New York Energy $mart℠
Small Commercial Lighting Program

Technical Guide for Effective, Energy-Efficient Lighting

Prepared by
The Lighting Research Center
Rensselaer Polytechnic Institute
for the
New York Energy $mart℠
Small Commercial Lighting Program

Sponsored by
New York State Energy Research and Development Authority
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Welcome to the New York Energy $mart℠ Small Commercial Lighting Program

The goal of this guide is to provide **New York Energy $mart℠** Small Commercial Lighting Program participants with more technical background and understanding related to effective, energy-efficient lighting design. To do that, this guide is presented in four parts:

- The first section of the guide describes the six design requirements for projects to receive incentives from the Program, and explains why these particular metrics were chosen.
- The second section of the guide provides an overview of lighting terminology – it will help you understand the language of lighting.
- Next, in the third section, is a discussion of the important elements of lighting design that constitute good lighting.
- The final section provides you with a practical path toward developing and implementing effective, energy-efficient lighting designs.

This guide and other tools and resources related to lighting are available for on-line viewing or download at the SCLP web site:

http://www.nyserda.org/sclp

Copies of all Program materials may be obtained upon request from your SCLP Account Manager. You may also direct any questions or requests for information that are not included in this guide to the SCLP toll free number 1 (866) 698-8177.

We appreciate all of our Allies' interest in learning more about how you can continue to foster the goals of the **New York Energy $mart℠** Small Commercial Lighting Program through promotion, design, and implementation of effective, energy-efficient lighting design.

Marilyn Dare
Assistant Project Manager
Energy Efficiency Services
NYSERDA

SECTION I
REVIEW OF THE SMALL COMMERCIAL LIGHTING PROGRAM AND DESIGN METRICS

A. Overview of the Goals of SCLP

SCLP promotes effective, energy-efficient lighting solutions in small commercial spaces (between 1,000 and about 25,000 square feet). The Program is a partnership with lighting contractors, distributors, lighting designers, manufacturers and their representatives, and others (herein referred to as lighting practitioners). SCLP was established to provide support to help design, select, and install lighting systems that are:

- energy-efficient
- cost effective, and
- help to improve the quality of the lighting for people who will use the space being lit.

SCLP provides lighting practitioners with tools and resources that help them to develop effective, energy-efficient lighting designs and installations. This guide is one of the tools designed to help meet this goal.

B. Selecting and Installing Effective, Energy-Efficient Lighting

In order to achieve an effective, energy-efficient lighting installation, you need to know how to design a lighting system, select lighting equipment, and install a lighting system that uses less energy than typical lighting systems – while meeting the needs of the people that will use it. To help guide you in this process SCLP has developed metrics, or measures, you can follow to help ensure that the lighting you select and install will be both effective and efficient. Using the SCLP program metrics will help assure that the lighting system you select and install:

- makes colors and skin tones appear natural;
- provides bright and uniform lighting in a space;

- does not use lighting fixtures that are glary or uncomfortable for people who work in or visit the space you are lighting;
- does not produce distracting reflections in computer screens or other shiny surfaces in the space;
- provides enough light for people to see and work comfortably throughout the day; and
- uses less energy and costs less money to operate than typical lighting systems.

If you follow the measures outlined below when you design a lighting system, select lighting equipment, and install lighting fixtures, you are much more likely to achieve an effective, energy-efficient lighting installation that will satisfy your clients.

C. Measures of Effective, Energy-Efficient Lighting

The following paragraphs describe the measures of effective, energy-efficient lighting used by SCLP.

a) Color Rendering Index of Lamps

When selecting the lamps for a lighting installation, those with a Color Rendering Index (CRI) of 70 or higher should be used. This will assure that colors and skin tones appear natural to the people who use the space. One of the most frequent complaints heard from people about energy-efficient lighting is that they do not like the way they look under the lighting. Selecting lamps with a 70 CRI or higher will help to avoid these complaints and will make the space appear much more pleasant to people. The CRI of a particular lamp can be found directly on the lamp package or in the manufacturer's catalog. Your SCLP Ally Distributor also will be able to help you choose lamps that meet this criterion.

It is recommended that you use lamps with a CRI of at least 80 in applications such as health care and specialty retail stores, where the color rendering of skin tones and merchandise is very important. A CRI of 65 or higher for metal halide (MH) lamps 250 watts or greater will be accepted in industrial and warehouse applications due to the current lack of MH lamps with a CRI of 70 and above.

The table below shows SCLP's CRI requirements and/or recommendations for specific spaces. See Section II-F to learn more about CRI.

	Color Rendering Index (CRI) Required Minimum / Recommendation
Auditorium	70 min.
Banking Activity Area	70 min.
Break Room (Dining)	70 min.
Classroom / Lecture Hall / Training room	70 min.
Closet	N/A
Conference / Meeting Room	70 min.
Convention Hall Multipurpose Area	70 min.
Corridor	70 min.
Dining	70 min.
Electrical / Mechanical Area	N/A
Examination Room (Medical)	70 min. / 80 +
Exercise Area	70 min.
Exhibition Hall	70 min.
Financial Institution	70 min.
Food Preparation (Kitchen area)	70 min.
Grocery Store General Merchandise Area	70 min. / 80+
Gymnasium Playing Area	70 min.
Hotel Function Area	70 min.
Hotel Lobby	70 min.
Industrial Area < 20ft. ceiling height	65 min. / 70+
Industrial Area > 20ft. ceiling height	65 min. / 70+
Kitchen / Food Preparation	70 min.
Laboratory Medical	70 min. / 80 +
Laboratory - Industrial	70 min.
Library	70 min.
Lobby - Hotel	70 min.
Lobby - Waiting Area (Other Buildings)	70 min.
Mall General Sales Area (see Retail Sales)	
Mall Arcade / Atrium / Concourse	70 min.
Manufacturing (Industrial) Area < 20ft. ceiling height	65 min. / 70+
Manufacturing (Industrial) Area > 20ft. ceiling height	65 min. / 70+
Medical and Clinical Care	70 min. / 80 +
Multipurpose Room (Meeting Room)	70 min.
Museum	70 min.
Nurses Stations (Medical)	70 min. / 80 +
Office, Private (< 300 sq. ft.)	70 min.
Office, Open Plan (> 300 sq. ft.)	70 min.
Reception Area (Lobby)	70 min.
Religious Worship	70 min.
Restaurant	70 min.
Restroom	70 min.
Retail Sales Fine Merchandise Area (Jewelry, fine apparel, accessories, china, and silver)	70 min. / 80+
Retail Sales General Merchandise Area and Wholesale Showroom	70 min. / 80+
Shipping (Industrial) Area < 20ft. ceiling height	65 min. / 70+
Shipping (Industrial) Area > 20ft. ceiling height	65 min. / 70+
Stairs (Support Area)	70 min.
Storage - Industrial, Commercial	70 min.
Theater - Motion Picture	70 min.
Theater - Motion Picture, Lobby	70 min.
Theater - Performance	70 min.
Warehouse Area < 20ft. ceiling height	65 min. / 70+
Warehouse Area > 20ft. ceiling height	65 min. / 70+

b) Spacing Criteria for Lighting Fixture

When you design and install a lighting system, it is important that the fixtures are not installed too far apart from each other, or too far away from the walls of the space. If the spacing of the fixtures is not correct, the room will look unevenly lighted and there will be areas that are too dark for people to see properly. Lighting fixtures should be installed within the manufacturer's recommended spacing criteria. Lighting fixture spacing criteria may be listed on the fixture's photometric or specification sheets, or in the manufacturer's catalog.

It is also important that the distance between walls and adjacent lighting fixtures should not exceed one-half of the manufacturer's spacing criteria. This will ensure that some light falls on the upper part of the walls, which will make the room appear brighter to occupants. If lighting fixtures are installed too far away from the walls of a space, the space will appear dark and occupants may complain about dark spots or insufficient light.

Another way to help provide enough light on the walls of a space is to use special lighting fixtures near the walls that direct light onto them. These fixtures are typically called wall-wash lighting fixtures and should be mounted no more than three feet from walls.

One more way to make a space look bright and well-lighted is to use lighting fixtures that are suspended from the ceiling. These direct some of the light up to the ceiling where it is reflected around the space. These fixtures are particularly effective at providing bright, comfortable lighting for places like offices, classrooms, and other areas where people work. These types of lighting fixtures are most often called direct/indirect lighting fixtures. They should be installed based on using the manufacturer's recommendations to provide uniform lighting at the work plane, and to also provide uniform ceiling brightness. The manufacturer's catalog information will tell you how far below the ceiling you should hang these fixtures (usually called suspension distance) and how far apart you should hang each row of the fixtures, based on the suspension distance you have selected.

Lighting fixtures that are meant to provide accent lighting (for example a lighting fixture installed to direct light at a work of art on the wall or at a mannequin in a store) are exempt from the spacing criteria requirement.

However, manufacturers will often provide guidelines regarding the distance between the accent light and the object being lighted depending on the ceiling height of the space. These guidelines ensure that the object is uniformly illuminated. It is important to follow these guidelines when installing these types of fixtures.

Manufacturers do not provide spacing criteria for most decorative lighting fixtures, such as chandeliers. Therefore these fixtures should be installed to make sure they hang in an appropriate location within a space.

