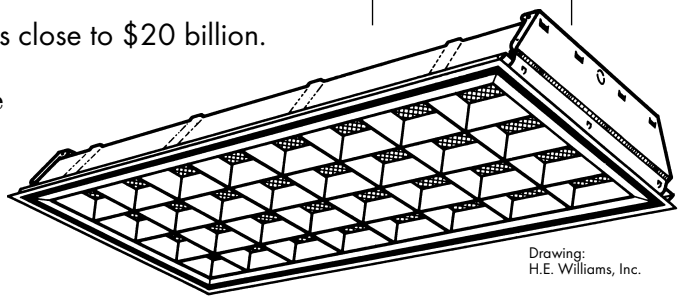
GREEN SEAL'S GREEN REPORT

SEPTEMBER–OCTOBER 2000

LINEAR FLUORESCENT LUMINAIRES

Lighting energy use accounts for about a quarter or more of the estimated one trillion kWh of energy yearly expended by the US commercial and industrial sectors. In fact, commercial and industrial lighting accounts for three-quarters of all lighting energy use in the US. Annually, the electricity cost to light US offices, factories, retail stores, warehouses, other commercial and industrial concerns, combined with outdoor lighting, is close to $20 billion.

Commercial and industrial lighting accounts for three-quarters of all lighting energy use in the US.



Drawing: H.E. Williams, Inc.

A large portion of the commercial and industrial lighting systems currently in use was put in place between 1960 and 1990, according to statistics. The systems that are in place often rely on the use of manually controlled incandescent and standard fluorescent lighting with magnetic ballasts, or even mercury vapor systems. These types of lighting systems and lighting controls are generally less efficient than those currently available, which include full-size and compact fluorescent systems with electronic ballasts, low-wattage high intensity discharge systems, and more advanced controls and sensors.

Luminaire designs—the science and art of combining lamps, ballasts, and other components to direct a lighting fixture's output—have advanced significantly, due to research findings, improved materials, and changes in user needs. Together with improved luminaire designs, the new lighting and control systems not only offer greater lighting comfort and productivity, but also longer lifetimes and reduced maintenance. Most importantly, these new luminaires and control systems combined are extremely efficient. Replacing the incandescent and fluorescent lighting systems of ten or fifteen years ago with these new systems can cut lighting energy use in half or more.

Less efficient indoor lighting sources often create heat along with light, and can be a serious source of excess heat in buildings. The additional cooling energy required to counteract this effect increases a building's total energy use. Thus, efficient lighting design not only reduces lighting energy usage and cost, it can also make a difference in other operational areas as well. This *Choose Green Report* is the second in a series of three by Green Seal™ focusing on commercial and business applications of energy-efficient lighting.

Energy derived from fossil fuels or other non-renewable energy sources can seriously affect the environment: mining and exploration can damage fragile areas; the burning of fossil fuels releases carbon dioxide and methane, the two largest contributors to global climate change. In addition to greenhouse gases, electric generation is a source of sulfur oxides (S0x), the leading cause of acid rain, and nitrogen oxides (N0x), the leading cause of urban air pollution. Although energy use is the main environmental issue associated with lighting, another is the use of natural resources required to manufacture fixtures and lamps. Commercial and industrial lamp disposal can be a problem, since they may contain high-pressure gases or mercury vapor.

This *Report* focuses specifically on linear fluorescent fixtures, especially for general office and retail usage—where good illumination is needed for long periods. For warehouses, factories, large retail stores and other situations where uniform levels of illumination are required from high-mounted fixtures (12 feet or more in ceiling height), Green Seal recommends that high-intensity discharge (HID) lighting systems be considered (see Green Seal's *Choose Green Report* on HID luminaires). Except for a few situations, applications of fluorescent lamp systems are recommended for most office, commercial, institutional, retail and even some industrial needs.

