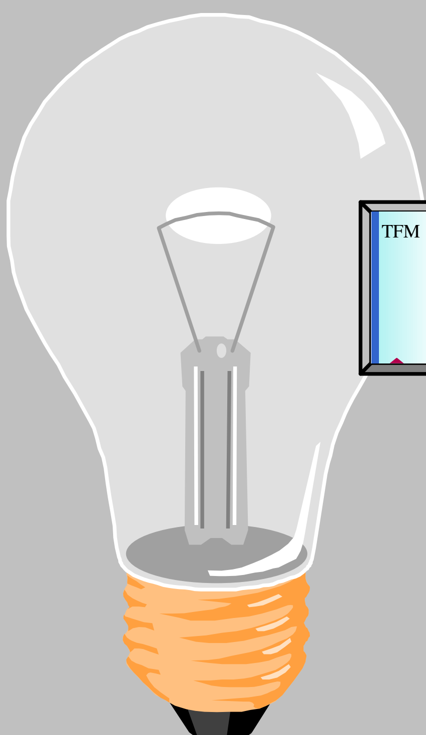
TFM Lighting Retrofit Manual



TFM

Lighting Retrofit Manual

First Edition

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Introduction

The Lighting Retrofit Manual is a guide for TFM Retrofit software purchasers to use in planning and implementing lighting retrofits in commercial buildings. Its purpose is to provide a general overview of the lighting retrofit process with commercial facilities and communicating effectively to facility and property managers.

Lighting retrofits require the expertise of lighting designers, installation contractors, lighting supply vendors and manufacturers, project manager, building personnel and financial organizations to successfully complete these projects. Each of these disciplines has unique characteristics and complex relationships to the whole process.

This manual is ***not*** intended to be an exhaustive technical resource for all aspects of the process. Instead, it is intended to provide an overview of the steps and issues critical to implementing a successful lighting retrofit. The fixture, lamp, and ballast database in the system will be expanded as TFM Retrofit is enhanced over time but allows the user to add or edit product types as they choose. ***The system, however, is not intended to cover every available option.*** Users are encouraged to work with the industry to refine and modify TFM Retrofit upgrade options to meet the needs of specific applications. It is intended that upgrade results be reassessed using specific manufacturer's performance data and that trial installations be implemented to assess lighting quality issues that are beyond the scope of the software.

This is the first edition of the TFM Lighting Retrofit Manual. As we develop future editions, TFM welcomes your suggestions and feedback for improving our products and services to better serve you.

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ASHRAE/IES 90.1-1989 Acknowledgment

In accordance with the Memorandum of Understanding, TFM and TFM Retrofit users agree to participate in designing lighting retrofits that meet or exceed the defined lighting energy standards. The current standard is ASHRAE/IES 90.1-1989, developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society (IES) of North America. Work is continuing to keep -the standard current. Addenda to the standard may be approved only after a public comment and committee review process is completed.

The ASHRAE/IES 90.1-1989 standard provides design requirements for building envelope, power distribution, HVAC, and lighting. The standard is set forth in a 147-page document that reflects input from two technical societies and public review. It is the third generation of this document since the first standard was developed in 1975.

A lighting design may comply with ASHRAE/IES 90.1-1989 by following the System/Component Method or the Building Energy Cost Budget Method. Here are the main features of each method.

System/Component Method

⇒ Maximum interior and exterior lighting power allowances (W/SF).

⇒ Credits are allowed for use of automatic controls in interior spaces (such as occupancy sensing, daylight sensing, lumen maintenance, or programmable timing).

⇒ Minimum ballast effectiveness factors are defined for most full-size fluorescent and HID ballasts.

⇒ Two alternatives for determining interior lighting power allowances:

1. Prescriptive Criteria (based on building type and size) *requires the minimum amount of effort to determine compliance*

2. System Performance Criteria (based on activities performed) *should be used when more innovative design flexibility is desired*

Building Energy Cost Budget Method

⇒ Involves building-wide energy consumption calculations to determine the design energy cost.

⇒ Compliance is achieved when the design energy cost is less than the energy cost is less than the energy cost budget based on prototype and reference data.

⇒ This method should be used when used the most innovative design concepts are being considered.

⇒ Also included in ASHRAE/IES 90.1-1089:

1. Principles of energy-efficient design
2. Glossary
3. Additional criteria on operations and maintenance
4. Two microcomputer-based compliance calculation program

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BUILDING SURVEY

The building survey is an interactive process of collecting information, assessing lighting conditions, determining needs and analyzing solutions. Comprehensive surveys and analyses will identify lighting upgrades that maximize energy savings, reduce annual maintenance and repairs expenses, while maintaining or improving lighting quality.

Survey Guidelines

⇒ The collection and analysis of building and lighting data are the most demanding tasks in the lighting upgrade process.

⇒ The building survey process involves three steps:

1. Obtain available information from building personnel prior to survey
2. Complete fixture count in all areas of the building (interior, exterior & parking garages)
3. Conducting lighting assessment and analysis

* In addition to identifying components and counting fixtures, the room survey should also address:

1. Review appropriate light levels for the task
2. Review lighting quality
3. Review condition of fixtures and room surfaces
4. Evaluation of task lighting options
5. Evaluate lighting control applications

⇒ Selecting lighting upgrade options that provide:

1. Appropriate light levels
2. Improve component and luminaire efficiency
3. Control operating hours
4. Maintain or improve lighting quality
5. Maximize energy savings

Building Information

⇒ Before beginning the actual room-by-room survey of the building (s), the following data should be collected:

1. Obtain available information on existing technologies
2. Verify any sensitive areas in the building (computer rooms, conference rooms, etc.)
3. Determine any upgrade preferences

⇒ *A facility* is defined as a group of buildings in a single location with a common owner. Some of the required survey data listed below may be common to the entire facility; other data may be common to individual buildings but may differ from other buildings in the facility.

1. Location
2. Electric rates
3. Demand charges

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4. kWh charges
5. Time-of-use rate schedules
6. Lighting system voltage
7. Occupancy hours
8. Existing lighting control systems
9. Age and type of existing lighting system
    - Fixtures
    - Ballasts
    - Lamps
10. Maintenance methods
    - Spot maintenance
    - Group maintenance
11. Future use of the building (s)

Technology Preferences

⇒ Some building owners may have specific preferences that affect the selection of lighting upgrade technologies. These preferences should be determined before conducting the analysis of lighting upgrade options. The following examples illustrate how user preferences can affect upgrade decisions:

Example 1: If the building is scheduled for remodeling in the near future and new deep cell parabolic louver fixtures are the building standard, consideration of other luminaire types or retrofits should be eliminated.

Example 2: If the existing fixtures are in a deteriorated condition, the building owner may specify a preference to replace them with new fixtures, rather than to upgrade the lamps, ballasts and lenses of the old fixtures.

⇒ Some building owners may specify preferences regarding the adoption of specific types of lighting designs or technologies. Use the following checklist to verify that only the lighting designs and technologies that are acceptable to the decision maker are included in the analysis. Note, however, that the exclusion of a design or technology may result in reduced energy savings. ***The TFM Retrofit 2.0 software provides for the standard technology selection but you can change this selection to meet the client's preference.***

Possible Client Preferences

⇒ Retrofit existing fixtures (instead of replacing)

⇒ Replace existing fixtures (instead of retrofitting)

1. One to one replacement
2. New layout

⇒ Conversion to a *task ambient* lighting design will (or will not) be considered

⇒ Painting, remodeling of room surfaces to improve light reflectance will (or will not) be considered

⇒ Conversion to an *indirect lighting* design will (or will not) be considered

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⇒ The use of *parabolic louvers* will (or will not be considered)

⇒ Decision makers may also choose to exclude *certain technologies* from consideration:

1. Specular reflectors
2. Electronic ballasts
3. Hybrid ballasts
4. Low-wattage electronic ballasts
5. T-8 Lamps
6. T-10 Lamps
7. T-12 Lamps
8. U-shaped T-8 or T-12 lamps
9. T-5 Twin tube lamps
10. Compact fluorescent lamps
11. Occupancy controls
12. Timer controls
13. Central controls
14. Exit sign replacement
15. Exit sign conversion
16. Current limiters / power reducers
17. Lens/Louver replacement

LIGHTING SURVEY

For many surveys, a great deal of time will be invested collecting and compiling information about the lighting in each individual room. Therefore, it is very important to understand what information is needed to make informed upgrade decisions and how to collect it. In some buildings with accurate "as-built" drawings or consistent, homogenous lighting systems, the room survey can be simple and rapid. Other buildings with areas that have been remodeled may have widely varying lighting conditions and will require more effort to survey. The following information should be collected during the room survey:

Room Surveys

⇒ **Determine the task to be performed in the room.**

Look for averages, but consider the most critical tasks that require higher light levels and quality.

⇒ **Determine the appropriate light levels.**

Target light levels should be based on the tasks performed in the space and the IES recommendations for illuminating such tasks. Other factors to consider include size and criticality of the task, quality of the lighting, and age of the occupant.

⇒ **Measure existing light levels.**

When measuring light levels, be sure to measure average light levels at the height of the work plane (where the seeing task is performed). Avoid unusually shadowed, reflected, or day-lit areas. Refer to Section 5.3 for more details on conducting a photometric survey.

⇒ **Assess lighting quality.**

Consider the effects of glare, lamp color temperature, color rendering, uniformity, comfort, and availability of light where it is needed.

⇒ **Count the number of mixtures.**

In small rooms, counting fixtures is a very simple task. However, in larger spaces, the assistance of a manually operated mechanical counter device may be used or use a check list.

⇒ **Collect mixture data.**

1. Nominal size (i.e., 2'x4', 2'x2', etc.)
2. Number of lamps per fixture
3. Type of lamps
4. Type of ballasts
5. Age of ballasts
6. Type of lens or louver

⇒ **Assess the condition of the lighting mixtures.**

1. Physical condition
2. Dirt accumulation
3. Number of lamp outages
4. Transparency of lens

⇒ **Assess the condition of the room.**

1. Room dimensions
2. Reflectance of walls, floor, and ceiling
3. Task (work plane) height
4. Availability of daylight

⇒ **Determine if task lighting is in use or feasible.**

The feasibility of task lighting is enhanced by:
1. The existence of modular or systems furniture
2. Feasibility of partially delamping ceiling fixtures
3. Extensive use of VDTs in the area
4. User acceptance/preference of task lighting

⇒ **Determine switching methods and patterns.**

1. Can the lights be manually turned off
2. Are lights turned off when not in use?
3. Are the lights automatically controlled?
4. Can the lights be automatically controlled?

LIGHTING EFFICIENCY

Improving lighting efficiency can be achieved without reducing lighting quality. In many cases, efficiency improvements will also improve lighting quality. There are four categories of lighting upgrades that reduce energy consumption and prevent pollution. By implementing measures (where feasible) in all four categories, energy savings will be maximized.

Lighting Output Values

⇒ **Adjust lighting levels and quality.**

Put the correct amount of quality light where it is needed and improve the effectiveness of the lighting by reducing glare and improving color rendering.

⇒ **Improve fixture component efficiency.**

Upgrade with high-efficiency lamps and ballasts to increase the efficiency of converting electricity to light.

⇒ **Improve luminaire efficiency.**

Get more of the light out of the fixture by retrofitting or replacing the fixture to improve the efficiency performance of the reflector and/or shielding materials. In addition, routine fixture cleaning improves luminaire efficiency.

⇒ **Control operating hours.**

Turn lights off when not needed by using automatic or manual lighting controls.

FINANCIAL ANALYSIS

In order to justify an investment in energy-efficient lighting technologies, an analysis must include detailed calculations of project cost, energy cost savings, maintenance cost impacts, disposal costs, tax considerations, capital investment and internal rate of return.. Many profitable lighting upgrade projects are delayed due to restricted availability of capital Utility incentives, national purchasing agreements, equipment financing, and performance guarantees can help Clients overcome this obstacle and obtain the financial advantages of energy efficiency.

Project Capital Options

⇒ Alternatives to using in-house capital for purchasing lighting upgrades include:

1. Conventional Financing
2. Lease Purchase Financing
3. Shared Savings Financing

⇒ These financing options can *provide positive cash flow* when the periodic energy cost savings exceed the payment amounts.

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⇒ The risk of the investment can be reduced or eliminated with:

1. Guaranteed Savings Certificate
2. Shared Savings Financing

TFM Financial Services

⇒ As part of the TFM Retrofit program, TFM provides exclusive discounted financial support through C & W Leasing, a national financial organization for lighting retrofits and various other energy conservation type applications. This program will show you how to get paid up front 100% of the retrofit project cost and protect your Client using a standard AIA contract.

TWO TYPES OF LEASES

FINANCE LEASE: A Lease with a $1.00 residual at the end of the lease which makes it tax deductible only through depreciation.

OPERATING LEASE: A lease with a 10% residual at the end of the lease which is 100% tax deductible to your business. It is expensed directly every month off of your income statement. Therefore you do not have to put the equipment on your balance sheet as an asset or have to deal with the depreciation.

HOW LEASING WORKS

APPLICATION: Application can be handled by fax or mailed to C & W Leasing. The following information on the application is needed to assure prompt credit decisions.

VENDOR INFORMATION: Vendor name and phone number.

LESSEE COMPANY INFORMATION: Complete business name, address, phone number and number of years in business.

PERSONAL INFORMATION: Complete name, address and social security number of all owners.

COMPANY BANK INFORMATION: Bank name, account numbers and phone numbers (if bank account is not two or more years old, please provide a previous account).

PERSONAL BANK. Please provide personal bank name, account number and phone number.

TRADE REFERENCE: Provide two trade references and phone numbers; of suppliers you have had credit with for two or more years.

LANDLORD: Provide name and phone number.

CREDIT: Personal credit, banks and trades are contacted. Lease is typed and credit decision is provided within 48 hours.

DOCUMENTATION: Upon approval and equipment description Lease documents will be Federal Expressed to the lessee and include a return federal Express at our expense.

FUNDING: Upon receipt of documents and verbal verification of delivery and acceptance from the lessee, vendor payment shall be sent Federal Express.

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WHAT IS LEASING ?

⇒ Leasing is a tax oriented method of equipment acquisition where the benefits exceed the cost on a monthly basis.

TAILOR PAYMENTS TO THEIR BUDGET

⇒ Always quote 24 or 36-month lease payments first. This gives you the flexibility of being able to lower the payment if necessary by going to a sixty-month lease.

⇒ Leasing helps overcome the cost objection in another way as well, by illustrating the savings in comparison to the cost. A persuasive argument for leasing state-of-the-art equipment is increased efficiency. More efficient products save businesses time and time equates to dollars. In presenting the lease payment, you can relate the amount of money saved to the nominal cost of leasing the system.

OVERCOMING OBJECTIONS TO LEASING

Q. "Shouldn't I own the equipment?"

A. Remind your customer that it is the use of the equipment that generates profits and time savings, not ownership.

Ask your client if they would pay their employees two years in advance. Most would consider the idea absurd. They pay employees as they produce. With a lease, you pay for your equipment as it produces. Why pay for it in advance? There is no extra benefit derived.

