 percent, depending on the current lighting technology in place. The older the current equipment and the more overlighted the spaces, the greater the savings.

Reduced Lighting Maintenance

Most energy efficient lighting retrofits also reduce maintenance costs. In many existing buildings, lighting system maintenance occurs only when there are equipment failures such as lamp and/or ballast burnouts. Routine group relamping and fixture cleaning are the exception rather than the rule. Since lighting retrofit programs usually involve significant equipment replacements, they may be overcoming 10 years or more of neglect. By offering an opportunity to initiate new maintenance procedures that can reduce maintenance costs in the long term, the building′s overall appearance will be enhanced. Future maintenance costs associated with old lamps and ballasts can be eliminated, since energy efficient products almost always have longer lives.

Return on Lighting Investment

Projected energy savings from lighting retrofits can be used as “equity” to finance the improvements. This capital is available through utility programs and state or federal programs, as well as energy service companies (ESCOs) that finance retrofits through future energy savings. It is frequently possible to package improvements so that older building equipment needing replacement can be included as part of the retrofit program.

Economic Competitiveness

Lighting retrofits enable companies to reduce operating costs and become more competitive in the world economy. This can result in greater economic growth for states and regions that actively promote energy efficiency retrofits.

Cleaner Air

A great deal of electricity is produced through natural gas and coal-fired generation plants, with the combustion process adding pollutants to the atmosphere. These pollutants contribute to climate change, acid rain, and other environmental problems. Energy savings through lighting retrofits can significantly reduce these emissions. The Environmental Protection Agency (EPA) has estimated the emission reductions associated with electricity energy savings.

For example, 87 billion kilowatt-hours of annual energy savings that would result from retrofit of commercial incandescent downlights with compact fluorescent or LED would eliminate 139 billion pounds of carbon dioxide emissions, 464 million kilograms of sulfur dioxide emissions, and 246 million kilograms of nitrogen oxide emissions.

Improved Public Image

Not only do lighting retrofits save energy, operating costs, and air pollution, they can help foster a more positive image for customers who implement the improvements and the utilities that promote the improvements. Participation in the EPA′s “Green Lights” program is based in large part on the EPA′s success in promoting a positive image for participating companies. The U.S. Green Building Council (USGBC), which created and supports the LEED® (Leadership in Environmental and Energy Efficient Design) building rating system, supports existing building upgrades through LEED for Existing Buildings and Reference Guides for Green Building Operations and Maintenance. This rating system has achieved international recognition and a greater degree of public recognition for its participants.

Improved Lighting and Productivity

It is very difficult, some would say impossible, to document and quantify the relationship between lighting retrofits and worker productivity. Few persons would argue, however, that improving the visual environment hurts productivity. On the contrary, there is little doubt that workers will be more productive if glare is removed from workplaces, the electric light provides better color rendering, and flicker is eliminated. The difficult part is assigning a monetary value to these benefits. If, however, workers complain about headaches and eye strain in the workplace, evaluating the lighting as a potential source of the problem would be easily justified.

Salary expenses dominate the cost of doing business, and only the slightest improvement can be quite significant. Based on a 1990 national survey of large office buildings, salary costs represented $131 per square foot, almost 85 times greater than electricity costs, which were estimated to be about $1.53 per square foot. A productivity increase of as little as 1 percent would just about equal the entire annual electric bill. While average salaries have increased a bit since then and energy costs have roughly doubled in many locations, the general idea still holds true.

Another way to illustrate the impact that lighting retrofits can have on worker productivity is to cite some examples.

- Pennsylvania Power & Light retrofitted the lighting system in a drafting room. The retrofit cost was $8,362 and energy cost savings were $2,035 per year. In addition, absenteeism went down by 25 percent and the productivity rate increased 13.2 percent.
- Gardeners Supply replaced the luminaires in its warehouse and distribution center at a cost of $64,000 for materials and labor, with energy savings of nearly 50 percent and a $15,000 utility rebate. The initial investment was recovered in under six months. While lighting in remote warehouse areas could remain off during much of

the day through the use of occupancy controls, lighting improvements in hazardous circulation zones helped improve safety. The brighter environment helped workers remain more alert, even on second shift.

- Boeing Aircraft Company retrofitted the lighting system in one of its manufacturing plants. Not only did the company save 90 percent of the electricity costs for lighting, it experienced a 20 percent improvement in detecting imperfections.

These examples all represent cases where the lighting retrofit improvements were justified on the energy savings alone. The increases in productivity were an unexpected additional benefit.