Because of their efficiency, new fluorescent systems in both old and newly built spaces can provide many advantages, including:

- Increased worker comfort and productivity
- Improved retail appearance
- Reduced lighting energy use
- Reduction of excess heat in buildings
- Fewer fixtures and bulbs per square foot (in some newly built spaces)

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Linear Fluorescent Luminaire Considerations

This *Report* covers linear fluorescent luminaires for commercial, institutional, and retail applications, ranging from where uniform levels of light are needed on work or retail surfaces, to where ambient lighting is needed for long periods. (Note: as used here, "fixture" refers to the enclosure for the lamps and ballast, while "luminaire" refers to the whole package). Suitable applications of fluorescent luminaires can include:

- office spaces
- retail stores
- certain industrial spaces
- schools and other institutions,
- hallways and lobbies

For most of the above spaces, fluorescent luminaires generally provide the greatest efficiency and ease of maintenance. A wide variety of luminaire designs exist to meet most needs, and pricing for these products can range from under $50 per unit with lamp, to $300 or more, depending on options, ballast selection and quantity.

Retrofit vs. New

Many fluorescent lighting systems put in place a decade ago may provide too much lighting, or provide the inappropriate type of lighting for current use. These ten- or fifteen years-old systems also tend to use more energy and produce excess heat, resulting in high energy consumption and user discomfort. Energy saving measures for these spaces can come from:

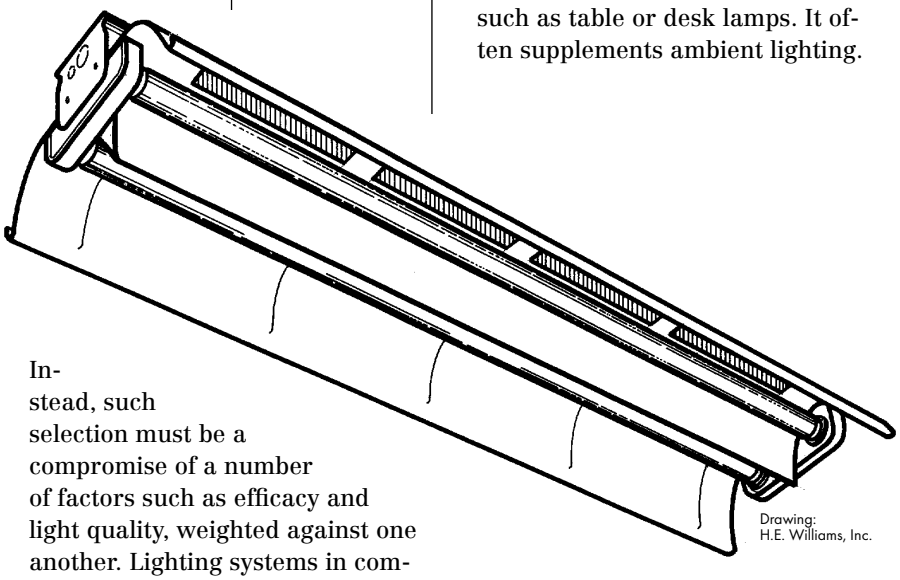
- Bringing over-lit areas to more comfortable lighting levels through de-lamping.
- Improving existing fixtures (through add-ons) to distribute and improve light quality.
- Installing control technologies such as sensors or automatic switching systems to reduce operating time.
- Retrofitting or replacing existing systems with the most efficient luminaires.

This *Report* deals with choosing efficient luminaires for new or existing office, commercial and retail applications only, and provides guidelines for efficient and appropriate luminaire selection. While the other three measures listed above can also significantly reduce energy use, they are beyond the scope of this *Report,* as each requires its own report to adequately cover the subject. This *Report* also assumes a certain level of familiarity with fluorescent and control systems terminology and technologies, and mostly focuses on luminaire selection. For a brief primer on linear fluorescent and control terminology, please see included box.

Currently, high-efficiency fluorescent lamp and ballast are available in various combinations, and in a number of different fixture designs to suit commercial and industrial applications. For luminaire selection, we recommend that you start with the luminaire design that suits your particular lighting needs, and choose an efficacious combination of linear fluorescent lamp and ballast (a system that provides high light output from the input wattage) to complete the package. In addition, lighting control strategies can significantly affect a system's overall energy consumption, so that measures such as automatic switching, daylight dimming, or sensors should be considered where appropriate. Current regional and local commercial building codes and regulations can also dictate the controls, energy consumption levels, and light levels for new and retrofitted spaces.