In addition, there is no cash outlay with a lease. **Remember the golden rule:**
If it appreciates, buy it. ***If it depreciates, lease it.***

Q. "But I do not want to pay interest!"

A. To overcome this objection, you must realize what a lease is. A lease is a monthly payment for the use of an asset.

Ask your client if they are leasing their office space. Yes? What is the interest rate? There is none, of course. They are making a monthly payment for the use of the office space. The same is true when they lease your product because they are paying for the use, like a rental, of the equipment.

Q. "Isn't the cost of leasing too high?"

A. Leasing is coat effective, particularly when careful consideration is given to all factors. "Cost" should be compared to other alternative funds cost. In a free market, competition and the decisions of a willing buyer and willing seller determine efficiency. Lessors add value to capital. That "value" is the added risk of equipment ownership assumed by lessors, asset management provided by lessors and flexibility in lease provisions. That value is very important to lessees and is already considered when deciding to lease. In determining actual cost, evaluation should include costs of alternative capital investment methods and returns on internal funds.

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Q. **"Why use leasing if you don't own the equipment at the end of the lease?"**

A. But another question is why would a company want to own equipment? Usually the importance of owning the equipment depends on the remaining, useful life of the equipment after the lease term. If the equipment would still be modern and useful, rather than obsolete or surplus, use beyond the end of the lease would be important.

If a lessee believes that it may wish to continue using the equipment after the lease, then the lessee may obtain an option to purchase or extend the lease to maximize flexibility in asset management.

UTILITY REBATE OPPORTUNITIES

There are several forms of utility incentives and financing options that reduce or eliminate the need for capital, reduce risk, and improve cash flow. Although third-party financing may be a slightly more expensive approach to procuring lighting upgrades, it may still be the best alternative because it allows the Client to retain more capital for use in their specific business activities.

⇒ Electric utilities in some areas are helping their customers reduce the initial cost of lighting improvements by offering rebates and other incentives. With reduced customer loads, an electric utility is able to meet new customer demand at a lower cost than building new generating capacity.

⇒ Before you proceed with your lighting retrofit proposal, contact your local utility and obtain specific incentive program information. Pay particular attention to customer eligibility criteria and qualifying technologies. And verify the *deadline for* the rebate application or upgrade completion to qualify for the financial incentives. To determine the incentives that may apply to your upgrades, consult the computerized Green Lights Financing Directory that includes descriptions utility incentive programs and other financing sources.

Retrofit Rebates

⇒ The utility company reimburses the building owner for a portion of the cost of implementing lighting efficiency improvements.

⇒ Rebates may be based on load reduction ($ per kW), or based on a fixed rebate for each energy efficient product purchased ($ per item).

⇒ A given technology may qualify under one or more programs offered by the utility. Typically, only one incentive program application may be submitted per building. Check with your utility representative for details.

⇒ Rebates have been the most common form of utility incentives during the last several years.

Utility Assistance

⇒ The utility pays some or all of the lighting improvement cost directly to the installing contractor *selected by the customer.*

⇒ Alternatively, the utility provides lighting upgrade products or services to the customer *through utility personnel or contractors selected by the utility.*

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⇒ Some utilities offer low-interest financing for energy conservation projects. Loan payments may be added to your utility bills.

LIGHTING EVALUATIONS

This section focuses on the questions that need to be addressed when evaluating any lighting upgrade and the methods that can be used to answer those questions. A checklist at the end of this section systematically lays out suggested methods for evaluating a lighting upgrade project.

Issues

⇒ The performance of lighting equipment can be estimated (calculated) or measured directly

⇒ Lighting systems may be evaluated on the basis of.

1. Light level
2. Energy efficiency
3. Occupancy/utilization
4. Quality/user acceptance

Actions

⇒ Assess *current* lighting system:

1. Measure light levels
2. Determine existing user satisfaction
3. Survey lighting system to determine potential lighting upgrade options

⇒ Evaluate lighting *upgrade options:*

1. Perform trial installation and measure illuminance and/or energy consumption
2. Estimate first cost, operating costs, and disposal costs

⇒ Verify lighting upgrade performance

1. Measure user acceptance
2. Measure system energy consumption

Estimating Lighting Equipment Performance

⇒ Lighting upgrades can also be considered at the system level. To evaluate any lighting upgrade system, you will need estimates of at least four quantities:

1. Illuminance provided on the work surface
2. Power taken to provide that illuminance
3. Energy consumed to produce that illuminance over time
4. Cost of the lighting system.

These quantities should be estimated prior to installation and measured after completion of installation.

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Estimating Illuminance

⇒ Proper light levels are necessary to enable people to work quickly, accurately, and comfortably. Accordingly, the one lighting criterion that should always be checked is the illuminance on the task.

⇒ For a regular array of fixtures, the illuminance on a horizontal plane (work surface) can be estimated by using simple arithmetic and manufacturers' photometric data. If the proposed lighting installation is not a regular array of fixtures, a computer program will be needed to calculate the illuminance. Most lighting consultants and manufacturers can make the necessary calculations.

⇒ Compare the estimated illuminance with the values recommended by the Illuminating Engineering Society of North America (IESNA) in their *Lighting Handbook.* Illuminance levels greatly above the recommended values are unnecessary and illuminance levels markedly below the recommended values are unwise. What constitutes a large departure from the recommended illuminance is a matter of judgment, but as a rough guide, a 20% difference is usually considered acceptable. For example, if the recommended illuminance is 50 footcandles, then illuminances in the range of 40 to 60 footcandles will all be acceptable. After completing the project, you should take actual measurements of illuminance.

⇒ Although illuminance is important to occupant acceptance, it is not the only aspect of lighting which can affect how acceptable people find the lighting. *Other aspects such as glare, flicker, veiling reflections, color rendering, and shadows are important.* None of these aspects of lighting can be estimated by simple numerical calculation. You can find a discussion of these factors in the IESNA *Lighting Handbook.* However, to ensure that all of these aspects are addressed in an upgrade design, consider seeking advice from an experienced lighting consultant.

Estimating Cost

⇒ The total cost of any proposed lighting installation is the sum of three costs:

1. Retrofit cost
2. Operating and maintenance costs
3. Disposal cost

Retrofit Cost

⇒ Methods of estimating the first cost of a proposed lighting installation are discussed previously.

Operating and Maintenance Costs

⇒ Operating costs are more difficult to estimate than first costs because they depend on a number of factors, which may themselves have to be estimated. To estimate operating costs, first determine the values of the following factors:

1. Electrical load (kilowatts), which can be one of the following:
   - ⇒ installed wattage, (kilowatts) or
   - ⇒ effective wattage if dimming or power
   - ⇒ reducing equipment is used (kilowatts)

2. Hours of use over a relevant period of time (hours)

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3. Unit cost of electricity for each time period (dollars/kilowatt-hour)

4. Electricity maximum demand costs (dollars) times when use occurs

   ⇒ electricity usage during maximum demand periods (kilowatts)
   ⇒ electricity maximum demand charges (dollars/kilowatt)

5. Maintenance costs, such as cleaning and relamping

⇒ Next, use the following formula to determine the electricity cost over the relevant period:

ELECTRICITY COST =
[electrical load x hours of use x unit cost of electricity for each time period] + electricity maximum demand cost

⇒ Basically, the electricity cost is the product of the electrical load, the hours of use, and the unit cost of electricity, plus any cost of lighting used in periods of maximum electricity demand. Contact your utility representative for electricity rates for your organization and for methods of calculating the electricity maximum demand cost. Utilities use various methods of calculating the demand costs.

⇒ Finally, calculate the total operating cost of the installation:

Total operating cost = electricity cost + maintenance costs

Disposal Cost

⇒ Disposal costs are made up of the cost for removing the lighting equipment and the cost of disposing it. Contact a local hazardous waste contractor for cost associated with ballast and tubes.

Testing Current Technologies

⇒ Field measurements may be made at various stages of a lighting upgrade project:

1. Before proceeding with the upgrade, field measurements can be used to *assess the existing lighting installation.*

2. By performing a *trial installation, field* measurements can be used to guide the decision on whether or not to cancel or modify the proposed upgrade specification, or to proceed with the upgrade in all proposed locations.

3. After completing the lighting upgrade, field measurements can be used to verify the retrofit performance.

⇒ The field testing will determine four basic questions:

1. Does the light meet IESNA recommended levels ?

2. Does the light levels and color rendering meet with the building occupants satisfaction ?

3. How can the energy efficiency of the installation be improved ?

4. Is energy being wasted in unoccupied spaces ?

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Measuring Light Levels

A light meter, a widely available instrument that can be used to measure light levels is an illuminance meter. With this instrument and a degree of common sense, you can carry out a simple photometric survey

RETROFIT TECHNOLOGY CHECKLIST

This checklist shows how the different techniques of evaluating lighting upgrade performance can be used in a lighting upgrade project.

⇒ The checklist is divided into three parts, each part leading to a decision point:

1. Part 1 is concerned with identifying the viability of an upgrade project.
2. Part 2 covers the detailed design of the lighting upgrade.
3. Part 3 is concerned with verifying that the upgrade is satisfactory to the occupants and is performing as expected.

Analyzing Current Lighting

1. Measure the illuminance provided by existing lighting; compare existing lighting with current standards.
2. Measure user satisfaction with existing lighting.
3. Survey your existing lighting system with assistance from lighting professionals and/or the Green Lights Decision Support System.
4. Make preliminary estimates of energy and cost savings to assess the viability of possible lighting upgrades.

⇒ **Decision:** Continue or cancel lighting upgrade project.

Analyzing Lighting Upgrade

1. Obtain specific upgrade options from consultant or the Green Lights Decision Support System; be sure that qualitative aspects of lighting have been considered.
2. Select lighting upgrade options to be pursued.
3. Confirm product data for proposed upgrade.
4. Estimate illuminance or perform illuminance measurements in a trial installation.
5. Estimate electrical load and energy consumption of proposed upgrade; alternatively, load and consumption values can be directly measured in a trial installation.
6. Estimate lighting power density or installation effectiveness and compare with current values.

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7. Check compliance of proposed upgrade with federal, state, and local codes.

8. Estimate first cost, operating cost, and disposal cost.

9. Evaluate financial viability of lighting upgrade.

10. Construct budget for lighting upgrade project.

⇒ **Decision:** Prepare lighting upgrade specification or cancel project.

Verify Completed Performance

1. Measure occupant acceptance of lighting upgrade.

2. Measure electrical load of installation.

3. Measure energy consumed by installation over known period.

4. Estimate energy wasted over a known period.

⇒ **Decision:** Extend, keep, modify, or remove lighting upgrade.

PROJECT MANAGEMENT

Implementation of a lighting upgrade project requires timely and organized management of labor, material and administrative resources. A comprehensive discussion of project management is beyond the scope of this manual This one-page section provides a checklist of issues and tasks that are important to successful project management. Remember, the more your organized, the less problems you'll have the next morning from the Client, complaining about the mess or damage. So be prepared !

Project Management Checklists

Safety and Insurance

1. Bid Bonds
2. Performance Bonds
3. Arbitration Considerations
4. Asbestos Considerations
5. Permits and Inspection Fees
6. Insurance (workman's compensation; public
7. liability; automobile)

Project Start-Up

1. Applicable Standards
2. Drawings and Specifications
3. Product Samples and Test Installations
4. Project Meetings
5. Subcontractor Approval
6. Equipment Storage

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7. Parking
8. Schedule of Work (Hours and Days)
9. Building Access and Key Control

Project Implementation

1. Daily Clean-Up and Waste Removal
2. Project Supervision
3. Changes in Scope of Work
4. Change Order Procedure
5. Payment Schedules and Conditions
6. Invoicing
7. Quality Control
8. Warranties/Servicing

WASTE DISPOSAL

Upgrading a lighting system will likely involve the removal and disposal of lamps, ballasts or fixtures. Some of this material may be classified as a hazardous substance and must be handled accordingly. Other materials can be recycled or should be disposed of in an environmentally responsible manner. This section provides an overview of issues relating to disposal of lamps and of ballasts.

Issues

1. The Federal Government does not specify the method of disposal for ballasts *except in the case of ballasts that are leaking PCBs.*

2. Some states have requirements for the transportation and disposal of non-leaking ballasts that contain PCBS.

3. Under current Federal law, mercury-containing lamps may be a hazardous waste and must be handled accordingly.

4. Some states further regulate lamp disposal.

5. EPA encourages environmentally responsible disposal or recycling of all lighting upgrade wastes.

Actions

1. Investigate and follow local requirements for handling and disposing of lamps and ballasts.

2. Identify ballasts that contain PCBS and ballasts that are leaking PCBS.

3. Remove, handle, and dispose of *leaking PCB* containing ballasts as a regulated hazardous substance.

4. Dispose of ballasts containing PCBS (but not leaking) by high-temperature incineration or disposal at chemical or hazardous waste landfill sites.

5. Maintain permanent records of PCB-containing ballast disposal.

6. If they test hazardous, manage mercury containing wastes in compliance with hazardous waste regulations.

FLUORESCENT BALLASTS DISPOSAL

Note.- The information in this section is believed to be correct as of July 1995. TFM does not provide legal advice, and this section is not intended to do so. Generators of wastes should check with local state, and regional authorities for the most up-to-date information.

The primary environmental concern regarding the disposal of used fluorescent lighting ballasts is the health risks associated with contact with polychlorinated biphenyls (PCBs). PCBS, potential carcinogens, are toxic chemical compounds that were widely used as insulators in electrical equipment such as capacitors, switches, and voltage regulators until the early 1980s.

⇒ Production of PCBs was banned in the United States in 1976 by the U.S. Environmental Protection Agency. PCBs are regulated under the Toxic Substances Control Act (TSCA) in Volume 40 Code of Federal Regulations (CFR) Part 761.

⇒ The proper method for disposing of used ballasts depends on a number of factors relating to the type and condition of the ballasts, as well as the regulations or recommendations that are in effect in the state where the ballasts will be discarded. Federal regulations pertain to the disposal of ballasts that are leaking PCBS. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), certain generators of PCB-containing ballasts can be held liable for disposing of ballasts in an unapproved manner.

⇒ Because disposal requirements vary from state to state, check with regional or local authorities for all applicable regulations in your area

Ballast Containing PCB

⇒ Fluorescent lighting ballasts contain a small capacitor that may contain high concentrations of PCBs (greater than 90% pure PCBs or 900,000 ppm). Use the following guidelines to identify ballasts that contain PCBS.

1. All light ballasts manufactured through 1979 contain PCBS.
2. Ballasts manufactured after 1979 that do not contain PCBs are labeled **"No PCBS".** These labels, however, are not certain proof that a ballast does not contain PCBS.
3. If a ballast is not labeled "No PCBS" it should be assumed to contain PCBS.
4. It is extremely important to determine if a ballast containing PCBs is leaking, it is removed from the fixture, so that it can be handled properly.

Federal Guidelines

If fluorescent light ballasts are not leaking PCBS, their disposal is not regulated under TSCA. The disposal of non-leaking PCB containing ballasts is regulated under CERCLA. Building owners who release a pound or more of PCBs (roughly equivalent to 12-16 ballasts) in a 24 hour period into the environment are required under CERCLA to notify the National Response Center. Building owners may be liable for throwing away PCB containing ballasts in a dumpster or local landfill under CERCLA.