OVERCOMING BARRIERS TO LIGHTING RETROFITS

In spite of the benefits and the availability of energy efficient lighting technologies, significant barriers deter businesses and building operators from embracing newer technologies. Customers often mistrust newer products, due to confusion about the technology, changing electrical and energy codes, and the risk of disruptions to ongoing operations. Electric utility energy management programs for the last two decades have helped demonstrate that customers will move toward more energy efficient lighting solutions when provided with accurate information and the promise of good returns on investment.

Barriers

Resistance to lighting improvements are a response to any or all of the following factors:

- A perception of high initial costs of lighting improvements
- Lack of perception of a need to save energy
- Poor understanding of the advantages of better lighting
- Mistrust in the reliability of newer technologies
- Confusion over a broad assortment of products
- Confusion and mistrust related to claims made by some lighting equipment manufacturers′ representatives
- Concern about disruptions to business during retrofit

For the most part, these perceptions are caused by a lack of information, which is gradually overcome. State- and utility-funded programs provide a reputable source of information. Articles by energy consultants and manufacturers′ advertising promote increased customer awareness of improved lighting products to those who subscribe to business and trade magazines. Resistance to change dissipates with the realization that lighting retrofits provide reliable reductions in operating costs. Environmental benefits and improved worker productivity may be harder to quantify, but many business owners have been convinced and are reaping the benefits.

Demand-Side Management (DSM) Programs

Begun in the early 1990s, regulated utilities developed these programs to manage electrical load growth with fewer economic and environmental costs than would result by building new power plants. Now, an environmentally conscious public prefers the efficiency alternative over construction of new power plants. As electrical energy costs rise creating a greater incentive for energy efficiency, the prevalence of spending for DSM programs has been diminished in many states. However, the need for reliable information and incentives to take on larger, more costly commercial and industrial retrofit projects has increased.

Successful programs reduce demand and energy use at a cost less than that needed to construct new generation capability. “Least-cost planning” is a term which applies to the process of carefully evaluating energy savings opportunities along side opportunities to increase generating capacity. Lighting retrofits usually surface as one of the most cost-effective ways to reduce electricity demand and energy use.

DSM programs can employ a number of strategies to promote investment in energy efficient lighting. These include providing general customer assistance; participating directly through subsidiary energy service companies (ESCOs); subsidizing lighting audits and technical recommendations for customers; subsidizing the cost of lighting improvements through rebates, grants, and financing; helping owners and designers select efficient lighting equipment and evaluate lighting options; purchasing savings through demand-side bidding; and providing education and demonstration facilities to the general public and to lighting professionals.

Of these three strategies, subsidizing lighting improvements has the greatest potential impact. Utility rebates can significantly reduce the installed costs, thereby accelerating payback periods and enhancing return on investment and lifecycle cost savings. The resultant increase in the economic value of a lighting improvement makes the project significantly more attractive to decision makers. Similarly, grants and attractive financing programs for audits and equipment installation also encourage building owners to complete lighting improvements.

PART I

THE SAVINGS POTENTIAL IN COMMON LIGHTING SYSTEMS

PART I addresses common retrofit and relighting opportunities for general lighting system types. Lighting System Retrofit Potential is organized into chapters first by technology, and then by special applications. Technology chapters include:

Linear Fluorescent Systems

Incandescent and Compact Fluorescent Systems

High Intensity Discharge Systems

Special Applications Lighting including:

Industrial Lighting

Outdoor Lighting

Special Commercial Applications

While categorizing by technology avoids repeated discussion of typical lamp- and ballast-based retrofit solutions, the special applications categories are useful in discussing unusual environments and control options. Included for each of these categories is:

General discussion of retrofit in the category

Brief descriptions of typical existing conditions

A discussion of specific retrofit options with guidelines for assessing those options. Tables are provided to quantify specific retrofit savings opportunities by lamp/ballast and luminaire type.

Guidelines for use of lighting controls are discussed in brief in each chapter, as their use may differ from one application and lamp source to another (see following table).

Case studies are offered to relate real-world conditions, where nothing goes exactly as planned. Retrofit often requires a flexible approach to specifying and installing components and lighting controls. The "if this, then that" scenario of specification often seems to work the best, as no matter how carefully you evaluate a facility, there will usually be surprises upon installation.

COMMERCIAL LIGHTING SYSTEMS

Commercial lighting includes the lighting systems used in office buildings, institutions, stores, schools, and all other nonindustrial buildings. Each of the three major lighting systems has broad application in commercial buildings. Industrial lighting systems are often found in environmentally severe conditions. Hospitality, including hotels, restaurants, and spas, is similar to residential lighting in aesthetic demands, but often uses commercial lighting technologies. The need to control these systems by dimming places greater demands for lighting technology improvements in the hospitality sector.