See Section II-M for more information on spacing criteria and Section IV-E to learn where to find this information for the particular lighting fixture in a photometric report.

c) *Luminous Intensity of Lighting Fixtures*

A common complaint about lighting is that the fixtures are uncomfortably bright to look at or work under, or that they cause reflections in computer screens. This problem is known as glare. One of the best ways to avoid glare from a lighting system is to select lighting fixtures that do not direct a lot of light toward people's eyes or onto their computers. The measure that is used to determine how much light is coming out of a lighting fixture in a particular direction is luminous intensity. Luminous intensity charts (sometimes called candela distribution charts), tables, or graphs can be found on a lighting fixture's photometric/specification sheet, or in the manufacturer's catalogs.

The unit of measure used for luminous intensity is the candela (cd). To know if a lighting fixture is going to be comfortable to look at or is likely to be too bright, you need to know how many candelas the fixture will produce at various angles. These angles are measured from directly below the lighting fixture. (See Section II-B for more information.) SCLP sets limits on the luminous intensity of lighting fixtures that can be used in the program. These limits are:

- Luminous intensity of lighting fixtures installed in open office plans should not exceed a maximum of 300 candelas at 55 degrees. This limit has become the industry standard established by the Illuminating Engineering Society of North America (IESNA) in the new RP-1 office recommended practice guide.

- Luminous intensity for other applications should not exceed a maximum of 600 candelas at 65 degrees.

- Luminous intensity for lighting fixtures used in high ceiling spaces such as warehouses (often referred to as either high-bay or low-bay fixtures) should not exceed a maximum of 1,000 candelas at 65 degrees.

See Section IV-E for an overview on how to read candela values at 55 and 65 degrees in luminous intensity tables and graphs. Lighting fixtures that are meant to provide accent lighting or decorative lighting are exempt from the luminous intensity requirement.

d) Average Illuminance in a Space

In order for a lighting system to be effective, it needs to provide enough light for the people who work in or visit the space. This is especially important in offices, schools, hospitals, or industrial facilities, where people work for long periods of time. If there is not enough light, people will complain that it looks dark or gloomy, that they cannot see well, that they have eye strain, or that they get headaches from the lighting. Much research has gone into the specification of proper light levels for various types of spaces. The IESNA *Lighting Handbook*, 9th edition provides recommended light levels, also called illuminance levels, for many types of spaces and buildings.

SCLP provides a chart of IESNA recommended light levels for many commercial space types based on general tasks performed in typical areas (see Section IV-D). When you enter your lighting project into the "on-line" project qualifying tool available on the SCLP website (www.nyserda.org/sclp), the tool calculates the approximate light levels that will be achieved in the space being lighted and lets you know if you will meet the recommended target light levels for that space type. This allows you to assure your client that the light levels in the space will meet IESNA recommendations. Refer to the IESNA *Lighting Handbook* if you are interested in recommended light levels for specific tasks.

e) Energy Use

Lighting represents over 25% of the energy use in most commercial buildings. In fact, lighting is the largest consumer of electricity among all building technologies. Therefore, it is important that you provide your client with a lighting system that will be effective, while using the least amount of energy possible. This will save your client money over the long run because their electricity bills will be lower.

SCLP helps you do this by setting limits on the amount of energy that the lighting system you install can use. These limits are defined in terms of the number of watts it takes to power the lighting system, divided by the total square footage of the space where the lighting system is installed (watts-per-square foot). This limit is often referred to Lighting Power Allowance (LPA). To qualify for SCLP, a project's total connected lighting load (watts [W]) divided by the total area (square feet [Sq. Ft.]) shall not exceed the average lighting power allowance (LPA expressed in W / Sq. Ft.) for the applicable space category listed in the SCLP Metric Chart (see Section IV-D). SCLP's lighting power allowance is 10% less than that allowed by the Energy Conservation and Construction Code of New York State space by space method.

Meeting the LPA requirements of SCLP assures that your project will be even more efficient than is required by the New York State code. Lighting practitioners should consider using lighting controls such as occupancy sensors to reduce energy use and ensure compliance with LPA requirements. See Section IV-G to learn more about the proper use and commissioning of occupancy sensors.

D. Why These Metrics Were Selected

The metrics or measures outlined above were selected based on many years of research into what makes lighting effective and energy-efficient. They were also selected because the information needed to use the metrics is easy to find. Lighting distributors and manufacturer representatives taking part in SCLP should have all of the information that you need to verify that your planned lighting installation will meet these metrics.

E. Why These Metrics are Important to Effective Lighting

In order for a lighting system to work effectively and provide good lighting, it needs to meet certain minimum criteria. The SCLP metrics were carefully selected to assure that lighting systems designed and installed in accordance with these would provide high-quality lighting in a cost-effective and energy-efficient manner. Following these metrics will help to improve the lighting installation you are installing for your client.

F. How to Describe These Metrics and the Benefits of Effective, Energy-Efficient Lighting to a Client

One of the most difficult things to do is to describe to the person who will use a lighting system the benefits it will provide. Item B in this section helps to explain the benefits of effective, energy-efficient in a simple manner. You should use the points listed there, as well as the additional materials SCLP provides, such as guides and case studies, to help your client understand why effective lighting is so important.

G. Using this training guide

This training guide has been developed to help contractors, lighting distributors, designers, and other people interested in effective, energy-efficient lighting to select and install lighting systems that will meet the needs of people while using less energy than typical lighting systems. The remainder of this guide is divided into the three sections outlined below. Each section is designed to provide helpful information for you to use when planning a lighting installation.

- ***Section II – Lighting Terminology:*** Lighting has some unique terms that are used throughout the industry. This section reviews the most important and widely used of these terms.

- ***Section III – Effective, Energy-Efficient Lighting:*** It is often difficult to understand what makes lighting effective, and energy-efficient. This section provides an overview of the important factors that determine if a lighting system will meet the benchmark of being effective and efficient.

- ***Section IV – Developing an Effective, Energy-Efficient Lighting Installation***: The process of developing a good lighting installation can often be confusing. This section walks you through this process and helps you to use the SCLP metrics to guide your selection and installation of lighting equipment.

SECTION II
LIGHTING TERMINOLOGY

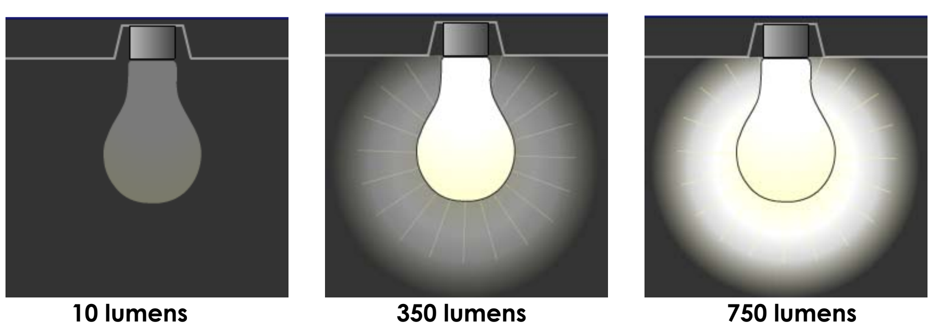
Nearly every field or profession has a specialized language or jargon unique to its own practitioners. The field of lighting is no exception. Designers, specifiers, and manufacturers within the lighting industry use unique terms and concepts that have evolved into professional usage over time. The terminology included in this section is used frequently throughout this manual. These terms represent important concepts in the study of lighting.

A. Lumen

The lumen (lm) is the time rate flow of light. While a lamp will have many candela values, depending upon the direction of interest (see Section II-B), it will have only one lumen output rating. The lumen rating can be considered as the measure of the total light output of a lamp. Ratings are determined and published by the lamp manufacturer. Since light output depreciates through time due to, among other things, the deterioration of the lamp components and the blackening of the interior surface of the bulb, lamp manufacturers often provide two lumen values:

- Initial lumens, also referred to as rated lumens, which are lumens measured before depreciation occurs.

- Mean lumens, also referred as design lumens, which are the lumens the lamp will most likely emit at 40 percent of the lamps' life.



During the design process, lighting practitioners use the lumen ratings of lamps to predict the illuminance in a space (see Section II-J). To obtain more realistic illuminance values, lighting practitioners should always use mean lumens in their calculations.

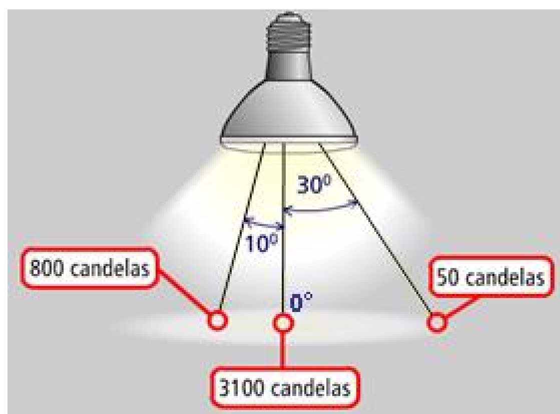
The following table shows a few examples of initial and mean lumen ratings for some commonly used lamps:

Lamp	Initial Lumens	Mean Lumens
60-W A19 incandescent	890	755
		2110
34-W T12 cool white fluorescent	2650	2280
		2850
26-W Quad CFL, 4100 K	1800	1550
		4135
70-W medium base metal halide, coated	5200	3400

Data taken from OSRAM/SYLVANIA and Philips Lamp Catalogs

Since energy-efficient design has become increasingly important to the end user, designers also evaluate the lumen output per watt consumed, or luminous efficacy, of the various lamp choices (see Section II-G).