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⇒ Small capacitor fluorescent lighting ballasts that contain PCBs are exempt from Federal TSCA requirements under 40 CFR 761.60(b)(2)(ii). (See the definition of small capacitor ballasts on the next page.) However, EPA does encourage proper disposal of PCB containing ballasts, as described in the 1979 preamble to 40 CFR 761 and reiterated in the final ruling on August 25, 1982 (47 FR 37342):

⇒ *"EPA encourages commercial and industrial firms that use and dispose of large quantities of small PCB Capacitors to establish voluntarily a collection and disposal program that would result in the waste capacitors going to chemical or hazardous waste landfills or high-temperature incinerators."*

⇒ Some EPA regional offices publish policies governing disposal of PCB containing ballasts which may be adopted by individual states in their region. States are not obligated to adopt regional policies.

Definition of a Small Capacitor Ballast

⇒ Ballasts contain a capacitor that contains dielectric fluid. The ballast is classified as a small capacitor ballast if the weight of the dielectric fluid is less than 1.36 kg (3 lbs.). If the weight is unknown, the following assumptions are made:

1. A capacitor whose total volume is less than 1,6-39 cubic centimeters (100 cubic inches) contains less than 1.36 kg of dielectric fluid.

2. A capacitor whose total volume is more than 3,278 cubic centimeters (200 cubic inches) contains more than 1.36 kg dielectric fluid (i.e. is not a small capacitor ballast and is subject to 40 CFR Part 761).

3. A capacitor whose total volume is between 1,639 and 3,278 cubic centimeters is considered to contain less than 1.36 kg dielectric fluid if the total weight of the capacitor is less than 4.08 kg (9 lbs.).

Leaking PCB-Ballast Disposal

⇒ Ballasts in a lighting system may be punctured or damaged, exposing an oily tar-like substance. If the leaking ballast is identified as containing PCBS, the ballast and all materials that come in contact with it are considered hazardous waste and are fully regulated and subject to federal requirements for PCBs under 40 CFR Part 761. *Leaking PCB containing ballasts must be incinerated at an EPA approved high-temperature incinerator*

⇒ It is very important that the removal, handling and disposal of leaking PCB-containing ballasts be done properly. Extra precautions must be taken to contain the exposure to the leaking ballast, since all ***materials that come in contact with the ballast or the leaking substance must also be treated*** as ***hazards waste.***

⇒ The handling and disposal of leaking PCB containing ballasts should be completed by personnel or contractors that are specifically trained and authorized to do so.

⇒ ***For proper packing, storage, transportation, and disposal information, call the TSCA assistance information hot-line at (202) 554-1404.***

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State Requirements

⇒ Although many states do not regulate the disposal of non-leaking PCB-containing ballasts, the disposal standards for these ballasts are more stringent in some states than Federal TSCA or CERCLA guidelines. State standards can take several forms (e.g., written regulations, regional policies, written and verbal recommendations, transportation documentation only).

⇒ Some states do not regulate PCB-containing ballasts as a hazardous waste, but prohibit their disposal in municipal landfills. The table on the following page provides a listing o f regulations and recommendations for each state.

⇒ When performing lighting upgrades, make sure your contractor removes all disconnected PCB containing light ballasts from the luminaires. Non-leaking PCB containing ballasts may be hazardous if left in the luminaires, especially in the event of a fire in the building.

Packing Ballasts for Disposal

⇒ Ballasts are packed, in accordance with PCB regulations, in 55-gallon drums for transportation -regardless of chosen disposal method.

1. One drum holds 150 to 300 ballasts depending on how tightly the ballasts are packed.

2. Void space is filled with an absorbent packing material for safety reasons.

Ballast Disposal Costs

⇒ High-temperature incineration and hazardous waste landfill costs can vary considerably. Disposal prices vary according to:

1. Quantity of waste generated
2. Location of removal site
3. Proximity to an EPA-approved high-temperature incinerator or hazardous waste landfill.

Negotiate with hazardous waste brokers, transporters, waste management companies, and disposal sites to obtain lower fees.

High-Temperature Incineration Costs

⇒ Incineration costs are calculated by weight:

1. Costs range from $l/lb. to $2.75/lb.;
2. Average cost is $1.85/lb., which equals
3. Approximately $5.75 per ballast.

Note: Estimated costs do not include packaging, transportation or profile fees.

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Chemical or Hazardous Waste Landfill Costs

⇒ Chemical or hazardous waste landfill costs are calculated by the drum.

1. Costs range from $65/drum to $385/drum;
2. Average cost is $150/drum; which equals
3. Approximately $1/ballast.

Note: Tightly packed drums lower your disposal costs. Estimated costs do not include packaging, transportation, or profile fees.

Transportation Costs

⇒ Transportation fees are calculated as cents per pound per mile and vary according to:

1. Number of drums to be removed from the site;
2. Distance from your location to the location of the high-temperature incinerator or hazardous waste landfill.

Transporters may be required to be registered or licensed to be authorized to move hazardous waste in certain states. Documentation of the movement of hazardous waste may be required even if a state does not regulate disposal or require the use of a licensed transporter.

Profile Fees

⇒ Operators of the high-temperature incinerator or hazardous waste landfill may charge a profile fee to document incoming hazardous waste. Profile fees vary depending on the volume of waste materials generated:

1. Profile fees range from $0 to $300 per delivery;

2. Fees may be waived if a certain volume or frequency of deliveries is assured or a working relationship has been established with a broker, lighting management company, or other contractor.

Record Keeping

1. Keep records (including year, make, and quantity) of all light ballasts removed in lighting upgrades that are not labeled "No PCBS".

2. Require your contractor to provide you with certificates of destruction for all PCB-containing ballasts that are incinerated or hazardous waste landfilled.

3. Request documentation from hazardous waste haulers who may be transporting your PCB containing light ballasts.

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Recycling of Ballasts

1. Used non-leaking ballasts may be recycled regardless of whether they contain PCBS.

2. Ballasts can be recycled to reclaim valuable metals and reduce the volume of solid waste sent to landfill sites.

3. Recyclers remove the chamber which contains the capacitor to reduce the volume and weight of materials sent to landfill or incinerator. The remaining ballast can yield copper, steel, and other valuable materials.

4. Recycling prevents toxic substances from being burned at your local incinerator or buried in a landfill.

WORKING WITH SUB-CONTRACTORS

Your lighting upgrade project sub-contract should include provisions for proper handling and safe disposal of lamps, ballasts, and other hazardous materials that may be associated with the project.

⇒ Here are some general guidelines:

1. Investigate your disposal options thoroughly.

2. Do not expect your contractor to be well-versed in all disposal requirements and options.

3. Ask your lighting or electrical contractor to provide disposal services (either directly or through a sub-contractor) as part of their contract.

4. Be specific in your disposal requests (e.g., high temperature incineration of PCB-containing ballasts at an EPA-approved incinerator).

5. Require documentation from the contractor (or sub-contractor) for transportation and proper disposal of hazardous wastes.

6. Ask for certifications, licenses, and references from all subcontractors providing waste disposal services.

LIGHTING UPGRADES

This appendix provides brief descriptions of currently available lighting upgrade technologies. For each upgrade listed, technologies are defined, common applications are listed, and any limitations are identified. Many product variations exist within each technology described; for application assistance for specific product types,, contact a professional lighting consultant or TFM.

Fluorescent Retrofits

⇒ The following upgrades may be performed on existing 2’x4’ fluorescent fixtures. Variations for 2’x2’, 1’x4’, and 1'x 8' troffers may be feasible; contact your local utility representative, lighting professional or TFM for further assistance.

Fixture Delamping

⇒ **Definition:** Delamping is simply the removal of one or more lamps from a fixture.

⇒ **Applications:** To save additional energy and to discourage occupant relamping, disconnect and remove the ballast that operated the removed lamps.

Two approaches to delamping may be used:

1. *Uniform delamping* for reducing light levels throughout the space

2. *Task-oriented delamping* to place more light directly in the work area and less light in the circulation areas

⇒ Relocating lamps so that they are centered on each half of the fixture will improve light output and distribution, and will result in a more acceptable upgrade appearance.

Fixture Qualifications

⇒ Delamping may be combined with the use of higher output lamps, reflectors, lens upgrades, fixture cleaning, and task lighting to minimize light output reduction.

⇒ In general, light levels are reduced in proportion to the number of lamps removed. However, in enclosed fixtures, delamping will result in a 5% to 10% increase in effectiveness (lumens per watt) due to the cooler operating temperature and reduced lamp shadowing that results. Depending on ambient temperature, delamping an open strip fixture may either increase or decrease effectiveness.

⇒ If the remaining lamps are not relocated, the appearance of a delamped fixture may not be acceptable.

⇒ The ballast used for operating the removed lamps should be disconnected. In addition, removing the unused sockets will prevent "snap-back" (re-installing lamps where they have been removed).

⇒ Delamping may not be feasible in two-lamp fixtures where the removal of one lamp extinguishes the other lamp. In such cases, consider installing partial output (low ballast factor) electronic ballasts.

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Specular Reflector Advantage

⇒ **Definition:** Removal of one or more lamps and installation of a specular "mirror-like" reflector inside the fixture behind the lamps to improve fixture efficiency by as much as 17%. (Efficiency can be improved by more than 17% if the existing fixture surface has deteriorated.)

⇒ **Applications:** Typically, the remaining two lamps in a 2'x4' fixture are relocated to positions centered on each side of the fixture for maximum utilization of the reflector. This enhances light output and distribution and will result in a more acceptable fixture appearance.

1. The ballast used for operating the removed lamps should be disconnected.
2. Reflectors may be combined with installation of higher output lamps and/or improved lenses to minimize light output reduction (and in some cases, increase light output).
3. To maintain light output over time, reflector surfaces should be cleaned at regular intervals.

Specular Reflector Qualifications

⇒ When using 50% of the original lamps in 2'x4' troffers, average light levels are typically reduced by 30% to 45% *(assuming comparable conditions of luminaire dirt and lamp age).* If existing fixture shows some surface deterioration (reduced efficiency that cleaning can't improve), reductions in light output resulting from installing reflectors and delamping will be lessened. To assess the performance of specular reflectors in your facility, set up a trial installation to compare the lighting in a room with clean, delamped fixtures to one with reflectors installed.

⇒ Even a well-designed reflector may affect light distribution. Potential effects should be assessed carefully using either fixture photometric data (primarily spacing criteria) or a trial installation. "Imaging" reflector designs, those that are designed to only make the fixture *appear to* have all four lamps installed, may reduce both light distribution and output.

⇒ If lamps need to be relocated or if the reflector is being used as part of an electrical enclosure, specify only UL-classified reflectors and accessories.

⇒ Check the design for accessibility to the ballast compartment.

⇒ Differences between manufacturers' reflector designs and materials can cause wide variations in reflector performance.

Power Reducers

⇒ **Definition:** Power reducers, known as current limiters are retrofit devices for fluorescent fixtures that reduce light output with a nearly corresponding reduction in energy consumption.

⇒ **Applications:** Most current limiters are designed to achieve a pre-set light output reduction and energy savings of 20, 33, or 50%.

⇒ Current limiters enable light-output reductions as an alternative to delamping. They may be preferred to delamping in applications involving 2-lamp luminaires where the removal of one lamp will also extinguish the other lamp.

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⇒ Current limiters may be installed directly inside the ballast compartment or installed as companion lamp. The use of the companion lamp design is discouraged because it can be easily removed from the luminaires eliminating future energy savings.

⇒ For maximum energy savings and efficiency, consider partial-output electronic ballasts as an alternative.

Power Reducer Qualifications

⇒ Current limiters do not improve the inherent effectiveness of the lamp/ballast system. However, due to the relationship between operating temperature and fluorescent effectiveness, slight increases in effectiveness may result with current limiters installed in enclosed fixtures. *Current limiters may not be used with some electronic ballasts.*

⇒ Most current limiters increase total harmonic distortion in rapid start systems to over 32%, which is considered an unacceptable level by most building engineers and utility companies. In addition, some current limiters can increase the current crest factor to over 1.7 in rapid start systems, which can void some lamp warranties. Check with the manufacturer of your lamps and ballasts to determine if the installation of current limiters will have any effect on their **warranties**.

Electronic Ballasts

⇒ **Definition:** Electronic, high-frequency versions of conventional magnetic "core-and-coil" ballasts.

⇒ **Applications:** In nearly every fluorescent lighting system, electronic ballasts can replace conventional ballasts. They provide about the same amount of light while reducing energy use up to 25%.

⇒ Other advantages are reduce weight, less humming noise, virtually no flicker, and the capability to operate up to four lamps at a time.

⇒ "Dimmable" ballasts are specifically designed to vary the light output of a fluorescent fixture based on input from a light sensor, manual dimmer, or occupancy sensor.

⇒ Some electronic ballasts are designed to offer both full and partial output ("low-wattage") capability. If partial output ballasts (low ballast factor) are specified in your upgrade, consider requesting that units be manufactured with single-option wiring to simplify installation and prevent installation at the full output setting. Partial output electronic ballasts are lower wattage versions that produce a nearly corresponding reduction in light output. These ballasts should be used for minimizing electricity consumption where reduced illumination is acceptable.

Electronic Ballast Qualifications

⇒ Both magnetic and electronic ballasts may cause electrical disturbances that can interfere with the operation of sensitive electronic equipment. Specify electronic ballasts with input current harmonics that meet the proposed ANSI standard: total harmonic distortion (THD) not to exceed 32% of line current. Note that some utilities will not offer rebates on electronic ballasts unless the THD is at or below 20%. Magnetic ballasts typically cause THD of 12-20%, while some electronic ballasts are available with THD under 5% and others have a measured THD that is well over 40%. The majority of electronic ballasts on the market today produce less than 30% THD.

⇒ Not all lamps work with all ballasts. Check with your lighting consultant or supplier about compatibility.

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⇒ Verify the "ballast factor" of the product you are considering. Lower values will reduce light levels and energy consumption.

⇒ Verify input wattage values for your proposed lamp-ballast combination because manufacturers' products will vary in this regard. Lower input wattages will increase energy savings and profitability, but will typically decrease light output.

Energy-Efficient Magnetic Ballasts

⇒ **Definition:** These ballasts are premium versions of the older standard magnetic "core-and-coil" ballasts and are now the standard for magnetic ballast production.

⇒ **Applications:** All magnetic ballast applications for full-size fluorescent lamps.

Energy-Efficient Magnetic Ballasts Qualifications

⇒ Other more efficient ballast options exist.

Hybrid Electromagnetic Ballasts

⇒ **Definition:** Energy-efficient magnetic ballasts that incorporate electronic components that cut off power to the cathodes (filaments) after the lamps are lit, resulting in an additional 2-watt savings per standard lamp.

⇒ **Applications:** All magnetic ballast applications for 4-foot T-10 or T-12 rapid start fluorescent lamps.

Hybrid Electromagnetic Ballasts Qualifications

⇒ Most hybrid design ballasts provide approximately 8-15% less light output than standard magnetic or electronic ballasts (due to low ballast factor).