The selection of an efficient luminaire today does not end with the choice of one that provides the most light output for the amount of input power. Instead, such selection must be a compromise of a number of factors such as efficacy and light quality, weighted against one another. Lighting systems in commercial and institutional applications should not just produce light in sufficient quantity, but also of good quality to ensure high levels of user comfort, productivity, interest, and accuracy, especially in office and retail situations. Most of the lighting systems installed ten and fifteen years ago that still exist today are lacking in both efficiency and quality compared to current systems, thus making a strong case for their wholesale replacement.

Good office and commercial lighting designs combine ambient, task, and accent lighting.



Drawing: H.E. Williams, Inc.

Good office and commercial lighting designs combine ambient, task, and accent lighting. Office lighting generally emphasizes performance and comfort, while retail lighting emphasizes ambiance and accent.

- **Ambient** or **general lighting** creates the light that fills a space, and can utilize any number of lighting methods (covered in box): direct, indirect, or combination. Ambient light levels can range from low to high depending on the application. Most office and other commercial /retail space use medium to high ambient levels with good CRI.

- **Task lighting** illuminates a specific workspace only, and can come from luminaires mounted above, or a portable luminaire, such as table or desk lamps. It often supplements ambient lighting.

- **Accent lighting** highlights specific features of a space: artwork, architectural attraction, or graphics. It directs and focuses light to create visual interest in a space rather than any specific function. Accent lighting is used more extensively in the retail environment to create dramatic effects.

TABLE 1

Lamp Technology	Approximate Efficacy Range (lpw)	Color Rendering Ability
Standard Incandescent	7 to 15	Excellent (100)
Tungsten Halogen	15 to 25	Excellent (100)
Compact Fluorescent	25 to 75	Good (70+) to Excellent (80+)
Full Size Fluorescent	65 to 95+	Medium (60+) to Excellent (80+)
Metal Halide	45 to 95+	Fair (50+) to Good (70+)

Fluorescent Technology Overview

A linear fluorescent luminaire generally consists of a ballast serving as a power regulator, a lamp or lamps providing light, housing for the lamp/ballast assembly, and optional reflector, diffuser, lens, or louver to help control and direct light output.

Fluorescent lamps are the most efficient source of light for general usage—they range in efficacy from 40 lumens per watt (lpw) to over 100 lumens per watt. In addition, they are long-lived and are available in a range of color rendering abilities and color temperatures. They are also able to maintain their light output much longer than a number of other lamp technologies. Table 1 compares some available lamp technologies, their efficacy range, and color rendering ability.

Fluorescent light is created by using an electric arc to excite low-pressure mercury vapor contained in a sealed glass tube. The excited mercury atoms in turn energize specially formulated compounds—phosphors—that coat the inside of the tube wall, creating light. Ballasts are used to create the arc needed to start and maintain light emissions, and to maintain the control and safe operation of the lamps. Linear fluorescent lamp design differs in size, phosphor type, fill gas (inert gases used to maintain pressure inside the lamp), cathode and base designs. Manufacturers offer lamps in a wide range of wattage, light output, color rendering ability, color temperature, and lifetime by using different combinations of size, phosphor, fill gas, and cathode design. Newer, more efficient lamps tend to have smaller diameters.

Three different methods can be used to start fluorescent lamps. With a few exceptions, the starting method of the lamp and the ballast must match.

Pre-heat starting causes flickering for several seconds before the lamps ignite. It is used on older lamp systems.

Rapid starting is the most common method. Lamps started with this method come on within a second with only a brief flicker.

Instant starting uses a high-voltage (400 to 1,000 V) pulse to jolt the lamps. This method starts lamps in under a tenth of a second.

Available Efficient Lamp-Ballast Systems

There is a large array of choices in full-size fluorescent systems. The most commonly installed systems in commercial facilities use T12 lamps and magnetic ballasts—the least efficient combination and usually the lowest

DEMYSTIFYING FLUORESCENT LAMP SIZE

Fluorescent lamps are classified according to their diameter in increments of 1/8 of an inch. Therefore, the popular lamp sizes can be deciphered as follows:

T 12	(also "T12" or T-12):	Lamp diameter is 12/8 inches, or 1.5 inches
T 8	(also "T8" or "T-8"):	Lamp diameter is 8/8 inch, or 1.0 inch
T 5	(also "T5" or "T-5"):	Lamp diameter is 5/8 inch, or 0.625 inch

first cost. Other choices for energy efficiency are described below.