B. C*andela*



Luminous intensity, also referred to as candlepower, is light emitted in a particular direction. Any given light source will have many different luminous intensities depending upon the direction considered. The unit of measure for luminous intensity of a light source in a specific direction is in candelas (cd). Since luminous intensity is a property of the source itself, the candlepower for a specified direction remains the same, regardless of distance from the source.

It is interesting to compare lamps of the same wattage with regard to luminous intensity. Imagine the lamps listed in the table below aimed straight down, with 0° representing a point directly beneath each one. Although not true for all sources, in these examples, the highest candela values occur at 0°.

Lamp	Candelas at 0°
75-W MR16 Flood	2,500
	14,000
75-W PAR38 Flood	3,150
	19,200

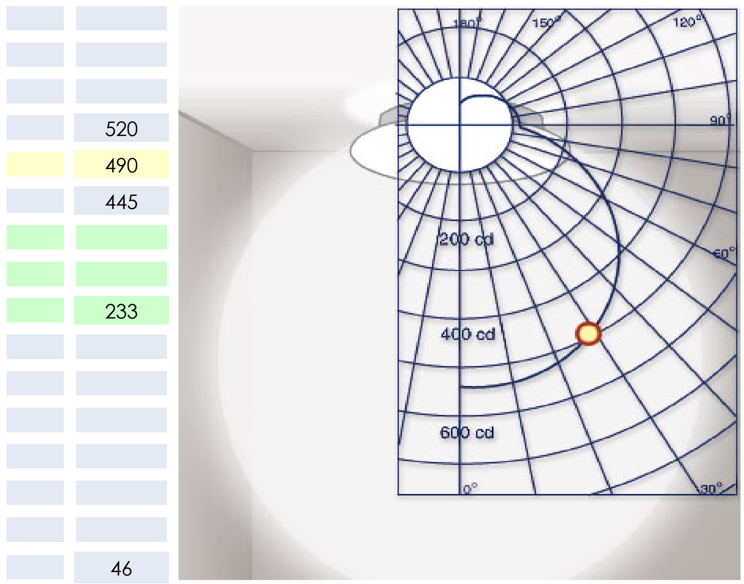
Data taken from OSRAM/SYLVANIA and Philips Lamp Catalog

Most lamp manufacturers publish luminous intensity rather than lumen output values for reflector lamps such as MR16 or PAR lamps, because these lamps are designed to redirect light in a specific direction. For non-directional sources such as linear and compact fluorescent lamps lumen output is more appropriate because it provides the total amount of light emitted in all directions.

C. Candlepower (Luminous Intensity) Distribution

The candlepower at various angles from a lamp or light fixture can be shown in a numerical table and in a graph as shown below. The candlepower summary table provides luminous intensity values at different angles while the candlepower graph shows a curve of plotted luminous intensity values, which allows us to visualize the light distribution of a particular lamp or light fixture. This data can be found in photometric reports. See Section IV-E for more on information luminous intensity distribution tables and graphs.

Intensity or Candlepower (CP) Distribution
Adapted from Specifier Reports: Energy-Efficient Residential Light fixtures



In this example, the luminous intensity at 30° is 490 candelas as seen both in the table and graph. SCLP is concerned with luminous intensity emitted at 55° and 65°. In this example, the luminous intensity values at these angles range approximately between 350 and 270 candelas. Can you locate those values on the graph?

D. Light Distribution

The light distribution of a light fixture can be defined as the pattern of light produced by a lamp or a light fixture. The light distribution of a light fixture depends on its photometric characteristics represented by a luminous intensity distribution curve described above. The International Commission on Illumination (CIE) has classified the light distribution of indoor light fixtures based on the percentage of light directed upward and downward as follows:

Direct: 90-100% downward

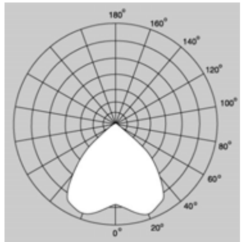


Photo: Courtesy of OSRAM SYLVANIA

Semi-direct: 60-90% downward; 10-40% upward

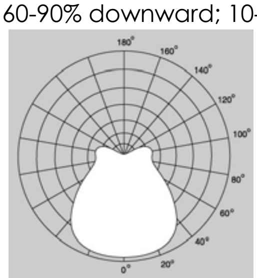


Photo: Randall Perry

Semi-indirect: 10-40% downward; 60-90% upward

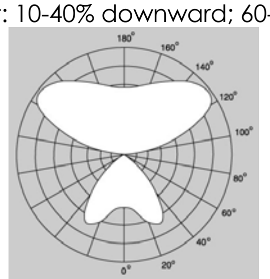


Photo: Courtesy of Litecontrol

Indirect lighting: 90-100% upward

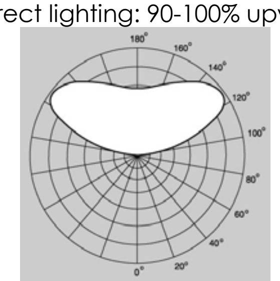


Photo: Courtesy of Litecontrol

General diffuse: 40-60% downward; 40-60% upward

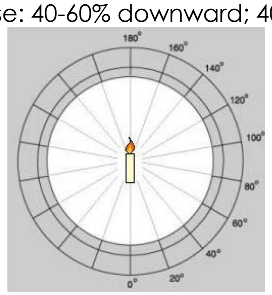


Photo: Courtesy of Kichler Lighting

The light distribution of the light fixtures to be used in an installation will affect both the number of luminaires to be used in the space as well as their layout and spacing.

E. Correlated Color Temperature (CCT)

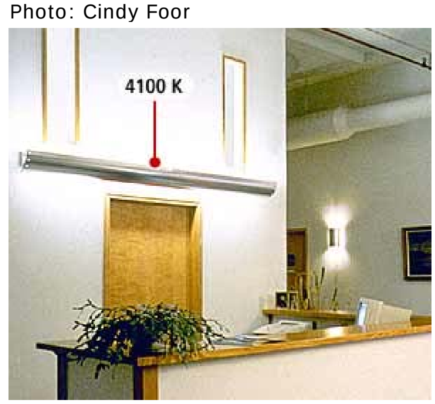
CCT is a specification of the color appearance of the light emitted by a lamp, relating its color to the color of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K). The CCT rating for a lamp is a general "warmth" or "coolness" measure of its appearance. However, contrary to the temperature scale, lamps with a CCT rating below 3200 K are usually considered "warm" sources, while those with a CCT above 4000 K are usually considered "cool" in appearance.

The correlated color temperature (CCT) designation for a light source gives a good indication of the lamp's general appearance, but does not give information of the specific spectral composition of the lamp or radiant power emitted by a light source at each wavelength or band of wavelengths in the visible region of the electromagnetic spectrum" (IESNA *Lighting Handbook*, 2000). Therefore, two lamps may appear to be the same color, but their effects on object colors can be quite different.

Photo: Randall Perry

The lamps shown in this room are "warm" in appearance. In the U.S. lower CCTs are usually used in settings that promote relaxation.

Photo: Cindy Foor



The lamps in this office are "cool" in appearance. In the U.S. higher CCTs are usually used in working settings.

Examples of the CCT of some common light sources are:

Source	CCT Range
Tungsten Halogen	3000 K – 3200 K
	3000 K – 6500 K
Metal Halide	2900 K – 5200 K
	2700 K – 5000 K

Data taken from OSRAM/SYLVANIA and Philips Lamp Catalog

F. Color Rendering Index (CRI)

Light sources differ in their ability to render the color of objects "correctly." CRI expresses the color rendering capability of a lamp on a scale of 0 to 100.

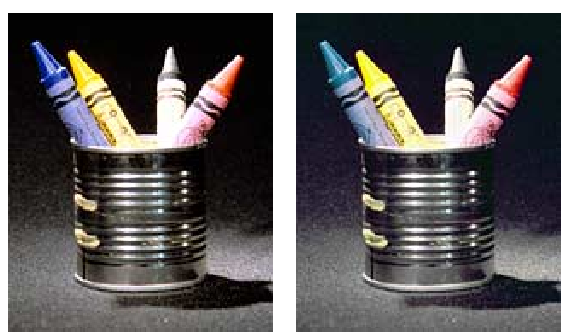
Photo: Javier Ten

CRI=90 **CRI=70** **CRI=50**

CRI is a general indicator of how "natural" object colors will appear when illuminated by a particular light source. Generally, a CRI of 70 and above will be required for most lighting applications.

CRI does not give particular insight into the effect of the appearance on any one color. In this case, the two light sources illuminating the object have a CRI of 70, however the light source on the right renders blue more naturally than the one on the left.

Photo: Javier Ten



CRI=70 **CRI=70**

Lighting practitioners should not compare CRIs of lamps with different CCTs because the CRI of a lamp relates to a reference source of similar color temperature. Incandescent lamps are the reference source for lower CCTs and daylight is the reference source for higher CCTs. In other words, manufacturers will assign the CRI of a lamp with a CCT of 3000 K after comparing its rendering ability to that of an incandescent lamp. Conversely, the CRI of lamp with a CCT of 4100 K will be rated against daylight's rendering abilities.