⇒ Hybrid ballasts should not be used in any dimming applications or with T-12 32-watt heater cutout lamps. Some heater cutout ballasts will not start T-10 lamps over the full range of primary voltage (re: California Energy Commission, March 1990)

⇒ For maximum efficiency and energy savings, consider installing electronic ballasts as an alternative.

32 Watt Heater Cutout Fluorescent Lamps

Definition: Energy-saving fluorescent lamps that incorporate a pair of thermally-activated switches that open after the lamp has completed its normal rapid-start ignition sequence, resulting in an additional 2-watt savings per lamp.

⇒ **Applications:** F40 lamp applications, subject to the following qualifications.

32 Watt HCF Lamp Qualifications

⇒ Heater cutout lamps should be used only on rapid-start circuits and not in fixtures with electronic ballasts, current limiters, or starters.

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⇒ The thermally-activated switches require a reset time of about one to ten minutes after the lamp is turned off (depending on ambient temperature and enclosure). This may present a limitation when used in frequently-switched areas. In addition, heater cutout lamps should not be used in emergency lighting fixtures.

⇒ Heater cutout lamps have a shorter rated life than other F40TI2 lamps.

⇒ For maximum energy savings and efficiency, consider installing T-8 lamps and electronic ballasts as an alternative.

34 Watt Energy Saver Fluorescent Lamps

⇒ **Definition:** Essentially standard 40-watt fluorescent lamps that are filled with an argon-krypton gas mixture (rather than just argon) that causes the lamp to draw only 34 watts.

⇒ **Applications:** This lamp may be used to replace standard 40-watt lamps in spaces that are currently over-illuminated. The savings of 6 watts per lamp reduces energy use by about 15%.

34 Watt ESF Lamps Qualifications

⇒ Although its unit wattage is reduced, its light output is also reduced. When operated on a standard or energy efficient magnetic ballast, it only generates about 81% of the light output of a standard 40-watt lamp-ballast system.

⇒ This lamp-ballast system is less energy efficient than the standard argon-gas lamp-ballast system because it generates fewer lumens per watt. This is due to increased ballast losses. In addition, these lamps cannot be dimmed as easily as standard 40-watt F4OTl2 lamps, and they are more sensitive to temperature.

⇒ For maximum energy savings and efficiency, consider installing T-8 lamps with electronic ballasts as an alternative.

T-8 Lamp-Ballast Retrofit

⇒ **Definition:** The T-8 lamp-ballast system has the highest effectiveness of any fluorescent system -- over 90 lumens per watt when used with an electronic ballast.

⇒ **Applications:** T-8 lamps have the same medium bipin bases of T-12 lamps, allowing them to fit into the same sockets. T-8 lamps operate on a reduced current (265 mA) and, therefore, must be operated using a ballast that is designed for T-8 lamp operation. T-8 lamps are available in 2’, 3’, 4’, 5’, and 8’ straight tubes, and 2’ U-tubes with either the standard 6” leg spacing now available for retrofit, or the 1.625” leg spacing for new applications.

⇒ All T-8 lamps use tri-phosphor coatings that improve color rendering performance.

⇒ One manufacturer produces a 36W T-8 lamp for 4' luminaires that produces over 30% more lumens than standard 32W T-8 systems when used with a dedicated higher-output electronic ballast. This system may be used to partially offset light reductions associated with delamping strategies, while providing over 90 lumens per watt.

T-8 Lamp-Ballast Retrofit Qualifications

⇒ Because converting to T-8 lamps requires new ballasts, the cost of new ballasts should be included in the project cost estimate. Consider installing electronic T-8 ballasts for maximum efficiency.

40 Watt T-10 Lamps

⇒ **Definition:** A high-efficient-y, high lumen output (approx. 3600 lumens) F40 fluorescent lamp. Using T-10 lamps instead of standard 40-watt cool-white T-12 lamps will increase light levels by about 17%.

⇒ **Applications:** T-10 lamps may be used with conventional T-12 ballasts.

⇒ Because T-10 lamps have a color rendering index of 80 or more, they improve the color rendering quality of the lighting system.

⇒ T-10 lamps are currently available as straight four foot lamps.

⇒ T-10 lamps are commonly used for increasing light levels, usually after strategically removing one or more lamps from a multi-lamp fixture and/or installing reflectors.

40 Watt T-10 Lamps Qualifications

⇒ Some heater cutout ballasts will not start T-10 lamps over the full range of primary voltage.

40 Watt T-12 High Lumen Lamps

⇒ **Definition:** Standard-size T-12 F40 lamps with a thick tri-phosphor coat that produces 6-8% more light with no increase in energy consumption compared to standard 40-watt lamps.

⇒ **Applications:** High-lumen T-12 lamps should be used where both a modest increase in light output and improved color rendering are desired.

Lens/Louver Upgrade

⇒ **Definition:** Clear acrylic lenses and large cell parabolic louvers are efficient fixture shielding materials.

⇒ **Applications:** Fixture efficiency can be significantly improved by replacing opaque diffusers or small-cell louvers with clear acrylic lenses or large-cell parabolic louvers.

⇒ To determine impacts on visual comfort, refer to the product's Visual Comfort Probability (VCP) data or perform a trial installation. Visual comfort is improved when light emitted at higher angles is shielded.

Lens/Louver Upgrade Qualifications

⇒ Smaller cell parabolic louvers (2" or smaller cells) provide high visual comfort (>O.90) but significantly reduce efficiency.

⇒ If sufficient plenum space is available above the ceiling grid, deep-cell parabolic louver upgrades can be retrofit in many kinds of existing fluorescent fixtures. Alternatively, consider installing new deep-cell parabolic louver fixtures.

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New Efficient Fixture Installations

⇒ **Definition:** Removing the existing luminaires and replacing them with new luminaires consisting of high-efficiency components such as T-8 lamps, electronic ballasts, deep-cell parabolic louver, and optional daylight-dimming control. In addition, indirect lighting systems are now available for retrofit applications.

⇒ **Applications:** Conditions that enhance the cost effectiveness of new fixtures include:

1. Where multiple fixture component replacements are considered (new lamps, ballasts, reflectors, lenses, etc.)

2. Where deep-cell parabolic louvers or indirect lighting systems are desired for combined efficiency and glare control

3. Where the space will be remodeled or the fixture locations will be changed

New Efficient Fixture Installation Qualifications

Before installing new luminaires, ask a lighting designer to verify the correct number and spacing of the luminaires based on published photometric data and the desired illumination level.

Task Lighting with Delamping

⇒ **Definition:** Providing light sources at specific task locations while reducing ambient (overhead) lighting.

⇒ **Applications:** "Task/Ambient" lighting designs are best suited for office environments with significant VDT usage and/or where modular furniture can incorporate task lighting under shelves. In other cases, desk lamps may be used to provide task illumination.

Task Lighting with Delamping Qualifications

⇒ Energy savings result when the energy saved from delamping exceeds the added energy used for the task lights. In some cases, the use of incandescent task lights may add more load than can be eliminated from the ambient lighting system. Compact fluorescent task lights are very efficient sources for task lighting.

⇒ Non-adjustable task light strips that are permanently mounted under cabinet shelves can cause reflected glare on work surfaces. To reduce reflected glare, specify compact fluorescent task lights that allow users to position the light to the side of the task.

Relamping and Cleaning

⇒ **Definition:** Relamping and cleaning light fixtures according to a schedule determined by lamp life, lumen depreciation characteristics, and ambient dirt conditions.

⇒ **Application:** Periodic group relamping and cleaning will significantly improve luminaire efficiency and reduce maintenance costs. The resulting increased light output from properly maintained luminaires may justify delamping, use of partial output electronic ballasts, or relamping with fewer higher output lamps.

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INCANDESCENT UPGRADES

Where ever applicable, alternatives to the use of incandescent lamps should be pursued. With recent advances in compact fluorescent and halogen lamps, the continued use of standard incandescent lamps is difficult to justify.

Compact Fluorescent Lamps

⇒ **Definition:** Compact fluorescent lamps are an energy-efficient, long-lasting substitute for the incandescent lamp. They are available in "twin-tube" and "quad tube" configurations (that require a separate ballast attachment) or self-ballasted units. Several retrofit adapters are available for convenient retrofit in existing incandescent sockets.

⇒ **Applications:** Compact fluorescents may be used in a variety applications including downlights, surface lights, pendant fixtures, task lights, compact troffers, sconces, exit lights, step lights, and flood lights. Although some compact fluorescent packages are too bulky to fit in some standard table lamps, plug-in (wall outlet) ballasts are now available that enable the use of screw-in compact fluorescent lamps to be used in table lamps without a ballast attachment.

Compact Fluorescent Lamps Qualifications

⇒ Compact fluorescents may not be suitable in high ceiling applications (greater than 12') or where tight control of beam spread is necessary.

⇒ Where dimming is important, compact fluorescents may not be appropriate for lighting retrofits. Some dimming compact fluorescents are available, but a new fixture is usually required.

⇒ Some compact fluorescent lamps have difficulty starting when with ambient temperature drops below 40°F, while others are designed to start at temperatures below freezing. Refer to manufacturer specifications.

⇒ The light output of compact fluorescent lamps is significantly reduced when used in fixtures that trap heat near the lamp or when exposed to cold temperatures. In addition, the *orientation* of the lamp can also significantly affect lumen output. Trial installations are recommended before purchasing large quantities.

⇒ Most lamps operating on magnetic ballasts require one to three seconds to start and rise to full output. Where instantaneous lighting is required, select T-5 rapid start systems or use electronic ballasts.

Compact Halogen Lamps

⇒ **Definition:** Tungsten-halogen incandescent lamps that are adapted for use as direct replacements for standard incandescent lamps. Halogen lamps are more efficient, produce a whiter light, and last longer than conventional incandescent lamps.

⇒ Traditional tungsten halogen lamps are manufactured as a double-ended tube. Compact halogen lamps consist of a small tungsten-halogen capsule lamp within a standard lamp shape similar to PAR lamps or general service A-type lamps.

⇒ **Applications:** The best applications are in accent lighting and retail display lighting, especially where tight control of beam spread is necessary. Other good applications include downlighting and "instant on" power floodlighting. The use of an optional infrared (IR) coating applied to the halogen capsule or specially designed reflectors can further increase the effectiveness of this light source in PAR lamp applications.

⇒ Compact halogen lamps may be used in full-range dimming applications, but dimming below 35% of full light output may affect lamp life.

Compact Halogen Lamps Qualifications

Lamps with optional diodes (for improving lamp optics) can flicker and have adverse effects on dimming and power quality. Due to their lower effectiveness, compact halogen lamps should not be used in applications where compact fluorescent lamps would serve satisfactorily.

Exit Sign Retrofits

⇒ **Definition:** The use of high-efficiency light sources in existing or replacement exit signs. The light source may be one of the following:

1. Compact fluorescent lamps (retrofit or new signs)
2. Tritium or Self-Luminous (new signs)
3. Light Emitting Diode (L.E.D.) (new signs)
4. Electroluminescent (E.L.) (new signs; retrofit panels introduced in 1993)

⇒ **Applications:** All emergency exit signs should illuminate 24 hours per day and be able to continue operation in the event of a power failure. Significant energy savings can be achieved by simply replacing or upgrading the exit signs with a low energy model.

Exit Sign Retrofit Qualifications

⇒ Check with local building codes for accepted emergency exit sign illuminance options.

Compact HID Sources

⇒ **Definition:** New manufacturing methods have produced low-wattage (< 100-watt) versions of metal halide and high pressure sodium lamps.

⇒ **Applications:** Primarily intended for new construction or remodeling applications, compact HID lamps are point sources which lend themselves to projection and floodlight applications as well as general illumination.

Compact HID Qualifications

⇒ All metal halide lamps are susceptible to lamp-to-lamp color differences and color shift over life.

⇒ Compact "white" high pressure sodium lamps offer improved color rendering compared to standard HPS lamps, but after their "color life," the color quality becomes similar to standard HPS lamps.

⇒ All HID lamps require warm-up and restrike periods, so frequent switching installations should not utilize these lamps.

HID Retrofits

The primary method for improving the efficiency of HID systems is to replace the light source with a more effective system. Other energy saving techniques that apply to fluorescent retrofits are also applicable to HID *systems: Delamping, central panel dimming, low-wattage lamps and ballasts, group relamping/cleaning, painting room surfaces with higher reflectivity paint, and task lighting.*

High-Efficiency HID Systems

⇒ **Definition:** Replacement or retrofit of existing highbay or outdoor lighting system with metal halide (MH), high pressure sodium (HPS), or low pressure sodium (LPS) lamps. Refer to Appendix D for a complete discussion of these lamps and their characteristics.

⇒ **Applications:** The most cost-effective upgrades involve replacing less efficient sources such as incandescent, HO/VHO fluorescent, or mercury vapor with MH, HPS, or LPS. This may involve a one-for-one luminaire replacement or a new layout of luminaires to take advantage of the different light distribution characteristics of HID fixtures.

High-Efficiency HID Systems Qualifications

⇒ The selection of the HID luminaire should be based on the following criteria that pertain to the task:

1. Color rendering quality
2. Efficiency
3. Lamp life
4. Lumen maintenance
5. Light distribution

Lighting Control Systems

These upgrades are designed to help eliminate unnecessary use of Lighting. They Limit the hours or intensity of Lighting system operation based on occupancy, time, or ambient Light levels.

Occupancy Sensors

⇒ **Definition:** A device that detects occupancy of a room and activates a control device that turns on the light fixtures. If no motion is detected within a specified period of time, the lights are turned off until motion is sensed again.

⇒ **Applications:** Occupancy sensors are suitable for a wide range of lighting control applications and should be considered in every upgrade decision.

⇒ Occupancy sensors are available in ceiling-mounted versions (that require a separate switching device) or wall-mounted versions (that can replace existing wall switches).

⇒ Common applications for wall-mounted sensors include separately switched areas such as conference rooms, classrooms, individual offices, and storage rooms. Ceiling-mounted sensors should be used in areas where wall-mounted switches would be inadequate, such as open office areas and spaces where objects obstruct the coverage of a wall-mounted sensor.

Occupancy Sensors Qualifications

⇒ The specification and placement of occupancy sensors should be performed by an experienced professional to ensure adequate occupancy sensing coverage. A properly designed and installed system should not disrupt normal business activity.

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⇒ Occupancy sensor systems must be "adjusted" after installation. This involves adjusting sensitivity and time delay settings as appropriate for the space. Occupancy sensors are not vandal-proof and are not recommended in areas prone to vandalism.

⇒ Before installing occupancy sensors in a system with heater cutout lamps or HID lamps, consider the potential annoyance of restrike delays.

⇒ For HID systems, consider installing capacity switching fixtures that are designed to be controlled by occupancy sensors. Upon sensing motion, the occupancy sensor will send a signal to the bi-level HID system that will instantly bring the light levels from a standby reduced level to 80% of full output, followed by the normal warm-up time between 80% and 100% of full light output. Depending on the lamp type and wattage, the standby lumens are roughly 15% - 40% of full output and the input watts are 30% - 60% of full wattage. Therefore, during periods that the space is unoccupied and the system is dimmed, savings of 40% - 70% are achieved.