"Energy Saving" Lamp/Ballast combination—The "energy saving" (ES) lamp is in fact a misleading term. While the rated lamp efficacy can be relatively high, these lamps are no more efficient than standard magnetically ballasted T12s. In addition, ES lamps have a higher rate of lumen depreciation than standard lamps, can be very sensitive to operating current, and cannot be deeply dimmed or operated on low-ballast-factor ballasts. In addition, they do not perform well in cold temperatures and cannot be used with cathode-cutout ballasts.

Electronic Ballasts—Fluorescent technology received a boost through the use of semiconductors to rectify and convert the current needed to operate lamps. Electronic ballasts can cut internal power losses 3 to 8 watts per ballast (from about 16 watts per ballast). They also operate lamps 10 percent more efficiently, and can cut losses by driving more lamps per ballast. They are also less affected by temperature and voltage variations, can automatically de-energize failed lamps, and eliminate lamp flicker. These improvements can combine to create very large energy savings—up to 90 percent is possible.

For most applications, the efficacious choice is a combination of electronic ballasts and T8 lamps.

Luminaire Technology Overview

The primary considerations of luminaire selection are the location and purpose for which the lighting system or systems will be used. The most efficient fluorescent luminaire extant is a "strip" type fixture with bare lamps and white or metal sheeting reflectors. While this lamp, fixture, and reflector combination is extremely efficient at converting the input wattage into light output, this fixture may not be appropriate for areas where glare is a major issue, such as in a computer-intensive office, specialty shopping area, or a precision-assembly work area, for example. Luminaire designs and their applications have evolved to meet these additional illumination demands of office and commercial spaces.

Today, the majority of commercial spaces, such as offices and mass retail environments, are still lit by direct fluorescent luminaires for a number of reasons, including first cost. Most office, institutional, and retail spaces (10 ft in ceiling height or less) use **troffers**—recessed, steel-trough luminaires with a lensed or louvered cover to guide light output. These luminaires are designed to fit into the space of one suspended acoustical ceiling tile 2-ft by 4ft in dimensions. Typically, they are installed in a grid pattern to provide general illumination throughout the space, and can provide the necessary office lighting levels (50 to 60 footcandles) for about 0.95 to 1 Watt per square foot.

Louvered troffers (or parabolic troffers) use polished, reflective louvers to direct light output. The louvers are usually made from materials such as aluminum or metal-coated plastic, and have a parabolic shape designed to reduce glare and hide the lamps from direct view. They are commonly found in open office areas, and are estimated to represent about 25 percent of the commercial fluorescent lighting market. Louvered troffer luminaire types are an increasingly popular choice for general office lighting.

The term "parabolic troffers" describes luminaires using large-cell or small-cell parabolic louvers. Large-cell luminaires are generally better at delivering light to the intended work surface, while small-cell luminaires are better at glare control. Standard luminaire sizes include 2 ft by 4ft, 2ft by 2ft, 1ft by 4 ft. Other sizes are also available.

There are three common variations of large-cell parabolic luminaires:

- Standard—generally, these have louvers about 3 inches deep, and are proficient at glare control and light delivery, but are quite bright to look at, due to the relatively shallow cells.
- Deep-cell—these have louvers that are 4 inches or more in depth. Deep-cell parabolic luminaires are not as effective as standard-cell in terms of light delivery, but they offer very good glare control, and are not as bright to look at as standard cell luminaires.
- Compound parabolic—these are specially designed louvers to create a low glare lighting condition for computer display-intensive work environments. These have excellent glare control. They are also designed to eliminate the reflective images on computer screens.