The following are typical CRI values for commonly used light sources.

Light Source	CRI
Incandescent	100
	75 - 85
Cool White Linear Fluorescent	62
	82
Standard Metal Halide	65
	22
Daylight	100

G. Efficacy

Efficacy for light sources and lighting systems is expressed in lumens per watt. For fluorescent and high intensity discharge (HID) sources, the associated ballast wattage should be included in determining the system efficacy, as should any reduction in lumen output associated with the lamp-ballast combination.

Lamp efficacy is calculated by dividing lamp lumens by lamp watts.

Example:

The efficacy of a100-W A19 incandescent lamp that produces 1740 lumens is 17.4 lm/watt.

1740 lm ÷ 100 W = 17.4 lm/watt

System efficacy (for ballasted sources) is derived by multiplying rated lamp lumens by the ballast factor (BF) and dividing the result by total input watts. BF is the measured ability of a particular ballast to produce light from the lamp(s) it powers.

Example:

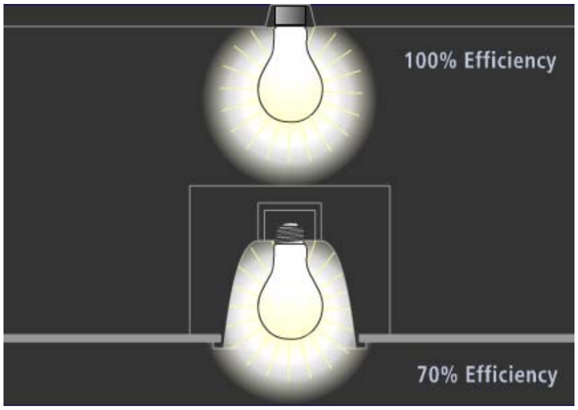
F32T8 lamps produce 2850 lm each on a 2-lamp electronic ballast. The ballast has a ballast factor (BF) of 0.95, with total input power of 62 W.

(2850 lumens x 2 lamps x 0.95 BF) ÷ 62 W = 87.3 lm/watt

H. Luminous Efficiency

Luminous efficiency expresses the percentage of initial lamp lumens that are ultimately emitted by the light fixture. The efficiency of a light fixture does not necessarily indicate its effectiveness in delivering lumens to the work plane, or its appropriateness for the application.

A 100-watt lamp in a porcelain socket has a luminous efficiency of 100%, since no lamp lumens are trapped in the light fixture. A deeply recessed downlight with black baffle with the same 100-watt lamp may have an efficiency of 70%. Depending upon the application, the less efficient light fixture may be the more appropriate choice of the two because of reduced glare potential.



I. Glare

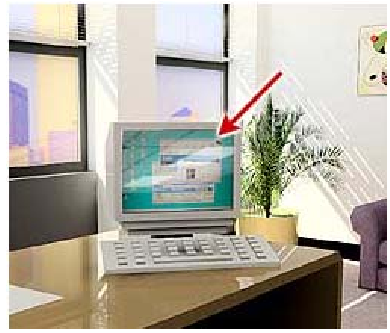
The IESNA defines glare as the sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted (IESNA *Lighting Handbook*, 2000). This causes annoyance, discomfort, or loss in visual performance and visibility. The magnitude of the sensation of glare depends upon such factors as the size of the glare source, relative position of the light and the viewer, the luminance of a source, the number of sources, and the luminance to which the eyes are adapted.

To describe the four most common types of glare effectively, it is useful to categorize them by origin: direct glare and indirect (reflected) glare, and by its effect on people: disability glare and discomfort glare.

- Bright areas, such as light fixtures, ceilings and windows that are directly in the field of view, cause direct glare. Indirect glare is caused by light that is reflected to the eye from surfaces that are in the field of view - often in the task area.

Photos: Feng Zhou

Direct glare from windows and luminaires



Reflected glare on the computer screen from ceiling luminaires

- Disability glare reduces visual performance and visibility. Discomfort glare produces physical discomfort. It is possible to experience disability without discomfort, and conversely, discomfort without disability; however, one often accompanies the other.

J. Illuminance

Illuminance is calculated as the number of lumens (lm) per unit area. The two common units used to measure illuminance are: ***footcandles (fc) = lm/ft²*** and ***lux (lx) = lm/m²***.

For conversion purposes:

- 1 fc = 10.76 lx
- 1 lx = .0929 fc

The IESNA recommends illuminance values for a variety of lighting applications. These recommendations are categorized according to the level of complexity of the visual task being performed. Visual tasks can range from simple, where visual performance is not as important (walking through a corridor), to very specialized, where visual performance is of critical importance (assembling small pieces of machinery).

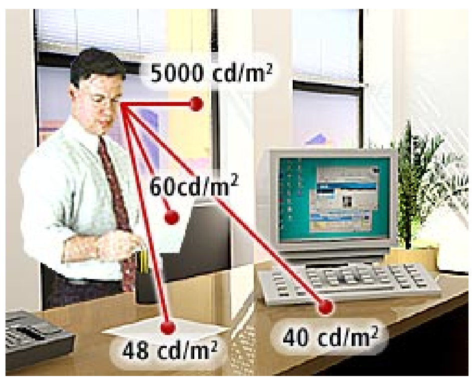
K. Luminance

Luminance is the photometric quantity most closely associated with one's perception of brightness. It usually refers to the amount of light that reaches the eye of the observer measured in units of luminous intensity (candelas) per unit area (m^2).

"Imagine a lampshade glowing in a living room. It has brightness. It also has a luminous intensity of a given number of candelas in a given direction. If the candlepower in a certain direction from one square meter of surface is 300 candelas, the luminance is said to be 300 candelas per square meter" (ED-100 IES Education Series, 1985).

When evaluating conditions with excessive high or low contrast, luminance should be considered, rather than illuminance. Luminance meters and luminance imaging photometer systems are available, which provide for the evaluation of the visual environment in units of luminous intensity per unit area (cd/m^2).

Photo: Feng Zhou



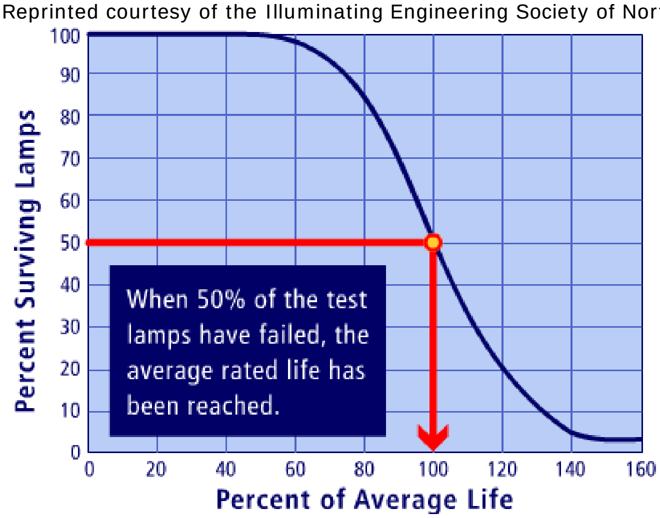
All surfaces have luminances.
Luminance in this case depends on
the surface's reflectance.

L. Lamp Life

Average rated life (of a light source) is usually the number of hours when 50% of a large group of lamps have failed. For incandescent lamps, the number of hours per start does not significantly affect the average rated life. For discharge sources such as fluorescent and high intensity discharge (HID), fewer hours per start (more switching) decreases lamp operating life; more hours per start increases it. The following operating hours per start are assumed in most published life ratings:

- Fluorescent - 3 hours per start
- HID - 11 hours per start

Adapted from IESNA *Lighting Handbook*
Reprinted courtesy of the Illuminating Engineering Society of North America



The actual life of any electric lamp is a median value of life expectancy. The actual life of any individual lamp, or group of lamps, may vary from the published average rated life. Listed below are a few typical average rated life ratings for some common light sources:

Common Light Source Average	Rated Life Rating*
54-W, 4 ft T5 HO fluorescent	20,000
	24,000
60-W A19, incandescent	1,000
	12,000
28-W 4 ft T5 fluorescent	20,000
	20,000
400-W metal halide, uncoated	10,000

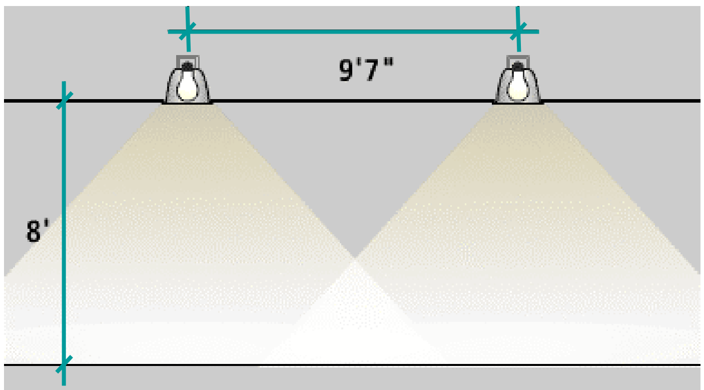
Data taken from OSRAM/SYLVANIA and Philips Lamp Catalogs

M. Spacing Criteria

Luminaire manufacturers provide spacing criteria (SC) or mounting height ratios (S/MH), for specific light fixtures with direct lighting distribution. These light fixtures include downlights, troffers, and high and low-bay light fixtures. These ratios are used to calculate the maximum recommended installation spacing to obtain an even pattern of light on the surface below the light fixtures. SC ratios help ensure that a space is evenly lighted by slightly overlapping the light distribution from each light fixture. SC typically range from 0.9 to 1.7, but can be as low as 0.5 or higher than 2.