Programmable Controls

⇒ **Definition:** Scheduling controls can be installed to ensure that lighting systems are turned off or dimmed according to an established schedule. These devices range from simple time switches to programmable "sweep" systems.

⇒ **Applications:** There are three basic types that can be used depending on the application and environment of the space.

1. Time switches are used to control lighting systems with predictable operation periods, such as outdoor signs, security lighting, and corridors.

2. Programmable time switches are devices that can be programmed for facilities having different daily operating schedules, such as different weekend/weekday schedules.

3. Sweep systems establish a programmed schedule for sequentially turning off lights throughout a floor or an entire building. A typical application is found in office buildings, where the systems ensure that lighting is not unnecessarily left on by the occupants. An important feature provides warning to occupants that allows them to override the sweep for their workspace.

Programmable Controls Qualifications

⇒ Unlike occupancy sensors, scheduling controls do not have the flexibility to eliminate wasted energy consumption during normal business hours.

⇒ 24-hour emergency lighting should be provided in areas with scheduling controls to provide safe access to lighting control override switches.

Photocell Applications

⇒ **Definition:** Photocells are devices used to sense light. Based upon the level of light, the photocell will open or close a relay or automatically adjust a dimmer setting. Many fluorescent dimming applications utilize a photocell that sends a signal to one or more dimmable electronic ballasts via a low voltage circuit.

⇒ **Applications:** Photocells can be useful for control of lighting systems based upon the quantity of daylight available in window areas; this is known as *daylight dimming or switching*. Photocells can also be

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used for adjusting fixture light output to compensate for aging lamps and accumulated dirt on luminaires; this is known as *lumen maintenance control.*

⇒ Because dimming (low-voltage) circuits are usually separate from existing power circuits, users have great flexibility in determining which fixtures will be controlled by the photocell.

⇒ Light levels should be maintained in accordance with standards established by the Illuminating Engineering Society of North America.

Photocell Applications Qualifications

⇒ Lumen maintenance controls (in interior spaces) save energy when accompanied by a good lighting maintenance program that includes group relamping and cleaning.

Dimming Controls

⇒ **Definition:** Using manual dimming controls, the light output from individual fixtures or groups of fixtures to match the area's visual requirements.

⇒ **Applications:** The most common application of tuning is in spaces where the visual task changes frequently. Applications include adjusting light level for various occupants of a space based on age and visual task requirements -- such as in a conference room.

⇒ Tuning can be accomplished by manually adjusting the potentiometer on a dimmable electronic ballast, or by installing an appropriate manual dimmer control at the switch location.

Dimming Controls Qualifications

⇒ Compact fluorescents and full-size fluorescents operating on magnetic ballasts require specialized dimming controls.

Panel-Level Dimming Systems

⇒ **Definition:** This strategy involves installing a control system at the electric panel to uniformly control all light fixtures on the designated circuits.

⇒ **Applications:** Circuit dimming can be controlled by inputs from occupancy sensors, photocells, timeclocks, energy management systems, and manual adjustments.

⇒ Panel-level dimming is a method for dimming HID systems.

⇒ Slight improvements in efficiency result from the dimming of fluorescent systems while slight reductions in efficiency result from the dimming of HID systems.

Panel-Level Dimming Qualifications

⇒ Some panel-level dimming systems are incompatible with electronic ballasts.

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TFM TECH NOTES

New Parabolic Fixtures

⇒ TFM Retrofit provides photometric data for parabolic fixtures with a typical 3" deep louver configuration. Louver depth options of 2" and 4" are available which will change both the efficiency and shielding characteristics of these fixtures. in addition, a number of louver finishes are available which will influence fixture aesthetics and performance. You may want to work with lighting consultants, manufacturers' representatives, and other industry sources to assess the impact of these variables on your upgrade.

⇒ Parabolic fixtures are deeper than lensed troffers, therefore upgrades may require plenum space above the existing units. Available space and potential modifications within the plenum must be assessed fully before selecting louver depth or specific manufacturers' products.

⇒ Fixture characteristics such as photometric performance, louver depth, louver finish, and spacing criteria may be important to consider during the selection of specific upgrade products and services. More information can be found in the Green Lights Lighting Upgrade Manual, the Lighting Research Center National Lighting Product Information Program Guide to Performance Evaluation of Efficient Lighting Products, the Illuminating Engineering Society of North America Recommended Practice for Lighting Offices Containing Computer Visual Display Terminals, and the California Energy Commission Advanced Lighting Technologies Application Guidelines.

Fixture Modification

⇒ Fixture modification upgrades that include delamping or delamping with reflectors use performance and cost data that assumes lamps will be relocated so as to be centered within the fixture. Relocation will improve light output and distribution, and will result in a more acceptable upgrade appearance. Upgrades that do not include lamp relocation may not maintain anticipated light levels.

⇒ TFM Retrofit currently cannot assess distribution of light resulting from an upgrade. Although a well-designed reflector will not compromise light distribution, potential for uneven illumination should be assessed carefully using both fixture photometric data (particularly spacing criteria) and a test installation. "Imaging" reflector designs (those that appear to have four lamps installed), may compromise both distribution and light output.

⇒ Fixture upgrade characteristics such as efficiency, louver finish, reflector material, lens selection, photometric performance, and spacing criteria may be important to consider during the selection of specific products, vendors, and lighting service companies. More information can be found in the Green Lights Lighting Upgrade Manual, the Lighting Research Center National Lighting Product information Program Specifier Report on Reflectors, and the California Energy Commission Advanced Lighting Technologies Application Guidelines.

Lamps

⇒ Lamp lumen output values used in TFM Retrofit analysis are presented as nominal references for selecting upgrade lamps. Upgrade equipment should have similar values since rated lumen output influences the light level estimates presented in TFM Retrofit. Manufacturers' products vary some in this regard, so it is important to verify initial lumen output and consider that lower values may compromise light levels in some spaces.

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⇒ Lamp characteristics such as color temperature, lamp lumen depreciation, and life may be important to consider during the selection of specific products

Ballasts

⇒ Ballast factors used in TFM Retrofit analysis are presented as nominal references for selecting upgrade ballasts. Upgrade equipment should have similar values since ballast factor influences the light level estimates presented in TFM Retrofit. Manufacturers' products will vary in this regard, so it is important to verify ballast factor and consider that lower values may compromise light levels in some spaces.

⇒ Ballast input wattage values used in TFM Retrofit analysis are presented as nominal references for selecting upgrade ballasts. Upgrade equipment should have similar values since input wattage determines the energy savings and profitability estimates made by TFM Retrofit. Manufacturers' products will vary in this regard, so it is important to verify ballast input watts and consider that higher values will reduce savings. Lower input wattage is usually associated with reduced ballast factor, which may compromise light levels in some spaces.

⇒ TFM Retrofit offers a number of ballast output options, including 50% output units. These are usually manufactured with both full and half output capability. They must be wired to provide only half output if estimated energy savings are to be achieved. Consider requesting that units be manufactured with single-option wiring to simplify installation and prevent use at the full output setting.

⇒ It is important to note that an upgrade to 50% output ballasts may also indicate an opportunity for reducing the total number of fixtures in a space, This option, which should be pursued with a lighting designer experienced with energy issues, may allow equivalent or greater savings at a reduced first cost. Space redesign should be investigated prior to implementing a lighting upgrade project with 50% output ballasts.

⇒ All ballasts for T8 lamps should be designed to operate only T8 lamps and not T12 or T10 lamps. TFM Retrofit holds data for 2, 3, or 4 -lamp electronic ballasts, matching the number of lamps in a fixture so that for most electronic ballasts, there is one ballast in each fixture. In many cases, users can also select 2-lamp units for 2 or 4 -lamp fixtures or 4 -lamp ballasts for tandem-wired 2-lamp fixtures. 1.5 lamps per ballast can be entered for some ballasts in 3-lamp fixtures to denote cases where a 1-lamp ballast is used in combination with a 2-lamp ballast. 1-lamp fluorescent fixtures can currently only be entered with 2-lamp ballasts, but ballast costs can be adjusted to obtain rough economic results where tandem wiring is not possible.

⇒ Ballast characteristics such as power factor, harmonics, flicker, noise, and warranty may be important to consider during the selection of specific products.

Compact Fluorescent Conversions

⇒ When assessing the potential for compact fluorescent or white high pressure sodium conversions, TFM Retrofit does not apply appropriate light loss factors or hold photometric data. Percent relative light output (RLO) values assume no fixture for INCAND, INC TASK, and CFL TASK fixture types. Because of the number of products and approaches available for both lamp and fixture conversion, specific options should be examined with the assistance of a lighting consultant, lighting management company, or product representative

⇒ Note that compact fluorescent lamps are incompatible with dimming hardware intended for incandescent lamps.

Occupancy Sensors

⇒ Because of the number of products, installation and operation issues, and approaches available for occupant sensing, specific options should be examined with the assistance of an appropriate vendor or consultant.

Timed Switching

⇒ Because of the number of products, installation and operation issues, and approaches available for timed switching, specific options should be examined with the assistance of an appropriate vendor or consultant.

Exit Sign Replacement Or Conversion

⇒ Exit sign upgrades must be checked to ensure that they meet local fire code requirements

Warehouse/Retail Upgrades

⇒ TFM Retrofit holds data for a basic set of HID, strip, and industrial fixture types as potential upgrade options. Industrial prismatic reflector HID fixtures (OPR or EPR) generally provide high efficiency and an uplighting component that improves lighting quality. These are available with both glass and plastic reflectors. The comparative merits between glass and plastic reflectors should be considered carefully before selecting a specific fixture. Fluorescent industrial fixtures can also be selected with an uplighting component which improves lighting quality and reduces dirt depreciation.

⇒ Fixture, lamp, and ballast options held by the system will be expanded as TFM Retrofit is enhanced over time. ***The system, however, is not intended to cover every available option.*** Users are encouraged to work with industry to refine and modify TFM Retrofit upgrade options to meet the needs of specific applications. It is intended that upgrade results be reassessed using specific manufacturer's performance data and that trial installations be implemented to assess lighting quality issues that are beyond the scope of the software.

HVAC Interaction

⇒ TFM Retrofit does not estimate heating or cooling energy impacts associated with lighting upgrades. In most commercial office and many retail applications, cooling cost savings due to reduced lighting load will exceed heating cost increases for a net decrease in building conditioning costs. As a result, both the energy and economic impact estimates made by TFM Retrofit can be considered generally conservative in these cases. In warehouse applications where heating is the primary type of conditioning, increased lighting efficiency may increase heating energy costs. Cost-effective measures can usually be implemented to more than compensate for this increase.

⇒ Compared to spot relamping existing fixtures, specifying group relamping for an upgrade results in significant labor savings. In practice, group relamping can also result in better lamp prices due to quantity purchases, and may allow for a more efficient design if an aggressive, permanent relamping policy reduces lamp lumen depreciation effects. Lamp cost and depreciation-related benefits are not considered by TFM Retrofit, but can be investigated with the assistance of a lighting consultant or lamp manufacturer.

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LIGHTING FUNDAMENTALS

A basic understanding of lighting fundamentals is essential for specifiers and decision-makers who are evaluating lighting upgrades. This section provides an overview of design parameters, technologies, and terminology used in the lighting industry.

The function of a lighting system is to provide sufficient illumination in a space that will enable the occupants to successfully complete their tasks. Although lighting can be costly, the quality and quantity of illumination can dramatically affect occupant productivity, comfort, and safety. Proper attention to the. quality and quantity of illumination can also enhance the appearance of a space.

Illumination

⇒ There are several measures of illumination that are used in the design of both new and retrofit lighting projects:

Quantity Measures

Common Term	Technical Term	Units
Light Output	Luminous Flux	Lumens (1m)
Light Level	Illuminance	Footcandles (Fc)
Brightness	Luminance	Footlamberts (fL)

Quality Measures

Attribute	Design Parameter
Glare	Visual Comfort Probability (VCP)
Uniformity	Spacing Criteria (SC)
Color Rendition	Color Rendering Index (CRI)

⇒ These terms are described in more detail in the sections that follow.

Quantity of Illumination

⇒ The diagram at right shows the interaction between light output, light level, and brightness. Although they are quantitative measures, they directly affect the quality of illumination.

Light Output

⇒ The most common measure of light output (or luminous flux) is the **lumen.** Light sources are usually given an output rating in lumens. For example, a T-12 40-watt fluorescent lamp may have a rating of 3050 lumens. Similarly, a light fixture's output can be expressed in lumens. As lamps and fixtures age and become dirty, their lumen output decreases -- this phenomenon is referred to as lumen depreciation. Most lamp ratings are based on *initial* lumens (i.e., when the lamp is new).

Light Level

⇒ Light intensity measured on a plane at a specific location is called **illuminance.** Illuminance is measured in **footcandles** which are defined as *workplane lumens per square foot.* Illuminance may be measured using a

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⇒ light meter located on the work surface where tasks are being performed. Using simple arithmetic and manufacturers' photometric data, illuminance may be predicted for a defined space. (Lax is the metric unit for illuminance, measured in lumens per square meter. To convert footcandles to lux, multiply footcandles by 10.76.)

Brightness

⇒ Another measurement of light is **luminance -**sometimes referred to as brightness. This is light "leaving" a surface, which takes into account the illuminance on the surface and the reflectance of the surface.

⇒ *The human eye does not actually see illuminance, it sees luminance.* Therefore, the ability to see is affected by both the amount of light delivered into the space and the reflectance of the surfaces in the space.

Determining Adequate Light Levels

⇒ The Illuminating Engineering Society of North America has developed a procedure for determining the appropriate average light level for a particular space. 'This procedure used extensively by designers and engineers recommends a target light level by considering the following:

1. The task(s) being performed (contrast, size, etc.)
2. The ages of the occupants
3. The importance of speed and accuracy

⇒ Then, the appropriate type and quantity of lamps and light fixtures may be selected based on the following:

1. Fixture efficiency
2. Lamp lumen output
3. The reflectances of surrounding surfaces
4. The effects of light losses from lamp lumen depreciation, dirt accumulation, and ballast efficiency
5. Room size and shape
6. Availability of natural light (daylight)

⇒ When designing a new or upgraded lighting system, one must be careful to avoid overlighting a space. In the past, spaces were designed for as much as 200 footcandles in places where 50 footcandles may not only be adequate, but superior. This was partly due to the misconception that the more light in a space, the higher the quality. Not only does overlighting waste energy, but it can also reduce lighting quality. Within a listed range of illuminance, the proper level is determined by: age of the occupant(s), speed and accuracy requirements, reflectances and contrast.

Quality of Illumination

⇒ Improvements in lighting quality can yield high dividends for U.S. businesses. Gains in worker productivity may result by providing corrected light levels with reduced glare. And even though the cost of energy for lighting is substantial, it is small compared to the cost of labor. Therefore, these gains in productivity may be even more valuable than the energy savings associated with new lighting technologies. In retail spaces, attractive and comfortable lighting designs can attract clientele and enhance sales.

⇒ The three quality issues addressed in this section are:

1. Glare
2. Uniformity of illuminance on tasks
3. Color rendition

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Glare

⇒ Perhaps the most important factor with respect to lighting quality is glare. Glare is a sensation caused by luminances in the visual field that are too bright. Discomfort, annoyance, or reduced productivity can result.