Lensed troffers use plastic lenses of acrylic or polycarbonate material in the luminaire cover or shield to direct light output, control glare, and hide the lamps from direct view. They are found

in many office and commercial applications, and are estimated to represent about 50 percent of the commercial fluorescent lighting market. Lensed luminaires redirect light to the work surface rather than diffuse it, and can be differentiated from diffusers by the clear materials and patterns of surface prisms. Diffusers are less efficient than lenses because their translucent plastic cover can absorb rather than redirect light.

Lenses made from polycarbonate are stronger than acrylic lenses, and are better at transmitting light. However, polycarbonate lenses are more expensive than acrylic lenses and can yellow over time as a result of the UV emissions from fluorescent light. Acrylic lenses can be stabilized against UV emissions. Combined with its lower lens cost, acrylic lensed troffers generally offer the lowest installed cost per square foot, which can be as low as about $1.

Troffer luminaires generally offer the lowest installed cost for the amount of light they provide, with lensed troffers generally costing less than louvered troffers. Other than troffers, fluorescent fixtures used in other office and commercial/retail applications often consist of two, three or even four lamp systems, utilizing four- and eight- foot long lamp-ballast systems, ranging in type from strip lights and shop lights to specialized applications. Some non-troffer common linear fluorescent fixtures and their uses are:

Strip Lights—These are the very basic linear fluorescent fixtures, consisting of ballast and bare lamps. They are used to provide general lighting where glare and appearance are not the primary requirements.

Cove Lights—Cove lights are a variation of strip lights used to provide up lighting from coves and similar architectural features where indirect or reflected light is needed.

Industrials—"Industrial" luminaires can be suspended or ceiling mounted, and use deep, white painted metal reflectors to reduce glare from their bare lamps. They are quite efficient (most, if not all of the light produced is directed outward), cost effective, and are often found in industrial, supermarket/retail or school settings.

Trough—"Trough" luminaires are an improvement over strip luminaires. They use a shallow trough to improve visual comfort over strip light. They are also efficient and are used in many low-cost industrial and retail settings, such as small markets, garages/ repair shops, or other industrial settings.

Wraparounds—These are a type of low-cost linear fluorescent luminaires designed for use where a finished appearance is required. They can be ceiling/wall mounted and consist of a strip luminaire surrounded by a diffuser or lens. They can be found in hallways, stairs, and other utility applications to provide general lighting.

Efficient Fluorescent Luminaire Choices

As discussed, the most common applications of linear fluorescent lighting, where uniform levels of illumination are required for long periods of time, include office, commercial, and retail spaces. General guidelines for the selection of luminaires—lamp, ballast and reflector systems—designed for these areas are outlined in the box on page 7.

An important consideration for selecting luminaires is whether the chosen fixtures will fulfill the illumination needs. The luminaire should provide both adequate illumination levels (in foot-candles) as well as color quality (CRI) needed for the particular application.

Environmentally Responsible Luminaire Selection

Green Seal™ has developed the list of criteria below to help you select luminaires that have less overall impact on our environment. These criteria take into account the most obvious resource reduction opportunity—energy efficiency (in the forms of lamp and system efficacy). Next, we also considered the performance of the luminaire, in terms of lamp longevity, ballast characteristics, manufacturers' warranty and factors such as safety testing, since these affect how soon a replacement system is needed, and because longer lasting products can reduce the volume of waste entering the waste stream. Finally, we considered the impacts of the luminaire—the metals, plastic and other components used as well as the production methods, where such information was available from the manufacturers.

Because of the number of products available, the selection process can be as straightforward as the determination of the required light levels and types based on user needs, and then selection of the lamp, fixture type, and number. In addition, we recommend that economic factors such as replacement lamp and labor cost also be factored into cost-benefit analyses, since a low-cost product may not prove to be inexpensive in the long run. Although this *Report* focuses only

Green Seal's Recommendations

FOR GENERAL LIGHTING

- ❑ Choose T8 lamps and electronic ballasts for luminaires.
- ❑ Choose lamps with the lowest mercury content available for your application.
- ❑ Generally, a 2-lamp or 3-lamp, 2-by-4 foot troffer luminaire is suitable for most applications. Lenses or louvers should be specified to industry standard.
- ❑ Consider using 2-foot T8 lamps or T8 "U-tubes" in shorter luminaires, such as 2-foot by 2-foot troffers, as they are more efficient and can cost less than other options.
- ❑ The new generation of lensed-troffer luminaires does not require specular reflectors, as the efficiency gains do not justify the additional cost.
- ❑ For general usage, polished silver or aluminum reflectors in louvered troffers can create glare.