SC x Mounting Height = recommended spacing for "even" pattern of light

Example for recessed downlights:
If a manufacturer's SC = 1.2, and recessed downlights are mounted in an 8 ft. ceiling, the recommended maximum spacing between downlights will be 1.2 x 8.0 ft.= 9.6 ft. (9 ft. 7 in.)



SECTION III
EFFECTIVE, ENERGY-EFFICIENT LIGHTING

An effective, energy-efficient installation is one that considers the *needs of people using the space*. Factors to be considered include visibility, visual comfort, and safety. Such an installation also addresses the *architectural characteristics of the space*, such as form, composition, and style. The design also is responsive to *economic and environmental concerns* such as maintenance and energy use and costs. The lighting practitioner should always try to keep these three building blocks in mind when planning a lighting design solution.

The IESNA, in collaboration with lighting designers and specifiers, has developed lighting design criteria for assessing and developing effective lighting environments. The criteria consist of sixteen design issues related to aesthetics, lighting equipment performance, and comfort and safety. All are intended to increase the quality of the visual environment. Depending on the nature of the lighting project, some design issues may be more applicable than others. Therefore it is important that the lighting practitioner is familiar with them. For more information, refer to the IESNA *Lighting Handbook*. This technical guide discusses in detail nine out of the sixteen design issues because they best relate with the SCLP objectives. These are:

- A) appearance of space and light fixtures,
- B) color appearance,
- C) direct glare,
- D) reflective glare,
- E) horizontal and vertical illuminance,
- F) light distribution on surfaces
- G) points of interest,
- H) luminance of room surfaces,
- I) system control and flexibility

These nine design issues along with the compliance with the SCLP's minimum criteria explained in Section IV will help the program participants obtain effective, energy-efficient lighting.

Each of the nine design issues are discussed below.

A. *Appearance of Space and Light Fixtures*

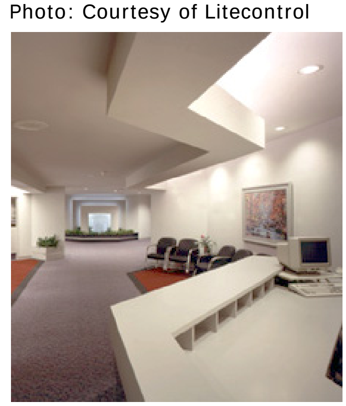
The lighting practitioner should always try to coordinate the appearance of the space and the light fixtures to create a pleasant environment that fits the image sought by the client, complements the architectural features, and is comfortable to the people occupying the space. The proper placement of light fixtures with respect to the location of the furniture can enhance the aesthetics of the space, as well as provide visual information such as boundaries and circulation patterns. This information can help occupants to find their way around the space.

Compare the spaces on the following page. In the space on the left, the lighting fixtures were installed without regard to the manufacturer's spacing criteria. This left shadows in the space and on the walls. Once the lighting was redesigned with appropriate spacing of the lighting fixtures, the room appears bright and evenly lighted, as shown in the illustration on the right.

Photos: Randall Perry

The client may want to create an image that reflects a particular type of business or a style such as casual, corporate, or contemporary. To accomplish this, the lighting practitioner should select light fixtures that match the style of the furniture and décor.

Photo: Courtesy of Litecontrol



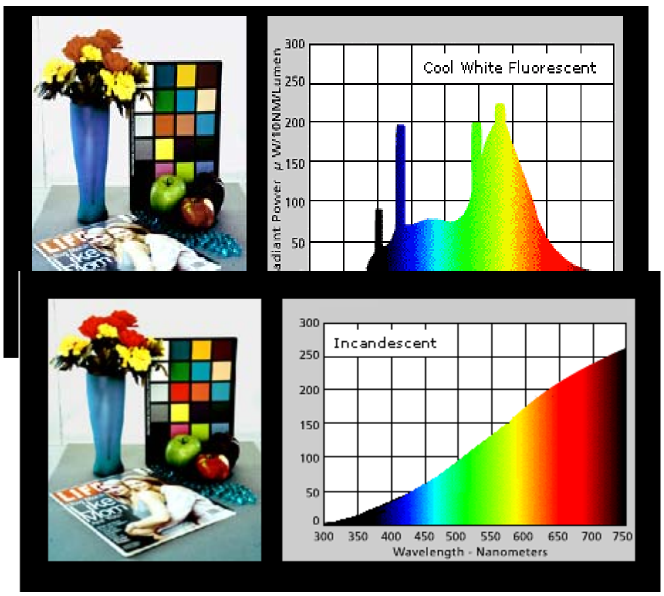
In the photo to the right, the lighting designer has used fluorescent lighting recessed into a cove in the ceiling that follows the lines of the architecture and built-in furniture. This creates a clean, modern appearance to the space.

B. Color Appearance

The color appearance of the space affects both visibility and aesthetics. Color appearance is not just a function of the colors used in the space such as on walls and furnishings. Also affecting color appearance are:

- <u>The spectral composition of the light source</u>, which may enhance or alter the perception of particular colors within the space. The spectral make-up of a light source affects its ability to render colors "naturally", as seen in the following examples:

Photos: Lighting Research Center Resource Collection



This particular fluorescent lamp has more power in the short wavelength of the visible spectrum (below 450 nanometers) than the incandescent lamp shown on the next page ; therefore blue colors appear more vivid.

The incandescent light source depicted has more power in the longer wavelengths (above 650 nanometers) of the visible spectrum; therefore red colors appear more vivid.

Combining wavelengths in different amounts can produce light that appears white to the eye. It is possible that the light from two lamps can have different wavelength combinations and yet appear exactly the same color (same nominal CCT) but their effects on objects may be very different.

- <u>The perception abilities of people.</u> The lighting practitioner may not know the perception abilities of the people occupying the space (how well people can distinguish among different colors), but he or she can specify lighting that complements the colors used in the space. The lighting practitioner can also anticipate how the lighting will behave depending on the type of materials and surfaces used. The lighting practitioner will have to gather this type of information prior to specifying the lighting, as discussed in Section IV-A.

- <u>The inherent properties of objects and surfaces.</u> One of those properties is reflectance, which expresses the percentage of light that is reflected back from a surface, the difference having been absorbed or transmitted by the surface. Some typical reflectance values for room surfaces are:

Room Surface	**Reflectance Value**
white acoustic-tiled ceilings	70 to 80%
-	40 to 60%
Darker-colored walls	20 to 30%
carpeting	15 to 30%

C. Direct Glare

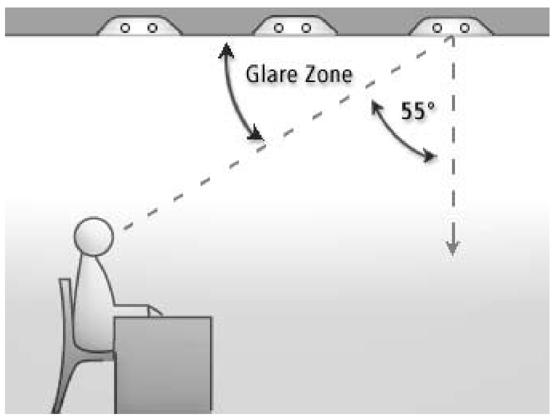
Glare can reduce visibility and create discomfort. Light fixtures, windows, and skylights are usually the sources of glare in interior applications. Studies have shown that people will better tolerate the brightness of windows than of light fixtures because they tend to value some of the benefits windows provide such as a view to the outside. Nevertheless, lighting practitioners should recommend the use of window blinds or perforated screens to limit the amount of direct sunlight coming into the space.

Photo: Cindy Foor

The perforated screens used on the windows of this office preserve the view to the outside while reducing the amount of direct sunlight into the space.

Glare from light fixtures is most likely to occur in the glare zone (between 55° and 90° from vertical) as seen in the figure below. One way to control glare is to limit the luminous intensity from the lamp or light fixture at those angles. SCLP has established maximum criteria with respect to luminous intensity at 55°and 65° based on different applications. See Section I-C(c) for a detailed discussion.

Adapted from IESNA *Lighting Handbook*
Reprinted Courtesy of the Illuminating Engineering Society of North America



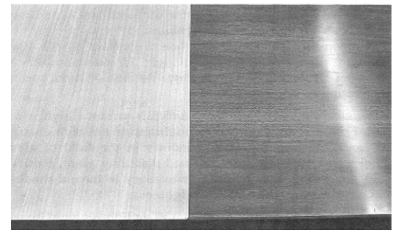
Another way to minimize glare is by limiting light fixture luminance. See Section II-K for a definition of luminance. The IESNA recommends that the luminance of the lighting system should not be more than 100 times that of surrounding surfaces. To achieve this, the lighting practitioner should specify light fixtures that illuminate the ceiling and the task, and increase the reflectance of the ceiling as shown in the following example.