⇒ A bright object alone does not necessarily cause glare, but a bright object in front of a dark background, however, usually will cause glare. The relationship between the luminance of an object and its background is called contrast. Although the visual task generally becomes easier with increased contrast, too much contrast causes glare and makes the visual task much more difficult.

⇒ Glare can be reduced by not exceeding proper light levels and by using lighting equipment designed to reduce glare. A louver or shield is commonly used to block direct view of a light source. Indirect lighting, or uplighting, can create a low glare environment by uniformly lighting the ceiling. Also, proper fixture placement can reduce **reflected glare** that reflects off of the work surfaces or computer screens.

⇒ Standard data now provided with luminaire specification sheets include tables of its **Visual Comfort Probability (VCP)** rating for a given room geometry. The VCP index provides an indication of the percentage of people in a given space that would find the glare from a fixture to be acceptable. A minimum VCP of 70 is often recommended for commercial interiors, while luminaires with VCPs exceeding 80 are becoming more common in computer areas.

Uniformity of Illuminance on Tasks

⇒ The uniformity of illuminance is a quality issue that addresses how evenly light is spread over a task area. Although a room's average illuminance may be appropriate, uniformity may be compromised due to:

1. Improper fixture placement based on the luminaire's **spacing criteria** (ratio of maximum recommended fixture spacing distance to mounting height above task height)

2. Retrofit of fixture with reflectors with a design that narrows the fixture's light distribution

⇒ The problems that non-uniform illuminance causes are:

1. Inadequate light levels in some areas
2. Visual discomfort when tasks require frequent shifting of view from underlit to overlit areas
3. Bright spots and patches of light on floors and walls that cause distraction and generate a low quality appearance

Color Rendition

⇒ The ability to see colors properly is another aspect of lighting quality. Light sources vary in their ability to accurately reflect the true colors of people and objects. The color rendering index (CRI) scale is used to compare the effect of a light source on the color appearance of its surroundings.

⇒ The CRI is defined on a scale between 0 and 100.

⇒ A higher CRI means a better color rendering, or less color shift. CRIs in the range of 75-100 are considered excellent, 65-75 are good, 55-65 are fair, and 0-55 are poor.

⇒ The CRI values for selected light sources are tabulated with other lamp data on the following page.

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LIGHT SOURCES

Several different light sources are used in commercial, industrial, and retail facilities. Each lamp type has particular advantages; selecting the appropriate source depends on installation requirements, life-cycle cost, color qualities, dimming capability, and the effect desired. The major types of lamps are:

1. Incandescent
2. Fluorescent
3. High Intensity Discharge -- Mercury Vapor
4. Metal Halide
5. High Pressure Sodium -- Low Pressure Sodium

⇒ Before describing each of these lamp types, some of the characteristics that are common to all lamps are defined below.

Efficiency

Some lamp types are more efficient in converting energy into visible light than others. The effectiveness of a lamp refers to the number of lumens leaving the lamp compared to the number of watts required by the lamp (and ballast), expressed in lumens per watt. By using a source with a higher effectiveness, less electrical energy is needed to light a space.

Color Temperature

⇒ Another characteristic of a light source is the color temperature. This is a measurement of "warmth" or "coolness" provided by the lamp. A warmer source is preferred in dining areas and living rooms; a cooler source if often preferred in an office environment.

⇒ Color temperature refers to the color of a blackbody radiator at a given absolute temperature, expressed in Kelvins. A blackbody radiator changes color as its temperature is increased -- first to -red, then to orange, yellow, and finally bluish white at the highest temperature. Note that a "warm" color light source actually has a lower color temperature. For example, a cool-white fluorescent lamp appears bluish in color with a color temperature of around 4100 K. A warmer fluorescent lamp appears more yellowish with a color temperature of around 3000 K. Refer to the diagram on page D-7 for color temperatures of various light sources.

Color Rendering Index

⇒ The color rendering index (CRI) is a relative scale (ranging from 0 - 100) that indicates the degree to which the perceived colors of objects illuminated by a given light source, conform to the colors of those same objects when lighted by a reference standard light source. In general, the higher the color rendering index, the less the color shift or distortion.

⇒ The CRI number does not indicate which colors will shift or by how much; it is rather an indication of the average shift of eight standard colors. Two different light sources may have identical CRI values, but colors may appear quite different under these two sources.

Incandescent Lamps

⇒ The incandescent lamp is one of the oldest electric lighting technology available. With efficiency ranging from 6 to 24 lumens per watt, incandescent lamps are the least energy-efficient electric light source and have a relatively short life (750-2500 hours).

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⇒ Light is produced by passing a current through a tungsten filament, causing it to become hot and glow. With use, the tungsten slowly evaporates, eventually causing the filament to break.

⇒ These lamps are available in a wide variety of shapes and finishes. The two most common types of shapes are the common "A-type" lamp (shown below) and the reflector-shaped lamps - (R-lamps or PAR lamps).

Tungsten-Halogen Lamps

⇒ The tungsten halogen lamp is another type of incandescent lamp. In a halogen lamp, the filament is contained inside a quartz capsule that contains a halogen gas. This gas allows the filament to operate at a higher temperature, which produces light at a higher effectiveness than standard incandescents. The gas also combines with the evaporated tungsten, and deposits it back on the filament, which increases lamp life and keeps the bulb wall from blackening and reducing light output.

⇒ Because the filament is relatively small, this source is often used where a highly focused beam is desired. New compact halogen lamps are popular in retail applications for display and accent lighting. In addition, tungsten-halogen lamps generally produce a whiter light than other incandescent lamps, are more efficient, last longer, and have improved lamp lumen depreciation.

Fluorescent Lamps

⇒ Fluorescent lamps are the most commonly used commercial light source in North America at this time. In fact, fluorescent lamps illuminate 71% of the commercial space in the United States. Their popularity can be attributed to their relatively high effectiveness, light distribution characteristics, and long operating life.

⇒ Fluorescent lamp construction consists of a glass tube that is:

1. Filled with an argon or krypton gas and a small amount of mercury
2. Coated on the inside with phosphors
3. Equipped with an electrode at both ends

⇒ Fluorescent lamps provide light by the following process:

1. An **electric discharge** (current) is maintained between the electrodes through the mercury vapor and inert gas.
2. This current excites the mercury atoms, causing them to emit non-visible **ultraviolet** (UV) **radiation.**
3. This UV radiation is converted into **visible light** by the phosphors lining the tube.

⇒ Discharge lamps (such as fluorescent) require a ballast to provide correct starting voltage and to regulate the operating current after the lamp has started.

Full-Size Fluorescent Lamps

⇒ Full-size fluorescent lamps are available in several shapes, including straight, U-shaped, and circular configurations. Lamp diameters range from I" to 21/2". The most common lamp type is the four-foot (F40), 11/2" diameter (T-12) straight fluorescent lamp.

⇒ Fluorescent lamps are available in colors ranging from warm (2700K) "incandescent-like" colors to very cool (6500K) "daylight" colors. "Cool white" (4100K) is the most common fluorescent lamp color. Neutral white (3500K) is becoming popular for office and retail use.

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⇒ Improvements in the phosphor coating of fluorescent lamps have improved color rendering and made some fluorescent lamps acceptable in many applications previously dominated by incandescent lamps.

Compact Fluorescent Lamps

⇒ Advances in phosphor coatings and reductions of tube diameters have facilitated the development of compact fluorescent lamps. Manufactured since the early 1980s, they are a long-lasting, energy-efficient substitute for the incandescent lamp.

⇒ Various wattages, color temperatures, and sizes are also available. The wattages of the compact fluorescents range from 5 to 40 -- replacing incandescent lamps ranging from 25 to 150 watts -and provide energy savings of 60 to 75 percent. While producing light similar in color to incandescent sources, the life expectancy of a compact fluorescent is about 10 times that of a standard incandescent lamp. Note, however, that the use of compact fluorescent lamps is very limited in dimming applications.

⇒ The compact fluorescent lamp with an Edison screw-base is a more recent development that offers an easy means to upgrade from an incandescent to compact fluorescent. Screw-in compact fluorescents are available in two types:

1. **Integral Units.** These consist of a compact fluorescent lamp and ballast in self-contained units. Some integral units also include a reflector and/or glass enclosure.
2. **Modular Units.** The modular type of retrofit compact fluorescent lamp is similar to the integral units, except that the lamp is replaceable.

High-intensity Discharge Lamps

⇒ High-intensity discharge (HID) lamps are similar to fluorescents in that an arc is generated between two electrodes. The arc in a HID source is shorter, yet it generates much more light, heat, and pressure within the arc tube.

⇒ Originally developed for outdoor and industrial applications, HID lamps are also used in office, retail, and other indoor applications. Their color rendering characteristics have been improved and lower wattages have recently become available -- as low as 18 watts.

⇒ There are several distinct advantages to HID sources:

1. Relatively long life (5,000 to 24,000+ hrs)
2. Relatively high lumen output per watt
3. Relatively small in physical size

⇒ However, this operating limitation must also be considered:

1. HID lamps require time to warm up. The time varies from lamp to lamp, but the average warm up time is 2 to 5 minutes before the lamp will reach full output. If there is a momentary interruption of current, or if the voltage drops too low to maintain the arc, the lamp will extinguish. At that point, the gases inside the lamp are too hot to ionize, and time is needed for the gases to cool and pressure to drop before the arc will restrike. This process of restriking takes between 5 and 15 minutes depending on which HID source is being used. Therefore, good applications of compact HID lamps are areas where lamps are not switched on and off intermittently.

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⇒ In increasing order of effectiveness, HID sources are:

1. Mercury-Vapor
2. Metal Halide
3. High Pressure Sodium
4. Low Pressure Sodium

⇒ Clear mercury vapor lamps, which produce a bluegreen light, consist of a mercury-vapor arc tube with tungsten electrodes at both ends. These lamps have the lowest efficacies of the HID family, rapid lumen depreciation, and a low color-rendering index. Because of these characteristics, other HID sources have replaced mercury vapor lamps in many applications. However, mercury vapor lamps are still popular sources for landscape illumination because of their 24,000 hour lamp life and vivid portrayal of green landscapes.

⇒ The arc is contained in an inner bulb called the arc tube. The arc tube is filled with high purity mercury and argon gas. The arc tube is enclosed within the outer bulb, which is filled with nitrogen. (See the typical HID lamp below.)

⇒ Color-improved mercury lamps use a phosphor coating on the inner wall of the bulb to improve the color rendering index.

Metal Halide

⇒ These lamps are similar to mercury vapor lamps but use metal halide additives inside the arc tube along with the mercury and argon. These additives enable the lamp to produce more visible light per watt with improved color rendition.

⇒ Wattages range from 32 to 2,000, offering a wide range of indoor and outdoor applications. The effectiveness of metal halide lamps ranges from 50 to 115 lumens per watt -- typically about double that of mercury vapor.

⇒ In short, the advantages of metal halide lamps are:

1. High effectiveness
2. Good color rendering
3. Wide range of wattages

⇒ There are some operating limitations of metal halide lamps that should be considered:

1. The rated life of metal halide lamps is shorter than other HID sources; lower-wattage lamps last less than 7500 hours while high-wattage lamps last an average of 15,000 to 20,000 hours

2. The color may vary from lamp to lamp, and shift over the life of the lamp

⇒ Because of the good color rendition and high lumen output, these lamps are good for sports arenas and stadiums. Indoor uses include large auditoriums and convention halls. These lamps are sometimes used for general outdoor lighting, such as parking facilities, but a high pressure sodium system is typically a better choice because of its higher effectiveness and because good color rendition may not be a priority in such applications.

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High Pressure Sodium

⇒ The high pressure sodium (HPS) lamp is widely used for outdoor and industrial applications. HPS lamps differ from mercury and metal-halide lamps in that they do not contain starting electrodes; the ballast circuit includes a high-voltage electronic starter. The arc tube is made of a ceramic material which can withstand temperatures up to 2372'F. It is filled with xenon to help start the arc, as well as a sodium-mercury gas mixture.

⇒ The effectiveness of the lamp ' is very high -- up to 140 lumens per watt. For example, a 400-watt high pressure sodium lamp produces 50,000 initial lumens. The same wattage metal halide lamp produces 40,000 initial lumens, and the 400-watt mercury vapor lamp produces only 21,000 initially.

⇒ Sodium, the major element used, produces the .golden" color that is characteristic of HPS lamps. Although HPS lamps are not generally recommended for applications where color rendering is critical, HPS color rendering properties are being improved. Some HPS lamps are now available in "deluxe" and 'white" colors that provide higher color temperature and improved color rendition. The effectiveness of low-wattage "white" HPS lamps is lower than that of lower-wattage metal halide lamps (Lumens per Watt of low wattage metal halide is 7585 LPW, while white HPS is 50-60 LPW).

Low Pressure Sodium

⇒ LPS lamps are low-pressure discharge systems that are similar to fluorescent systems, they are commonly included in the HID family. Low pressure sodium (LPS) lamps are the most efficient light sources, but they produce the poorest quality light of all the lamp types. Being a *monochromatic* light source, all colors appear black, white, or shades of gray under an LPS source. LPS lamps are available in wattages ranging from 18-180.

⇒ LPS lamp use has been generally limited to outdoor applications such as security or street lighting and indoor, low-wattage applications where color quality is not important (e.g. stairwells). However, because the color rendition is so poor, many municipalities do not allow them for roadway lighting.

BALLASTS

All discharge lamps (non-incandescent) require an auxiliary piece of equipment called a ballast. There are three main functions of a ballast:

1. Provide correct **starting** voltage. The lamps require a higher voltage to start than to operate.
2. **Matches** the line voltage to the operating voltage of the lamp.
3. **Limit** the lamp current. Once the arc is struck the lamp impedance decreases. Therefore, the current must be limited to prevent immediate destruction.

⇒ Because ballasts are an integral component of the lighting system, they have a direct impact on *light output.* The **ballast factor** is the ratio of a lamp's light output using a given ballast, compared to the lamp's rated light output on a laboratory standard ballast. General purpose ballasts have a ballast factor that is less than one; special ballasts may have a ballast factor greater than one.

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Fluorescent Ballasts

⇒ There are two general types of fluorescent ballasts:

1. **MAGNETIC ballasts** (known as magnetic, electromagnetic or core-coil ballasts)

   There are three sub-classes of **magnetic ballasts:**

   ⇒ **standard core-coil** (no longer sold in the US for most applications)
   ⇒ **high-efficiency core-coil**
   ⇒ **cathode cut-out**

2. **ELECTRONIC ballasts**

Magnetic Ballasts

⇒ Standard core-coil magnetic ballasts are essentially core-coil transformers that are relatively inefficient in operating fluorescent lamps. The high-efficiency ballast replaces the aluminum wiring and lower grade steel of the standard ballast with copper wiring and enhanced ferromagnetic materials. The result of these material upgrades is a 10 percent system efficiency improvement.

⇒ "Cathode cut-out" (or "hybrid") ballasts are high efficiency core-coil ballasts that incorporate electronic components that cut off power to the lamp cathodes (filaments) after the lamps are lit, resulting in an additional 2-watt savings per standard lamp. Also, most hybrid magnetic ballasts provide approximately 8-15% less light output while consuming 17-32% less energy than energy-efficient magnetic ballasts.