FOR COMPUTER-INTENSIVE LIGHTING

- ❑ Choose T-8 lamps and electronic ballasts (Use T-5 lamps and electronic ballasts where needed for additional energy savings).
- ❑ Choose lamps with the lowest mercury content available for your application.
- ❑ Consider luminaires with parabolic troffers rather than lensed troffers for better glare control
- ❑ Where warranted, choose luminaires with parabolic troffers designed specifically for use with computer monitors

on the selection of luminaires for indoor office, institutional, and commercial usage, the criteria listed below can be used for other applications of linear fluorescent luminaire.

Luminaire Energy Efficiency—In this *Report*, Green Seal™ used the Federal Energy Management Program (FEMP) recommended luminaire efficacy ratings (LER) where available (see Table 3 on page 8). LER is derived from the National Electrical Manufacturers' Association (NEMA) standard LE-5 as a baseline for identifying energy-efficient luminaires. This must be done with the same ballast, fixture type and bulb type/wattage ratings in order to make an equal comparison.

LER is defined as: LER = (Luminaire efficiency x Total rated lamp lumens x Ballast Factor) ÷ Input Watts

Green Seal recommends that you look for luminaires that have high LERs (meeting or exceeding the FEMP levels for the categories listed in the included table) and have been tested by a qualified testing lab. Where LERs are not readily available, we recommend the luminaire efficiency (LE) levels in Table 2 (see page 8), which were derived from Green Seal's own research):

Lamp Color Rendering and Color Temperature—In general, we recommend that you choose efficient luminaires with good light output and excellent color rendering index (80+) for areas where accurate color perception is needed, such as specialty retail. This recommendation also holds true for areas of highly detailed activities, such as drafting or computer-intensive work. For general lighting (mass retail, office or hallways), we recommend efficient luminaires with adequate light output and good CRI (70+). If the area to be lit requires a lesser degree of illumination but an image or "look" is needed (company waiting area, lobby, or specialty retail, for example), then the lamp color temperature and lamp CRI should be taken into consideration.

Lamp Longevity—Although most linear fluorescent sources last for a long time, various factors can affect system performance and reduce lamp life. The selection of a durable system not only ensures that less solid waste will be introduced into the environment, it also means that the components

TABLE 2

Luminaire Type	No. of Lamps	Luminaire Efficiency (LE)
2 by 4 Recessed – Lensed	2	0.76
2 by 4 Recessed – Lensed	3	0.77
2 by 4 Recessed – Lensed	4	0.75
2 by 4 Recessed – Louvered	2	0.65
2 by 4 Recessed – Louvered	3	0.75
2 by 4 Recessed – Louvered	4	0.63
Wraparound	2	0.81
Wraparound	4	0.71
Industrial	2	0.89

TABLE 3 **Federal Energy Management Program Efficiency Recommendations for Linear Fluorescent Lumni-**

LUMINAIRE TYPE (NEMA DESSIGNATION)	NO. OF LAMPS	RECOMMEDED LER
2x4 RECESSED		
Lensed (FL)	2	62 or higher
	3	61 or higher
	4	61 or higher
VDT-Preferred Louvered (FP)	2	50 or higher
	3	51 or higher
	4	54 or higher
WRAPAROUNDS		
4' Wraparound (FW)	2	63 or higher
	4	62 or higher
STRIPS		
4' Strips (FS)	1	70 or higher
	2	70 or higher
INDUSTRIALS		
4' Industrials (FI)	2	67 or higher
8' Industrials (FI)	2	68 or higher
2x2 RECESSED		
VDT-Preferred Louvered (FP)	2	41 or higher
Lensed (FL)	2	49 or higher

have been tested to be used as a system, thus ensuring user satisfaction and reducing failure incidents. Green Seal™ recommends choosing systems with rated lamp life of 10,000 hours or more.