Photos: Courtesy of Litecontrol

These suspended luminaires provide soft, diffuse lighting by distributing the light upward to the ceiling, which reflects it back to the space, thus limiting glare.

D. Reflected Glare

Reprinted Courtesy of the Illuminating Engineering Society of North America



Reflected glare occurs when bright reflections from polished of glossy surfaces reduce visibility or create discomfort, as is shown in the photograph to the right.

Lighting practitioners may not have control over the types of surfaces used in a space. However, it is possible to reduce reflected glare by providing illumination sideways to the task, as shown in the figure on the following page. Reflected glare on computer screens can be mitigated by using diffuse reflecting screens, which are increasingly popular. It can also be controlled by setting the properties of the screen so there is color contrast between the text and background (for example, dark text on a bright background).

Adapted from IESNA *Lighting Handbook*
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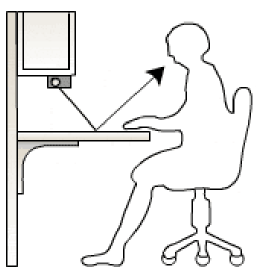
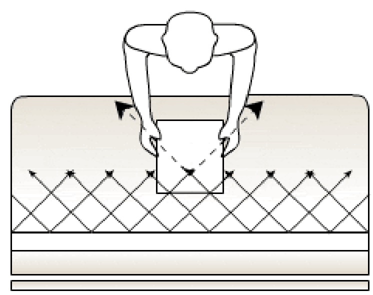


Task lights that do not redirect the light away from a person's view can cause veiling reflections and/or reflected glare.



With an appropriate lens, light from task lights is redirected to help eliminate veiling reflections and/or reflected glare.

E. Horizontal and Vertical Illuminance

Traditionally, illuminance has been considered to be the most important criterion used to evaluate the lighting in a space. Although we have emphasized in this section other important criteria that must be considered when designing a lighting solution, failing to meet target illuminances can seriously compromise the comfort and safety of the people occupying a space.

Illuminance is usually thought of as the amount of light-per-unit area arriving to a horizontal surface such as a desk or the floor. For applications such as retail, vertical illuminance—that is, light arriving to a vertical surface—is far more important for merchandize placed on racks and mannequins. The lighting practitioner must ensure the use of light fixtures that deliver light accordingly as shown in the figure below.

Courtesy of OSRAM SYLVANIA

Semi-recessed accent lights are used in retail to focus light on merchandise. These can be repositioned as displays change.

SCLP has established target illuminance values for different applications. See Section IV-D for a complete list. In the case of horizontal illuminance, the plane on which the illuminance is specified for interior and industrial locations is assumed to be at 30 inches (0.76 m) above the floor, typically where a task is being carried out. In spaces such as corridors or hallways, the plane on which the illuminance is specified is the floor.

F. Light Distribution on Surfaces

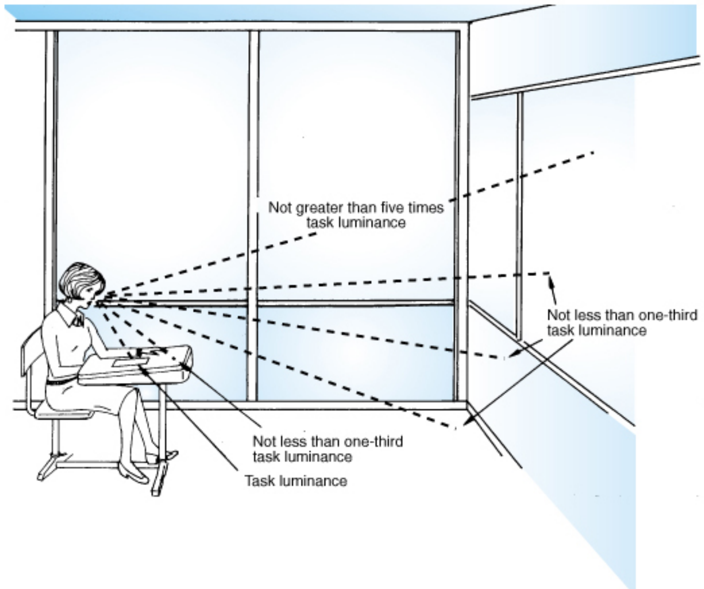
Photo: Russ

Downlights can cast confusing patterns on floors if spaced too far apart from each other or used improperly.

Visibility and comfort are compromised when light fixtures are placed too far apart, creating non-uniform patterns of light and dark on the floor and walls, or when objects cast disturbing shadows over visual tasks. Manufacturers provide spacing recommendations to ensure that harsh patterns of excessive brightness/darkness are eliminated. SCLP requires that all light fixtures comply with manufacturers' recommended spacing criteria. These are found in photometric reports and specification sheets provided by the manufacturers. See Section IV-E(c) for more details.

To achieve more even light distribution on surfaces, the IESNA recommends specific luminance ratios. The luminance of a visual target and its surroundings should not exceed a ratio of 3:1. The luminance of a ceiling and the adjacent wall should not exceed a ratio of 5:1. See the classroom example below.

Reprinted Courtesy of the Illuminating Engineering Society of North America



Note that spaces with totally uniform brightness will lack visual interest. To add visual interest without introducing visual distractions, a good rule of thumb is to match illuminance patterns with architectural features such as the regular pattern of sconces. This leads us to the next design issue, points of interest.

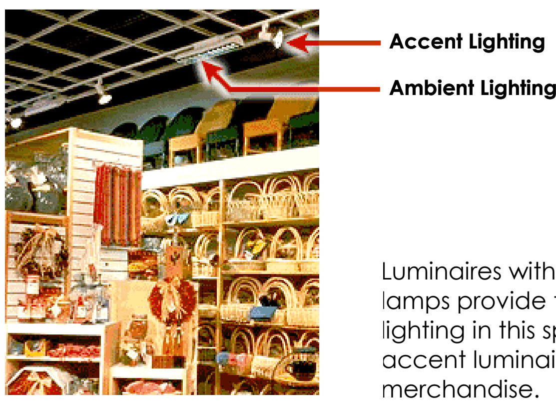
G. Points of Interest

The IESNA defines a point of interest as the object or area to which attention is drawn, using movement, brightness differences, and/or color contrast. In the example below, interest is created through the use of single pendants, which highlight the round tables and create a soft glow on the floor.

Photo: Robert Kerr

A pendant lighting fixture is used over the table to draw attention to the seating area.

Usually, points of interest are created with accent lighting. Accent lighting used alone can create a very dramatic effect, as in museums or retail settings. It is important to provide enough ambient lighting for people to move about the space. Accent lighting is generally used as a highlighting feature, complementing other lighting systems in the same space. A common error, particularly in retail settings, is to use accent lighting only and highlight everything. This results in a very energy-inefficient lighting system, especially when incandescent lamps are the primary light source. It is better to use more efficient light sources, like fluorescent lamps, for ambient lighting, and limit accent lights to highlighting only the most important features of a room. Although, lighting power allowances for accent lighting is less restrictive than for ambient lighting, lighting practitioners still need to consider the overall amount of energy that the installed lighting system will use.



Luminaires with fluorescent lamps provide the ambient lighting in this space, while the accent luminaires highlight the merchandise.

H. Luminance of Room Surfaces

The luminance of surfaces can affect the perception of brightness in a space. Consider the examples below. The two spaces are almost exactly the same in terms of furniture arrangement and décor. Both have exactly the same lighting system, which delivers the same amount a light to the desks. The space on the left, however, looks brighter than the space on the right. The only difference is the color of the overhead bins.

Photos: Robert J. Eovaldi

Color, illuminance, and reflectance (the amount of light that a surface reflects back) affect luminance. The IESNA recommends the use of matte surfaces of high reflectance (for example, white-painted walls and light-colored furniture finishes) as effective materials for increasing room surface luminances.

Light fixtures such as wall washers and indirect/direct light fixtures that light the walls and ceiling are also useful for increasing room surface luminances. SCLP requires that wall washers be placed no more than three feet from walls. If wall washers are not available, ambient lighting light fixtures can also light the walls if they are placed close to the wall. SCLP requires the distance between walls and adjacent light fixtures to be placed no more than one-half the light fixture spacing criteria. See Section II-M for information on spacing criteria. The IESNA also recommends using lenses, reflectors, or louvers to soften the pattern of light and distribute more light to the top of walls.

Photo: Cindy Foor

Recessed wall washers provide brightness to the wall in this small private office.

Photo: Cindy Foor

The recessed troffers in this office close to the walls illuminate the walls which makes the space appear brighter and more open.

Light fixtures that deliver direct and diffuse light to the occupant and the task usually increase comfort and satisfaction because they reduce distracting shadows, reduce overhead glare, and improve facial modeling.

Suspended luminaires in this classroom illuminate the ceiling but also provide lighting to the work plane.

Photo: Lighting Research Center

Downlights tend to create sharp facial shadows. To avoid such shadows it may be necessary to use a combination of downlights and luminaires that distribute light laterally.

I. System Control and Flexibility

Spaces such as conference rooms and auditoriums house a variety of visual tasks, including meetings and multimedia presentations. To accommodate these tasks, the lighting system must have the capability of providing different lighting scenes and different light levels, as seen in the examples below. The lighting system should be flexible enough to control the lighting separately to light the walls, the work plane, and also provide points of interest. Switching and/or dimming can be used to accomplish this.