Outdoor lighting systems are unique applications, operating in a broad range of temperatures and climate conditions. Recent technological developments bring new options to the table for this large sector of the lighting market.

Commercial lighting constitutes about 40 percent of the electric lighting load in the United States. Most commercial lighting systems, other than hospitality and retail display lighting, are based on fluorescent and HID lamps. While the design of fluorescent lamps and ballasts has evolved considerably over the last 40 years, much of the older fluorescent technology is still in place, and until recent changes in federal legislation[1] has been commonly sold in the United States. Even the newest products bear strong physical resemblance to the oldest fluorescent products. The general public, therefore, does not always understand the difference between the poor color quality, noisy, magnetically ballasted T-12 technology of the past, and significantly improved properties of the more advanced, high-efficiency T-8 and T-5 fluorescent systems. Many engineers and local lighting distributors are also not aware of recent advances in high performance lamp and ballast technology, and may not be making optimal selections for efficiency. Rather, sales are often based on what is commonly available.

LIGHTING SYSTEM RETROFIT APPLICATIONS

Category	Lighting System Type	Notes
General Commercial	Fluorescent Troffers	Most common, and most easily retrofit with new lamp/ballast or fixture replacement
	Fluorescent Nontroffers	Strips, wraparounds, direct/indirect, pendant-mounted, cove lights, undershelf, medical; many retrofit opportunities in older systems
	Downlights	Very common, including wallwashers, accent lights; depending on existing technology includes best retrofit savings potential
	Decorative Luminaires	Chandeliers, pendants, sconces, table and floor lamps, etc., lamp and fixture replacement options; dependent on new lamp technology and how well they match incandescent lamps in appearance and function
	Utility Lighting Exit Signs	Sometimes overlooked, easily retrofitted, Inexpensive to replace although hours of use may limit retrofit economic benefits
	Track Lighting	Commercial retrofit options available for significant energy savings, improved halogen lamp technology for more limited savings but broader application

Category	Lighting System Type	Notes
Hospitality and Residential	Most systems above	Special design and dimming control considerations
Industrial	Fluorescent	Common and easily accomplished with special consideration of broader temperature and exposure conditions
	High Bay	New system replacement options provide excellent savings opportunities, with special temperature and controls considerations
	Low Bay	Retrofit and system replacement options, depending on existing technology and controls
	Damp Location (Vaportight)	Systems deteriorate rapidly, replace rather than retrofit
	Wet Location (Watertight)	Generally requires fixture replacement
	Special Purposes/Environments	Cold and hot temperature, caustic, explosive, etc., special systems not easily retrofit

Category	Lighting System Type	Notes
Outdoor	Roadway and Parking Lots	New technology options, significant maintenance as well as energy savings
	Floodlights	New technology options, maintenance and energy savings
	Security	Replacement and redesign for energy efficiency and improved visibility
	Decorative	New retrofit alternatives to incandescent and mercury vapor, solid state option potential
	Landscaping	Fixture replacement options with new technology

Lacking assistance and/or intervention by federal and state energy efficiency mandates and programs, obtaining high performance options may involve more hassle and cost than should be the case. However, federal laws prohibit the sale of outdated and inefficient light sources, and higher electricity costs will inevitably bring higher efficiency fluorescent lamp and ballast technology into greater use.

Commercial application of hardwired compact fluorescent (CF) luminaires (as opposed to screw-based compact fluorescent lamps), especially in recessed can lighting, started in the 1980s. The significant energy benefits of hardwired compact fluorescent luminaires, using “permanent” ballast and pin-based compact fluorescent lamps, brought early adoption in many engineered buildings. Compact fluorescent fixtures installed before 2000, and many lower wattage CF fixtures even today, use magnetic ballasts. With the Department of Energy′s “Energy Star” rating of electronically ballasted hardwired luminaires, we are now seeing considerable improvement in energy and starting performance for residential luminaires. Commercial luminaires typically have not been evaluated, but often use ballasts that meet or exceed the Energy Star specifications.

Compact fluorescent screw-based lamps (CFL) have become ubiquitous as a retrofit application in all types of buildings where the simplicity of this retrofit has helped overcome initial, as well as continuing, resistance to a full changeover from incandescent sources. More discussion of this category of retrofit option is included in Chapter 2.

High Intensity Discharge (HID) systems have undergone significant improvements as well. The advent of electronic ballasts for metal halide lamps, and the improved color, wattage options, and efficiency of lamps