Electronic Ballasts

⇒ In nearly every full-size fluorescent lighting application, electronic ballasts can be used in place of conventional magnetic "core-and-coil" ballasts. Electronic ballasts improve fluorescent system effectiveness by converting the standard 60 Hz input frequency to a higher frequency, usually 25,000 to 40,000 Hz. Lamps operating at these higher frequencies produce about the same amount of light, while **consuming 12 to 25 percent less power.** Other advantages of electronic ballasts include less audible noise, less weight, virtually no lamp flicker, and dimming capabilities (with specific ballast models).

⇒ There are several electronic ballast designs available.

1. **Standard T-12 Electronic Ballasts (430 mA).** These ballasts are designed for use with conventional (T-12) fluorescent lighting systems. Some electronic ballasts that are designed for use with 4' lamps can operate up to four lamps at a time. Parallel wiring is another feature now available that allows all companion lamps in the ballast circuit to continue operating in the event of a lamp failure. Electronic ballasts are also available for 8' standard and high output T-12 lamps.

2. **Electronic Ballasts (265 mA).** Specifically designed for use with T-8 (1-inch diameter) lamps, the T-8 electronic ballast provides the highest efficiency of any fluorescent lighting system. Some T-8 electronic ballasts are designed to start the lamps in the conventional rapid start mode, while others are operate in the instant start mode. The use of instant start T-8 electronic ballasts may result in up to 25% reduction in lamp life (at 3 hours per start) but produces slight increases in efficiency and light output. (Note: Lamp life ratings for instant start and rapid start are the same for 10 or more hours per start.)

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3. **Dimmable Electronic Ballasts.** These ballasts permit the light output of the lamps to be dimmed based on input from manual dimmer controls or from devices that sense daylight or occupancy.

Types of Fluorescent Circuits

⇒ There are three main types of fluorescent circuits.

1. Rapid start
2. Instant start
3. Preheat

⇒ The specific fluorescent circuit in use can be identified by the label on the ballast.

⇒ The rapid start circuit is the most used system today. Rapid start ballasts provide continuous lamp filament heating during lamp operation (except when used with a cathode cut-out ballast or lamp). Users notice a very short delay after "flipping the switch," before the lamp is started.

⇒ The instant start system ignites the arc within the lamp instantly. This ballast provides a higher starting voltage, which eliminates the need for a separate starting circuit.

⇒ The preheat circuit was used when fluorescent lamps first became available. This technology is used very little today. A separate starting switch, called a starter, is used to aid in forming the arc. The filament needs some time to reach proper temperature, so the lamp does not strike for a few seconds. This low-cost circuit is used today mainly for low wattage applications such as compact fluorescent lamps and inexpensive task lights.

HID Ballasts

⇒ Like fluorescent lamps, HID lamps require a ballast to start and operate. The purposes of the ballast are similar: to provide starting voltage, to limit the current, and to match the line voltage to the arc voltage.

⇒ With HID ballasts, a major performance consideration is lamp wattage regulation when the line voltage varies. With HPS lamps, the ballast must compensate for changes in the lamp voltage as well as for changes in the line voltages.

⇒ *If the wrong HID ballast is installed,* it can:

1. Waste energy and increase operating cost
2. Severely shorten lamp life
3. Significantly add to system maintenance costs
4. Produce lower-than-desired light levels
5. Increase wiring and circuit breaker installation costs
6. Result in lamps cycling when voltage dips occur.

⇒ Capacitive switching is available in new HID luminaires that can be controlled by occupancy sensors. Upon sensing motion, the occupancy sensor will send a signal to the bi-level HID system that will instantly bring the light levels from a standby reduced level to 80% of full output, followed by the normal warm-up time between 80% and 100% of full light output. Depending on the lamp type and wattage, the standby lumens are roughly 15-40% of full output and the input watts are 30-60% of full wattage. Therefore, during periods that the space is unoccupied and the system is dimmed, savings of 40-70% are achieved.

⇒ Electronic ballasts for some types of HID lamps are beginning to become commercially available.

LUMINAIRES

⇒ Fixtures

A luminaires or light fixture, is a unit consisting of the following components:

1. Lamps
2. Lamps sockets
3. Ballasts
4. Reflective material
5. Lenses, refractors, or louvers
6. Housing

⇒ The main function of the luminaire is to direct light using reflective and shielding materials. Many lighting upgrade projects consist of replacing one or more of these components to improve fixture efficiency. Alternatively, users may consider replacing the entire luminaire with one that is designed to efficiently provide the appropriate quantity and quality of illumination.

⇒ There are several different types of luminaires. The following is a listing of some of the common luminaire types:

1. General illumination fixtures such as 2x4, 2x2, & lx4 fluorescent troffers
2. Downlights
3. Indirect lighting (light reflected off the ceiling/walls)
4. Spot or accent lighting
5. Task lighting
6. Outdoor area and flood lighting

Efficiency

⇒ The efficiency of a luminaire is the percentage of lamp lumens produced that actually exit the fixture. The use of louvers can improve visual comfort, but because they reduce the lumen output of the fixture, efficiency is reduced. Generally, the most efficient fixtures have the poorest visual comfort (e.g. bare strip industrial fixtures); conversely, the fixture that provides the highest visual comfort level is the least efficient. Therefore, a lighting designer must determine the minimum efficiency and visual comfort probability (VCP) needed for a space. Recently, some manufacturers have started offering fixtures with excellent VCP and efficiency. These so-called "superfixtures" combine state-of-the-art design and materials to provide the best of both worlds.

⇒ Surface deterioration and accumulated dirt in older, poorly maintained fixtures can also cause reductions in luminaire efficiency.

Directing Light

⇒ Each of the above luminaire types consist of a number of components that are designed to work together to *produce and direct* light. Because the subject of light production has been covered by the previous section, the text below focuses on the components used to direct the light produced by the lamps.

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Reflectors

Reflectors are designed to redirect the light emitted from a lamp in order to achieve a desired distribution of light intensity outside of the luminaires.

⇒ In most incandescent spot and flood lights, highly specular (mirror-like) reflectors are usually built-in to the lamps.

⇒ In standard *fluorescent* troffers, however, the reflector surface usually consists of a white enamel painted surface that evenly reflects light away from the fixture. The reflectance of the white surface is typically 80-90%, but the light is evenly reflected and is not directionally controlled.

⇒ One energy-efficient upgrade option is to install a custom-designed mirror-like reflector to enhance the light control and efficiency of the fixture, which will allow a partial delamping of the fixture. Reflectors are available in anodized aluminum sheet (standard or enhanced reflectivity) or silver film laminate materials. Silver film laminate is generally considered to have the highest reflectance, while aluminum sheets are considered more durable.

⇒ Proper design and installation of reflectors can have more effect on performance than the reflector materials. In combination with delamping, however, use of reflectors may result in reduced light output and may redistribute the light, which may or may not be acceptable for a specific space or application. To ensure acceptable performance from reflectors, arrange for a trial installation and measure "before" and "after" light levels using the procedures outlined in previous sections.

Lenses and Louvers

⇒ Most indoor commercial fluorescent fixtures use either a lens or a louver to prevent direct exposure to the lamps. Light that is emitted in the so-called glare zone' (angles above 45 degrees from the fixture's vertical axis) can cause visual discomfort and reflections that reduce contrast on work surfaces or computer screens.

⇒ **Lenses.** Lenses made from clear ultravioletstabilized acrylic plastic deliver the most light output and uniformity of all shielding media. However, they provide less glare control than louvered fixtures. Clear lens types include prismatic, batwing, linear batwing, and polarized lenses. Lenses are usually much less expensive than louvers.

⇒ **Louvers.** Louvers provide superior glare control and high visual comfort than lens-diffuser systems. The most common application of louvers is to eliminate the fixture glare reflected on computer screens. So-called "deep-cell" parabolic louvers -with 5-7" cell apertures and depths of 2-4" -- provide a good balance between visual comfort and luminaire efficiency. Although small-cell parabolic louvers provide the highest level of visual comfort, they reduce luminaire efficiency by 35-45% compared to clear lenses. For retrofit applications, both deep-cell and small-cell louvers are available for use with existing fixtures. Note that the deepcell louver retrofit adds 2-4" to the overall depth of a troffer; verify that sufficient plenum depth is available before specifying the deep-cell retrofit. The chart on the following page shows the efficiency and VCP for various shielding materials.

Distribution

⇒ One of the primary functions of a luminaire is to direct the light to where it is needed. The light distribution produced by luminaires is characterized by the Illuminating Engineering Society of North America as:

1. **Direct --** 90% to 100% of the light is directed downward for maximum use;
2. **Indirect --** 90% to 100% of the light is directed to the ceilings, upper walls and is reflected to all parts of a room;
3. **Semi-Direct --** 60 to 90 percent of the light is directed downward with the remainder directed upward;
4. **General Diffuse or Direct-Indirect --** equal portions of the light are directed upward and downward; and
5. **Highlighting --** characterized by the distance of the beam of light and focusing ability

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GLOSSARY

⇒ **AMPERE:** The standard unit of measurement for electric current that is equal to one coulomb per second. It defines the quantity of electrons moving past a given point in a circuit over a period of time. Amp is an abbreviation.

⇒ **ARC TUBE:** A tube enclosed within the outer glass envelope of a HID lamp and made of clear quartz or ceramic that contains the arc stream.

⇒ **BALLAST:** A device used to operate fluorescent and HID lamps. The ballast provides the necessary starting voltage, while limiting and regulating the lamp current during operation.

⇒ **BALLAST CYCLING:** Undesirable condition whereby the ballast turns lamps on and off (cycles) due to the overheating of the thermal switch inside the ballast. This may be due to incorrect lamps, improper voltage being supplied, high ambient temperature around the fixture, or the early stage of ballast failure.

⇒ **BALLAST EFFICIENCY FACTOR:** The Ballast Efficiency Factor (BEF) is the Ballast Factor (see below) divided by the input power of the ballast. The higher the BEF -- *within the same lamp-ballast type* -- the more efficient the ballast.

⇒ **BALLAST FACTOR:** The Ballast Factor (BF) for a specific lamp-ballast combination represents the percentage of the rated lamp lumens that will actually be produced by the combination.

⇒ **CANDELA:** Unit of luminous intensity, describing the intensity of a light source in a specific direction.

⇒ **CANDELA DISTRIBUTION:** A curve, often on polar coordinates, illustrating the variation of luminous intensity of a lamp or luminaire in a plane through the light center.

⇒ **CANDLEPOWER:** A measure of luminous intensity of a light source in a specific direction, measured in candelas (see above).

⇒ **COEFFICIENT OF UTILIZATION:** The ratio of lumens from a luminaire received on the work plane to the lumens produced by the lamps alone. (Also called "CU")

⇒ **COLOR RENDERING INDEX (CRI):** A scale for the effect of a light source on the color appearance of an object in comparison with the color appearance under a reference light source. Expressed in a scale from I to 100, where 100 is no color shift. In general, a low CRI rating indicates that the colors of objects will appear unnatural under that particular light source.

⇒ **COLOR TEMPERATURE:** The color temperature is a specification of the color appearance of a light source, relating the color to a reference source that is heated to a particular temperature, measured by the thermal unit Kelvin. The measurement can also be described as the "warmth" or "coolness" of a light source. Generally, sources below 3200K are considered "warm;" while those above 4000K are considered 'cool" sources.

⇒ **COMPACT FLUORESCENT:** A small fluorescent lamp that is often used as an alternative to incandescent lighting. The lamp life is about 10 times longer than incandescent lamps and is 3-4 times more efficacious. Also referred to as PL, Twin-Tube, CFL, or BL4-X lamps.

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⇒ **CONSTANT WATTAGE (CW) BALLAST:** A premium type of HID ballast in which the primary and secondary coils are isolated. Considered a high performance, high loss ballast featuring excellent output regulation.

⇒ **CONSTANT WATTAGE AUTOTRANSFORMER (CWA) BALLAST:** A popular type of HID ballast in which the primary and secondary coils are electrically connected. Considered an appropriate balance between cost and performance.

⇒ **CONTRAST:** The relationship between the luminance of an object and its background.

⇒ **CUT-OFF ANGLE:** The angle from a fixture's vertical axis at which a reflector, louver, or other shielding device cuts off direct visibility of a lamp. It is the complementary angle of the shielding angle.

⇒ **DAYLIGHT COMPENSATION:** A dimming system controlled by a photocell that reduces the output of the lamps when daylight is present. As daylight levels increase, lamp intensity decreases. An energy-saving technique used in areas with significant daylight contribution.

⇒ **DIFFUSE:** Term describing dispersed light distribution. Refers to the scattering or softening of light.

⇒ **DIFFUSER:** A translucent piece of glass or plastic sheet that shields the light source in a fixture. The light transmitted throughout the diffuser will be redirected and scattered.

⇒ **DIRECT GLARE:** Glare that is produced by a direct view of light sources. Often the result of insufficiently shielded light sources. (See GLARE)

⇒ **DOWNLIGHT:** A type of ceiling luminaires usually fully recessed, where most of the light is directed downward. May feature an open reflector and/or shielding device.

⇒ **EFFICACY:** A metric used to compare light output to energy consumption. Efficacy is measured in lumens per watt. Efficacy is similar to efficiency, but is "pressed in dissimilar units. For "ample, if a 100 watt source produces 9000 lumens, then the effectiveness is 90 lumens per watt.

⇒ **ELECTRO-LUMINESCENT:** A light source technology used in exit signs that provides uniform brightness, long lamp life (approximately eight years), while consuming very little energy (less than one watt per lamp).

⇒ **ELECTRONIC BALLAST:** A ballast that uses semiconductor components to increase the frequency of fluorescent lamp operation -- typically in the 20-40 kHz range. Smaller inductive components are used to provide the lamp current control. Fluorescent system efficiency is increased due to high frequency lamp operation.

⇒ **ELECTRONIC DIMMING BALLAST:** A variable output electronic fluorescent ballast.

⇒ **EMI:** Abbreviation for Electromagnetic interference. High frequency interference (electrical noise) caused by electronic components or fluorescent lamps that interferes with the operation of electrical equipment. EMI is measured in micro-volts, and can be controlled by filters. Because EMI can interfere with communication devices, the Federal Communication Commission (FCC) has established limits for EMI.

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⇒ **ENERGY-SAVING BALLAST:** A type of magnetic ballast designed so that the components operate more efficiently, cooler and longer than a "standard magnetic" ballast. By U.S. law, standard magnetic ballasts can no longer be manufactured.

⇒ **ENERGY-SAVING LAMP:** **A** lower wattage lamp generally producing fewer lumens.

⇒ **FLUORESCENT LAMP:** A light source consisting of a tube filled with argon, along with krypton or other inert gas. When electrical current is applied, the resulting arc emits ultraviolet radiation that excites the phosphors on the inside of the lamp wall, causing them to radiate visible light.

⇒ **FOOTCANDLE (FC):** The English unit of measurement of the illuminance (or light level) on a surface. One footcandle is equal to one lumen per square foot.