Photos: Randall Perry

The lighting in this multimedia auditorium provides flexibility to support activities such as lectures where people take notes (left) and multimedia presentations (right).

Flexibility should not be a consideration only for conference rooms and auditoriums. Studies have shown that satisfaction increases when office workers have some control over the lighting in their space. This control can be through the use of task lighting. Classrooms can also benefit from lighting control and flexibility. In the examples below, general ambient lighting is used for regular classes, while accent lighting is used for art classes to enhance textures and tri-dimensionality.

Photos: Randall Perry

This art classroom has two lighting systems controlled separately. The ambient lighting is used for classes such as painting, and the accent lighting is used for sculpture classes.

SECTION IV
DEVELOPING AN EFFECTIVE, ENERGY-EFFICIENT INSTALLATION

When facing the task of lighting a space, lighting practitioners usually tend to narrow in very quickly on the type of equipment needed to accomplish the job. However, important issues must be considered before selecting lighting fixtures. These include the client's needs and tasks to be performed in the space, the amount of light needed to perform those tasks, the way the space will look (including both practical and aesthetic considerations), and compliance with energy codes and standards. The IESNA's *Lighting Handbook* and many other lighting references offer different systems, usually referred to as a 'Design Process', to walk lighting practitioners through the process of creating a lighting design. The following is a summary of the most important steps to developing an effective, energy-efficient lighting installation:

A. Analyzing the project
B. Establishing goals
C. Formulating a design concept
D. Establishing illuminance and power density targets
E. Selecting lighting equipment
F. Installing the lighting equipment
G. Commissioning the lighting system after installation

A. Analyzing the Project

The first step to take when approaching a potential lighting project, whether it is part of a renovation or in new construction, is to analyze the project to understand the needs to be fulfilled by the lighting system. This phase in the process is particularly important because the information gathered now will help to inform the rest of the project. Use the following checklist of questions as a guide to help walk through this project stage:

1. ***What does your client wish to achieve from the lighting renovation or new construction project?***
   Most clients will not be able to answer this question directly. You will often have to ask a series of guiding questions to help them to express their ideas about the lighting. Some of the questions you may want to ask your client are:

- ***Why do you want to install a new lighting system?***
  You need to understand your client's motivation for undertaking the lighting project. If this is a renovation project, ask your client what they did or did not like about the previous lighting system, or what they like or dislike about lighting systems in other buildings they are familiar with. Carefully note each of their preferences. You may need to ask further questions, such as:

  - ***Is easy maintenance of the lighting system important to you?***
    - Clients will often want lighting systems that will allow them to replace lamps less often, or are easier to clean. These are two benefits of newer, more-efficient lighting systems.
  - ***Is reducing the energy used by your lighting system important to you?***
    - Clients don't often realize how much energy their lighting system is using. It is often helpful to point out that a new lighting system can reduce their lighting energy use by 30% or more.
  - ***Do you feel you need more light or less light in any areas of your facility?***
    - Clients will often identify that either there was not enough light in certain areas of a space, or that the lighting fixtures were too bright in some areas. Note each of these comments and see what types of lighting fixtures are currently installed.
    - If your client indicates that there is not enough light, perhaps the lighting fixtures were spaced too far apart or the system was not properly selected. If your client indicates that the fixtures in some areas were glary, perhaps an inappropriate lighting fixture was selected for the space. You can address these issues by selecting and installing a new lighting system using the guides established for the SCLP.

- ***What first impression do you want to make on visitors to the space?***
  This is an important question to ask because many clients will not realize how much the selection of a lighting system will affect a visitor's impression of a space.
  - If a client indicates they would like a "high-tech," "modern," or "new" look for their space, a suspended linear fluorescent or other "direct-indirect" lighting system might be appropriate. The lighting should fit the style of the space.
  - If a client indicates that they would like a "high-end" or "rich" look to a space, you may want to include some decorative lighting fixtures hanging below the ceiling or wall sconces to the lighting plan. You may

also want to choose accent lighting to highlight architectural elements or art work in the space.

- If a client wants the space to appear "bright" or "spacious" you may want to use lighting fixtures that will light the walls of the space (wall-wash fixtures), in addition to the other lighting fixtures, to give the space a brighter appearance.

2. ***What are your client's requirements for the lighting system?***

   You should ask your client what the lighting system must do. While the answer would seem simple, "light the space," there are several considerations that will affect how you design the lighting installation. Some specific questions you may want to ask include:

   - ***What tasks or activities will be performed in the space?***

     Different tasks will often require different types of lighting systems. For example:

     - ***Will computers be used in the space?***

       Computers are now commonly found in offices, schools, healthcare facilities, and many other settings. If a number of computers are going to be used in a space for long periods of time throughout the day, you will want to consider selecting fixtures that meet the strictest luminous intensity or glare metric requirements for the SCLP.
     - ***Will there be tasks carried out in the space that will be difficult to see?***

       In many spaces, especially in manufacturing facilities, there might be tasks which may include working on complex machinery, working on objects of very small size, or reading very small print, that will require more light than usually recommended for the type of space. Therefore, you will want to select task lighting (rather than increase ambient lighting) for the areas where this additional light will be needed.

   - ***What atmosphere should the lighting create in the space?***

     Lighting in offices should be evenly distributed throughout the space. Lighting for an expensive restaurant should not be evenly distributed; it should have some light on tables, for example, and very little light in other areas. Lighting in the lobby of a hotel where you want people to sit and relax should not be as bright as other areas such as the reception desk where staff will be working and greeting guests.

     Lighting also can be used to create a feeling for a space, for example:

     - Evenly distributed lighting at levels found in offices and classrooms give a space a bright, spacious, appearance where people know they have come to work.

- Lighting that is not evenly distributed like that found in intimate restaurants, lounges, and hotel lobbies gives the space a relaxing feeling.

B. *Establishing Goals*

Once you have completed the analysis of your lighting project, it is important to establish goals for the lighting installation. These goals will help you to communicate what the lighting installation will do for your client. The goals should be based on the information you have gathered in the first step of this process, and should reflect your client's needs and desires for the lighting system. The goals should be simply worded, clearly stated, and should be measurable in some way. A simple way to phrase goals is to begin with statement ***The lighting system will…***

In most cases, specific goals should be included for each of the following areas:

The space or spaces you are lighting

- How the space and lighting will look:
  - *Example goal*: "The lighting system will provide a bright, clean appearance for the space."
  - *Example goal:* "The lighting system will be well integrated with the other architectural elements in the space."

The people who will work in or visit the space

- What the lighting will help people to do:
  - *Example goal:* "The new lighting system will improve visual comfort (reduce glare) for occupants and visitors to the space."
  - *Example goal:* "The lighting system will provide enough light for people to comfortably work in the space."

Energy use and maintenance

- How much energy, time, and/or money the new lighting system will save over and existing system:
  - *Example goal:* "The new lighting system will reduce the energy used by the existing system by ___%."
  - *Example goal:* "The lighting system will reduce maintenance costs by ___%."

The behavior of people in the space:

- Where people are going to look (focal areas):
  - *Example goal:* "The lighting system (for a retail store) will draw shoppers' attention to the merchandise."
- How people move (circulation):
  - *Example goal:* "The lighting system (for a hotel lobby) will help direct visitors to the reception desk."

C. Formulating a Design Concept

In its simplest form, the design concept should communicate to your client how the lighting system you are going to install will achieve the goals you have outlined. Many lighting designers will use an illustration, drawing, or computer rendering to convey the design concept, but this is not required.

For example, if one of the goals you have stated is:

"The lighting system will provide a bright, clean appearance for the space."
Your design concept statement should include information on how you are going to achieve this goal.

- "An indirect lighting system will be used to light the ceiling and upper walls so that the space appears bright."

As another example, if one of the goals you selected is:

"The lighting system (for a hotel lobby) for will help direct visitors to the reception desk."
Your design concept statement might include one of the following:

- "Decorative pendant lighting fixtures are going to be hung over the reception desk to draw visitors attention," or
- "Light levels over the reception desk will be designed to be at least three times brighter than the general, ambient lighting to draw visitors' attention."

In many cases your design concept will include three types of lighting:

- ***Ambient lighting –*** this is the general lighting for the space, usually provided with lighting fixtures mounted on, into, or near the ceiling. This provides the lighting people need to move around the space.
- ***Accent lighting –*** This is lighting that makes the space more interesting, or is used to direct people's attention to areas of interest. This includes decorative lighting fixtures, wall sconces, and directional lighting, such as track lighting, that can be aimed at feature items in a space.

- ***Task lighting –*** This is lighting provided in a particular area of a space where people will be performing a certain task. For example, desk lighting in offices, or lighting over a check-out counter in retail store.

You might not include all three of these lighting types in every lighting design that you develop. However, you should consider if each is needed when developing your design concept.

D. Establishing Illuminance and Power Density Targets

After you have completed your design concept, you will need to select light level (illuminance) and lighting power allowance targets for each of the spaces in which you will be installing a lighting system. These are typically found in design guides, energy codes, or lighting handbooks. SCLP has established both the target illuminances and the lighting target power allowances (see table, page 38). Target illuminances are based on the recommendations of the IESNA. These have been determined based on many years of research into the visual requirements typical tasks that occur in each of the spaces listed. SCLP lighting power allowances are set 10% more restrictive than the requirements of the Energy Conservation Construction Code of New York State. This is to encourage the installation of the most efficient lighting systems available.