Lamp Mercury Content—All fluorescent lamps contain a small amount of mercury vapor. Green Seal recommends that you select lamps with the lowest mercury content for your particular application. Maximum lamp mercury level should not exceed the State of California's requirements, at 3.8 milligrams per 4-ft lamp.

Lamp and Ballast Combination—Green Seal recommends that you choose luminaires using T-8 lamps, in 2-, 4- and 8-foot length, and electronic ballasts. They represent the most efficacious combination for all indoor office, retail, institutional, and commercial applications. Choose T-5 lamps and electronic ballast where applicable.

Ballast Performance—Ballasts play a critical role in fluorescent luminaire performance, and are an integral part of the lighting system. We recommend electronic ballasts meeting the following requirements:

- Class P thermal protection.
- Sound Rating of Class A or quieter.
- Compliance with ANSI/IEEE C62.41 specifications for withstanding electrical transients.
- Compliance with FCC Class A Part 18.305 and 18.307 Subpart for EMI and RFI.
- Have a current crest factor of 1.7 or less.
- Have total harmonic distortion of no more than 32% and power factor no less than 0.9.

Longevity of Luminaire Components—Because these fixtures tend to be used for long periods, we recommend choosing lenses or diffusers constructed of glass, or UV-stable optical-grade plastics that are also heat-stable. Reflectors, if included, should also be UV resistant and heat-stable.

Luminaire Reliability—Green Seal™ recommends choosing products with a manufacturer's warranty of at least two years for free replacement or repair of luminaire housing and electronics, and at least one year for lamp(s), if included.

Electrical Safety—To ensure longevity and safety of luminaires, Green Seal™ recommends that luminaires be tested by an independent laboratory, such as Underwriters Laboratories (UL), the Canadian Standards Association (CSA) or equivalent.

Warranty—At a minimum, we recommend products should carry a manufacturer's warranty of 2 years or more, to ensure user satisfaction while reducing failure incidents, replacement costs, and waste.

Production Methods and Materials—We also recommend that you consider products that were made using methods and materials that are less damaging to the environment, and products with recycled contents, where such information is available from the manufacturer.

DIRECT AND INDIRECT LIGHTING

Until a few years ago, most fluorescent luminaires available for general or office area lighting were of the ceiling-mounted, **direct** (closed) type fixtures. These fixtures used metal or white painted reflectors to direct all light downward, and often employ translucent lenses to help the even distribution of the light and reduce glare. With the advent of the computer-driven office, as well as more emphasis on worker comfort, such fixtures are no longer preferable for such an environment. However, most offices and retail situations still rely on direct luminaires, due to the fact that they tend to be more efficient, and are suitable for distributing light directly over task areas for a reasonable cost. Major drawbacks of direct luminaires include glare, dark ceilings, and dimly lit higher wall portions in office with high ceilings.

Indirect luminaires are now available in a wide variety for an increasing number of applications. These open fixtures are designed to be suspended or mounted at some distance below the ceiling, allowing light to bounce off of wall and ceiling surfaces, creating a softer illumination level and reducing glare and contrast. Indirect lighting provides lower ambient illumination and delivers better visual comfort than direct lighting because of its ability to distribute light more evenly. However, indirect lighting also requires more design expertise, higher ceiling height (9 to 10 ft.), and tends to cost more for both fixtures and labor.

Direct/Indirect fixtures are variations of the indirect concept. These fixtures emit light upward and downward only, and are designed to be suspended from ceilings, although their rank can include table and floor lamps. Direct/indirect luminaires can range from mostly direct to mostly indirect, according to the up and down lighting proportions. These luminaires can be a good compromise between the need for the higher efficiency (lower energy use) direct lighting and the more visual and spatial comfort of indirect lighting. Like indirect fixtures, their use may require fewer fixtures, but require more design expertise, higher ceilings, and they tend to be more costly than direct fixtures.

One final type of luminaires—**diffuse luminaires**—emit uniformly in all directions and include bare lamps, globes, table and floor lamps, and chandeliers. These luminaires are generally chosen more for ornamental reasons than for functional applications, and are included in this discussion for completeness only, since they tend to be less efficient than the other three luminaire types.