⇒ **GLARE:** The effect of brightness or differences in brightness within the visual field sufficiently high to cause annoyance, discomfort or loss of visual performance.

⇒ **HALOGEN:** (See TUNGSTEN HALOGEN LAMP)

⇒ **HARMONIC DISTORTION:** A harmonic is a sinusoidal component of a periodic wave having a frequency that is a multiple of the fundamental frequency. Harmonic distortion from lighting equipment can interfere with other appliances, as well as the operation of electric power networks. The total harmonic distortion (THD) is usually expressed in a percentage of the fundamental line current. THD for 4-foot fluorescent ballasts usually range from 20% to 40%. For compact fluorescent ballasts, THD levels greater than 50% are not uncommon.

⇒ **HID:** Abbreviation for High Intensity Discharge. Generic term used to describe mercury vapor, metal halide, high pressure sodium, and (informally) low pressure sodium light sources and luminaires.

⇒ **HIGH-BAY:** Pertains to the type of lighting in an industrial application where the ceiling is 20 feet or higher. Also describes the application itself.

⇒ **HIGH OUTPUT (HO):** A lamp or ballast designed to operate at higher currents (800 mA) and produce more light.

⇒ **HIGH POWER FACTOR:** A ballast with a .9 or higher rated power factor, which is achieved by using a capacitor.

⇒ **HIGH PRESSURE SODIUM LAMP:** A high intensity discharge (HID) lamp whose light is produced by radiation from sodium vapor (and mercury).

⇒ **HOT RESTART or HOT RESTRIKE:** The phenomenon of re-striking the arc in an HID light source after a momentary power loss. Hot restart occurs when the arc tube has cooled a sufficient amount.

⇒ **IESNA:** Abbreviation for Illuminating Engineering Society of North America.

⇒ **ILLUMINANCE:** A photometric term that quantifies light incident on a surface or plane. Illuminance is commonly referred to as *light level,* It is expressed as lumens per square foot (footcandles), or lumens per square meter (lux).

⇒ **INDIRECT GLARE:** Glare that is produced from a reflective surface.

⇒ **INSTANT START:** A fluorescent circuit that ignites the lamp instantly with a very high starting voltage from the ballast. Instant start lamps have single-pin bases.

⇒ **LAMP LUMEN DEPRECIATION FACTOR (LLD):** A factor that represents the reduction of lumen output over time. The factor is commonly used as a multiplier to the initial lumen rating in illuminance calculations, which compensates for the lumen depreciation. The LLD factor is a dimensionless value between 0 and 1.

⇒ **LAY-IN-TROFFER:** A fluorescent fixture; usually a 2' x 4' fixture that sets or "lays" into a specific ceiling grid.

⇒ **LENS:** Transparent or translucent medium that alters the directional characteristics of light passing through it. Usually made of glass or acrylic.

⇒ **LOUVER:** Grid type of optical assembly used to control light distribution from a fixture. Can range from small-cell plastic to the large-cell anodized aluminum louvers used in parabolic fluorescent fixtures.

⇒ **LOW POWER FACTOR:** Essentially, an uncorrected ballast power factor of less than .90 (SEE NPF)

⇒ **LOW-PRESSURE SODIUM:** A low-pressure discharge lamp in which light is produced by radiation from sodium vapor. Considered a monochromatic light source (most colors are rendered as gray).

⇒ **LOW VOLTAGE LAMP:** A lamp - typically compact halogen - that provides both intensity and good color rendition. Lamp operates at 12V and requires the use of a transformer. Popular lamps are MR11, MR16, and PAR36.

⇒ **LOW-VOLTAGE SWITCH:** A relay (magnetically-operated switch) that permits local and remote control of lights, including centralized time clock or computer control.

⇒ **LUMEN:** A unit of **light flow,** or luminous flux. The lumen rating of a lamp is a measure of the total light output of the lamp.

⇒ **LUMINAIRE:** A complete lighting unit consisting of a lamp or lamps, along with the parts designed to distribute the light, hold the lamps, and connect the lamps to a power source. Also called a fixture.

⇒ **LUMINAIRE EFFICIENCY:** The ratio of total lumen output of a luminaire and the lumen output of the lamps, expressed as a percentage. For example, if two luminaires use the same lamps, more light will be emitted from the fixture with the higher efficiency.

⇒ **LUMINANCE:** A photometric term that quantifies brightness of a light source or of a surface that is illuminated and reflects light. It is expressed as footlamberts (English units) or candelas per square meter (Metric units).

⇒ **LUX (LX):** The metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter. One lux equals .093 footcandles.

⇒ **MERCURY VAPOR LAMP:** A type of high intensity discharge (HID) lamp in which the major portion of the light is produced by radiation from mercury vapor. Emits a bluegreen cast of light. Available in clear and phosphor-coated lamps.

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⇒ **METAL HALIDE:** **A** type of high intensity discharge (HID) lamp in which the major portion of the light is produced by radiation of metal halide and mercury vapors in the arc tube. Available in clear and phosphor-coated lamps.

⇒ **MR-16:** A low-voltage quartz reflector lamp, only 2" in diameter. Typically the lamp and reflector are one unit, which directs a sharp, precise beam of light.

⇒ **NADIR:** A reference direction directly below a luminaires or "straight down" (O degree angle).

⇒ **NPF (NORMAL POWER FACTOR):** **A** ballast/lamp combination in which no components (e.g. capacitors) have been added to correct the power factor, hence normal (essentially low) power factor (typically .5 or *50%).*

⇒ **OCCUPANCY SENSOR:** Control device that turns lights off after the space becomes unoccupied. May be ultrasonic, infrared or other type.

⇒ **OPTICS:** A term referring to the components of a light fixture (such as reflectors, refractors, lenses, louvers, etc.) or to the light emitting or light-controlling performance of a fixture.

⇒ **PAR LAMP:** A Parabolic Aluminized Reflector lamp. An incandescent, metal halide, or compact fluorescent lamp used to redirect light from the source using a parabolic reflector. Lamps are available with flood or spot distributions.

⇒ **PAR 36:** A PAR lamp that is 36 one-eighths of an inch in diameter with a parabolic shaped reflector (SEE PAR LAMP).

⇒ **PARABOLIC LUMINAIRE:** A popular type of fluorescent fixture which has a louver composed of aluminum baffles that are curved in a parabolic shape. The resultant light distribution produced by this shape provides reduced glare, better light control, and is considered to have greater aesthetic appeal.

⇒ **PARACUBE:** A metallic coated plastic louver made up of small squares. Often used to replace the lens in an installed troffer to enhance its appearance. The paracube is visually comfortable, but the luminaire efficiency is lowered. Also used in rooms with computer screens because of their glare-reducing qualities.

⇒ **PHOTOCELL:** A light sensing device used to control luminaires and dimmers in response to detected light levels.

⇒ **PHOTOMETRIC REPORT:** A photometric report is a set of printed data describing the light distribution, efficiency, and zonal lumen output of a luminaires This report is generated from laboratory testing.

⇒ **POWER FACTOR:** The ratio of A.C. volts x amps through a device to A.C. wattage of the device. A device such as a ballast that measures 120 volts, I amp, and 60 watts has a power factor of 50%. (volts x amps = 120 VA, therefore 60 watts / 120 VA = .5) Some utilities charge customers for low power factor systems.

⇒ **PREHEAT:** A type of ballast/lamp circuit that uses a separate starter to heat up a fluorescent lamp before high voltage is applied to start the lamp.

⇒ **QUAD-TUBE LAMP:** A compact fluorescent lamp with a double twin tube configuration.

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⇒ **RADIO FREQUENCY INTERFERENCE (RFI):** Interference to the radio frequency band caused by other high frequency equipment or devices in the immediate area. Fluorescent lighting systems generate RFI.

⇒ **RAPID START (RS):** The most popular fluorescent lamp/ballast combination used today. This ballast is designed to quickly and efficiently preheat lamp cathodes to start the lamp. Uses a "bi-pin" base.

⇒ **ROOM CAVITY RATIO:** Room Cavity Ratio (RCR) is a ratio of room dimensions used to quantify how light will interact with room surfaces. A factor used in illuminance calculations.

⇒ **REFLECTANCE:** The ratio of light reflected from a surface to the light incident on the surface. Reflectances are often used for lighting calculations. The reflectance of a dark carpet is around 20%, and a clean white wall is roughly 50% to 60%.

⇒ **REFLECTOR:** The part of a light fixture that shrouds the lamps and redirects some of the light emitted from the lamp.

⇒ **REFRACTOR:** A device used to redirect the light output from a source, primarily by bending the waves of light.

⇒ **RECESSED:** The term used to describe the doorframe of a troffer where the lens or louver lies above the surface of the ceiling.

⇒ **REGULATION:** The ability of a ballast to hold constant (or nearly constant) the output watts (light output) during fluctuations in the voltage feeding of the ballast. Normally specified as +/percent change in output compared to +/percent change in input.

⇒ **RELAY:** A device that performs the actual on or off switching of an electrical load due to small changes in current or voltages. Examples: low voltage relay and solid state relay.

⇒ **RETROFIT:** Refers to upgrading a fixture, room, building, etc., by installing new parts or equipment.

⇒ **SEMI-SPECULAR:** Term describing the light reflection characteristics of a material. Some of the light is reflected directionally, with some amount of scatter.

⇒ **SHIELDING ANGLE:** The angle measured from the ceiling plane to the line of sight where the bare lamp in a luminaire becomes visible. Higher shielding angles reduce direct glare. It is the complementary angle of the cutoff angle. (See CUTOFF ANGLE).

⇒ **SPACING CRITERION:** A maximum distance that interior fixtures may be spaced that ensures uniform illumination on the work plane. The height above the work multiplied by the spacing criterion equals the center-to-center luminaire spacing.

⇒ **SPECULAR:** Mirrored or polished surface. The angle of reflection is equal to the angle of incidence. This word is used to describe the finish of the material used in some louvers and reflectors.

⇒ **STROBOSCOPIC EFFECT:** Condition where rotating machinery or other rapidly moving objects appear to be standing still due to the alternating current supplied to light sources. Sometimes called "strobe effect."

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⇒ **T12 LAMP:** Industry standard for a fluorescent lamp that is 12 one-eighths **(11/2** inches) in diameter. Other sizes are T10 **(11/4** inches) and T'8 (1 inch) lamps.

⇒ **TANDEM WIRING:** A wiring option in which a ballasts is shared by two or more luminaires. This reduces labor, materials, and energy costs. Also called "master-slave" wiring.

⇒ **THERMAL FACTOR:** A factor used in lighting calculations that compensates for the change in light output of a fluorescent lamp due to a change in bulb wall temperature. It is applied when the lamp-ballast combination under consideration is different from that used in the photometric tests.

⇒ **TRIGGER START:** Type of ballast commonly used with 15-watt and 20-watt straight fluorescent lamps.

⇒ **TROFFER:** The term used to refer to a recessed fluorescent light fixture (combination of trough and coffer).

⇒ **TUNGSTEN HALOGEN LAMP:** A gas-filled tungsten filament incandescent lamp with a lamp envelope made of quartz to withstand the high temperature. This lamp contains a certain proportion of halogens, namely iodine, chlorine, bromine, and fluorine that slows down the evaporation of the tungsten. Also commonly referred to as a quartz lamp.

⇒ **TWIN-TUBE:** (See COMPACT FLUORESCENT LAMP)

⇒ **ULTRA VIOLET (UV):** Invisible radiation that is shorter in wavelength and higher in frequency than visible violet light (literally beyond the violet light).

⇒ **UNDERWRITERS' LABORATORIES (UL):** An independent organization whose responsibilities include rigorous testing of electrical products. When products pass these tests, they can be labeled (and advertised) as "UL listed." UL tests for product safety only.

⇒ **VANDAL-RESISTANT:** Fixtures with rugged housings, break-resistant type shielding and tamperproof screws.

⇒ **VCP:** Abbreviation for Visual Comfort Probability. A rating system for evaluating direct discomfort glare. This method is a subjective evaluation of visual comfort expressed as the percent of occupants of a space who will be bothered by direct glare. VCP takes into account luminaire luminances at different angles of view, luminaire size, room size, luminaire mounting height, illuminance, and room surface reflectivity. VCP tables are often provided as part of photometric reports.

⇒ **VERY HIGH OUTPUT (VHO):** A fluorescent lamp that operates at a "very high" current (1500 mA), producing more light output than a "high output" lamp (800 mA) or standard output lamp (430 mA).

⇒ **VOLT:** The standard unit of measurement for electrical potential. It defines the "force" or "pressure" of electricity.

⇒ **VOLTAGE:** The difference in electrical potential between two points of an electrical circuit.

⇒ **WALLWASHER:** Term used to describe the luminaires designed to illuminate vertical surfaces.

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⇒ **WATT (W):** The unit for measuring electrical power. It defines the rate of energy consumption by an electrical device when it is in operation. The energy cost of operating an electrical device is determined by its wattage times the hours of use. In single phase circuits, it is related to volts and amps by the formula: Volts x Amps x P.F. = Watts. (Note: For *A-C.* circuits, P.F. must be included.)

⇒ **WORK PLANE:** The level at which work is done and at which illuminance is specified and measured. For office applications, this is typically a horizontal plane 30 inches above the floor (desk height).

⇒ **ZENITH:** The direction directly above the luminaire (180 degree angle).

RESOURCE PUBLICATIONS

To obtain more in-depth information on lighting fundamentals and technologies, please refer to the following publications:

⇒ *Advanced Lighting Technologies Guidelines,* California Energy Commission, 1990.

⇒ *Commercial Lighting Efficiency Resource Book,* Electric Power Research Institute, CU-7427, September 1991.

⇒ *Compact Fluorescent Lamps,* Electric Power Research Institute, CU-2042R, July 1991.

⇒ *EPA Lighting Upgrade Manual*, Green Lights Program, 4th Edition, February 1993.

⇒ *Fundamentals of Commercial and Industrial Lighting,* 5th Edition, The Electrification Council, 1984.

⇒ *Guide to Performance Evaluation of Efficient Lighting Products,* Lighting Research Center, June 1991.

⇒ *NEMA Guide to Lighting Controls,* National Electrical Manufacturers Association, 1992.

⇒ *Occupancy Sensors,* Electric Power Research Institute, BR-100323, 1992.

⇒ *Profiting from Lighting Modernization,* National Lighting Bureau, 1987.

⇒ Rea M.S., Pasini I. and Jutras L., *Lighting Performance Measured in a Commercial Building,* Lighting Design + Application, January 1990.

⇒ *Retrofit Lighting Technologies,* Electric Power Research Institute, CU-3040R, July 1991.

⇒ *Specifier Reports: Electronic Ballasts,* Lighting Research Center, December 1991.

⇒ *Specifier Reports: Power Reducers,* Lighting Research Center, March 1992.

⇒ *Specifier Reports: Specular Reflectors,* Lighting Research Center, July 1992.

⇒ *Specular Retrofit Reflectors,* Electric Power Research Institute, CU-2046, October 1991.

⇒ *Technical Lighting Bulletins,* North Carolina Alternative Energy Corporation, January 1991.

⇒ *Technology Assessment.- Energy-Efficient Commercial Lighting,* Lawrence Berkeley Laboratory, March 1989.

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