SOME LIGHTING DEFINITIONS

Ballast—The operation of light sources such as fluorescent, high-intensity discharge, and low voltage halogen requires a ballast to control the current needed to operate these light sources. Ballast can be magnetic, hybrid, or electronic. The latter types can be found in better-quality luminaires and permit better control of lamp operations.

Ballast Factor (BF)—The light output of a fluorescent lamp(s) operated on a ballast as a percentage of the light output when operated on a standard "reference" ballast. Ballasts with high ballast factor put out more light from a given lamp than ballasts with low ballast factor.

Color Correlated Temperature (CCT)—Also known as ***color temperature,*** and expressed in degrees Kelvin, it measures the color appearance of the light that comes from a light source. Available lamp color temperature range from 1700 degrees Kelvin to 5000 degrees Kelvin, with 2700–3500 degrees Kelvin being the comfortable range for most public areas.

Color Rendering Index (CRI)—CRI measures light sources' ability to render color of objects. CRI uses a scale of 0 to 100, with 100 representing the color rendering ability similar to sunlight. Light sources with "good" color rendering indices range from 70 to 80 CRI. Sources with CRI of 80+ are considered to have "excellent" CRI.

Efficacy—Efficacy measures a light source's ability to convert electric energy into light. It is measured in lumens per watt (lpw). The higher the lpw, the more efficient a light source. Efficacy can be measured for both lamp as well as lamp/fixture combination (system efficacy).

Illuminance—This term refers to the amount of light that falls on a surface, measured in foot-candles. It is equal to the number of lumens striking a surface, divided by the area of the surface. Foot-candle values can be determined for both horizontal surfaces, like a desktop, and vertical surfaces, like a chalkboard. One foot-candle is equal to the light of one standard candle striking one square foot of surface located one foot away.

Light Output—Also known as ***light quantity,*** used to described the quantity of light from a source. It is measured in lumens. Light quantity measurement is taken directly at the light source and is a calculation of the flow of light. The brighter the light source, the higher its lumen measurement. For example, a typical 60 W incandescent bulb will have the lumen output of approximately 700–800 lumens.

Lumen Maintenance—The term used to describe a light source's ability to maintain a consistent light output overtime. Most light sources suffer from reduced output as they age, some more drastic than others. It can be more noticeable in longer-lived sources.

Luminaire—This term is generally used to describe a hard-wired, fixed position apparatus that houses a light source and related components (ballasts, reflector, sockets), and provides illumination in a prescribed manner.

Luminaire Efficacy Rating (LER)— Measures the lumen output of a fixture as a function of input power, enabling comparisons between fixtures. The higher the LER, the more efficient the luminaire. LER is defined as: LER = (Luminaire efficiency x Total rated lamp lumens x Ballast Factor) ÷ Input Watts (The National Electrical Manufacturers Association (NEMA) publishes the *Procedure for Determining Luminaire Efficiency Ratings for Fluorescent Luminaires* (NEMA LE-5))

Luminaire Efficiency—Measures a luminaire's light output. It is a ratio of the lumen output of the luminaire to the lumens produced by the lamp/ballast combination(s) used in the luminaire, expressed as a percent. In other words, it compares the light that comes out of the luminaire to the light of the lamp. LE does not take into account the ballast factor.

Types of Lighting—Lighting can be separated into three distinct categories: general, task, and accent. General (or ambient) lighting fills a space with overall illumination. Its main purpose is to allow occupants to see and move around. Task lighting is designed to facilitate intensive visual activities without eye discomfort. It generally involves the bright illumination of an area. Accent lighting is used for decorative purposes; to add drama, set a mood, or highlight certain features of a space.

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WHO IS GREEN SEAL™?

Green Seal 's mission is to achieve significant environmental benefits by encouraging organizations and individuals to choose environmentally responsible products and services. We accomplish this goal in two key ways.

First, we set rigorous environmental standards for products and services and award a seal of approval to those meeting the standards. When consumers select products bearing the Green Seal, they know they are buying products that have a lessened impact on the environment, without sacrificing performance.

Second, through our ***Choose Green Report,*** *we help large and small institutions become environmentally sensitive shoppers. We provide detailed guidance — such as this report —on how organizations can protect the environment while saving money.*