Space Type	Lighting Power Allowance (LPA) W / Sq. Ft.		Light Level Target (Foot Candles)
	SCLP Allowance	Other Lighting	
Auditorium	1.4		10
Banking Activity Area	1.8	A	50
Break Room (Dining)	1.3		30
Classroom / Lecture Hall / Training room	1.4		30
Closet	0.9		N/A
Conference / Meeting Room	1.4	A	30
Convention Hall Multipurpose Area	1.4	A	30
Corridor	0.7		5
Dining	1.3	A	10
Electrical / Mechanical Area	0.9		N/A
Examination Room (Medical)	1.4	D	50
Exercise Area	1.0	A	50
Exhibition Hall	3.0		10
Financial Institution	1.8	A	30
Food Preparation (Kitchen area)	2.0		50
Grocery Store General Merchandise Area	1.9	C	50
Gymnasium Playing Area	1.7		100
Hotel Function Area	2.2	A	30
Hotel Lobby	1.7	A	10
Industrial Area < 20ft. ceiling height	1.9		30
Industrial Area > 20ft. ceiling height	2.7		30
Kitchen / Food Preparation	2.0		50
Laboratory Medical	1.4	D	50
Laboratory - Industrial	1.9		50
Library	1.6	A	30
Lobby - Hotel	1.7	A	10
Lobby - Waiting Area (Other Buildings)	0.9	A	10
Mall General Sales Area (see Retail Sales)			
Mall Arcade / Atrium / Concourse	1.3		30
Manufacturing (Industrial) Area < 20ft. ceiling height	1.9		50
Manufacturing (Industrial) Area > 20ft. ceiling height	2.7		50
Medical and Clinical Care	1.4	D	50
Multipurpose Room (Meeting Room)	1.4	A	30
Museum	1.4		10
Nurses Stations (Medical)	1.4	D	30
Office, Private (< 300 sq. ft.)	1.4		50
Office, Open Plan (> 300 sq. ft.)	1.4		30
Reception Area (Lobby)	0.9	A	30
Religious Worship	2.9	A	10
Restaurant	1.5	A	30
Restroom	0.7		10
Retail Sales Fine Merchandise Area	1.9	C1	30
Retail Sales General Merchandise Area and Wholesale Showroom	1.9	C	30
Shipping (Industrial) Area < 20ft. ceiling height	1.9		30
Shipping (Industrial) Area > 20ft. ceiling height	2.7		30
Stairs (Support Area)	0.7		5
Storage - Industrial, Commercial	0.9		10
Theater - Motion Picture	0.9		10
Theater - Motion Picture, Lobby	0.9	A	30
Theater - Performance	1.4		10
Warehouse Area < 20ft. ceiling height	1.9		10
Warehouse Area > 20ft. ceiling height	2.7		10

Please visit www.nyserda.org/sclp for the most current list.

"Other Lighting" Codes:
A: plus 0.9 W/Sq. Ft. for Accent Lighting
C: plus 1.4 W/Sq. Ft. for Accent Lighting
C1: plus 3.5 W/Sq. Ft. for Accent Lighting
D: plus 0.9 W/Sq. Ft. for Medical Lighting

E. *Selecting Lighting Equipment*

Now that you have completed the steps outlined above, you must decide on the type of light sources you will use in the project for: light distribution (diffuse, directional); performance characteristics (lumen output, life, color, wattage); and how light should enter the space (down, up, sideways).

Light fixture selection is typically based on physical appearance, initial cost, or capability to provide target illuminance values alone. Unfortunately, these factors alone do not provide an adequate understanding of how the light fixture will perform, nor the lighting effect it will produce in a space. Before selecting a lighting fixture, you should also consider:

- Light distribution of the light fixture
- Lighting patterns produced by the light fixture in the space
- Efficiency in delivering light to where it is needed
- Amount of light going from the light fixture to the area that needs to be lighted and amount of light going beyond that area
- Glare

The issues above are related to the photometric performance of a light fixture. The IESNA *Lighting Handbook*, defines photometric performance as the "efficiency and effectiveness with which [the light fixture] delivers the light produced by the lamp to the intended target." Photometric performance may be measured either by the manufacturer or by an independent testing laboratory and the results are presented in a photometric report.

Photometry measures the intensity of the light emitted by the lamp(s) in a light fixture. A photometric report is a summary of such measurements and describes "the efficiency and effectiveness with which [a light fixture] delivers the light produced by the lamp to the intended target." (Lighting Handbook, 2000)

The data in a photometric report fall into three broad categories:

- General Information: The general information consists of a title block that includes information such as a description of the light fixture and its components;
- Photometric Data: The photometric data provides data related to the performance of the light fixture such as candela distribution summary table, luminous intensity distribution curve, and light fixture efficiency;
- Application Data: The application data includes coefficient of utilization table and spacing criteria. The application data is designed to aid lighting

professionals in choosing light fixtures for spaces of different sizes and surface characteristics.

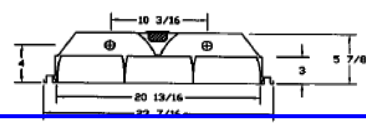
Lighting practitioners participating in SCLP must refer to the photometric data in a photometric report to find out whether the light fixture(s) they are specifying comply with the minimum luminous intensity criteria.

The following section explains how to read three specific sections of a photometric report: the luminous intensity distribution curve, the candela distribution summary table, and spacing criteria. These sections are highlighted in the photometric report sample on the next page.

REPORT NO. 220P148 DATE: 12-15-2000
CATALOG NO. 2EP3GAX-232S36I
LUMINAIRE: 2 X 4 Recessed Convertible Body Luminaire with an 18 cell semi-specular low iridescent parabolic louver.
LAMP: Two - FO32/35K - 2800 Lumens ea. - 32 Watts ea.
BALLAST: Magnetek B232I120RH Electronic - L.O.B.F. = 88.1%
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.
LUMEN TO CANDELA RATIO USED = 9.19
TOTAL INPUT WATTS = 60.0 AT 120.0 VOLTS

CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
0	1491	1491	1491	1491	1491	
5	1480	1491	1512	1527	1537	144
15	1406	1460	1524	1565	1573	424
25	1288	1376	1370	1334	1319	619
35	1124	1209	1088	1108	1154	713
45	917	925	938	1116	1280	788
55	656	656	868	940	950	724
65	274	327	329	283	216	302
75	29	31	27	27	27	33
85	4	4	5	4	5	5
90	0	0	0	0	0	



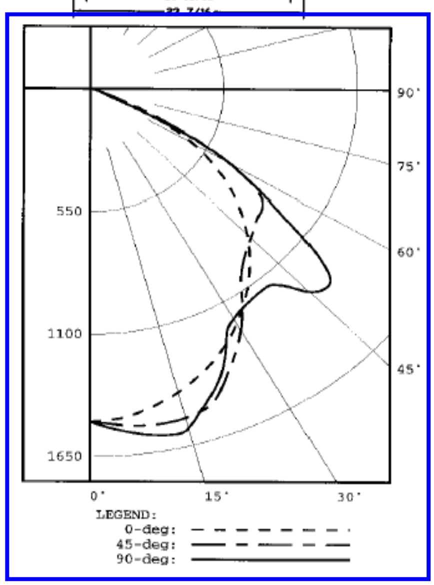
ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 30	1187	21.2	31.6
0- 40	1901	33.9	50.6
0- 60	3413	60.9	90.9
0- 90	3753	67.0	100.0
90-180	0	0.0	0.0
0-180	3753	67.0	100.0

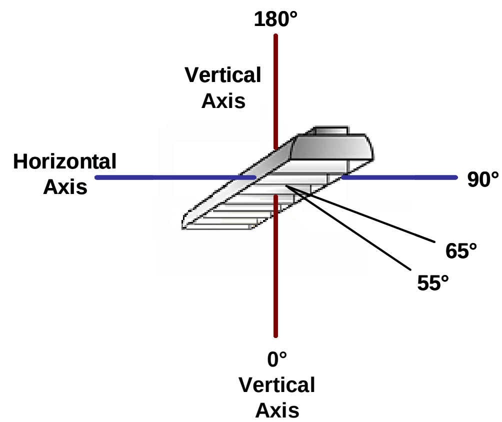
TOTAL LUMINAIRE EFFICIENCY = 67.0 %
TOTAL REFLECTANCE OF PAINT = 86.9 %
LUMINAIRE EFFICACY RATING = FP55
COST OF LIGHTING = 4.36
CIE TYPE - DIRECT
PLANE : 0-DEG 90-DEG
SPACING CRITERIA : 1.2 1.2
PLANE : 0-DEG 90-DEG
LUMINOUS LENGTH :44.938 20.813

LUMINANCE DATA IN CANDELA/ SQ. METER

ANGLE IN DEG	AVERAGE 0.0	AVERAGE 45.0	AVERAGE 90.0
45	2149.	2198.	3000.
55	1895.	2508.	2745.
65	1074.	1290.	847.
75	186.	173.	173.
85	76.	95.	95.



a) ***Luminous Intensity Distribution Curve***



Luminous intensity distribution curves are typically represented in polar plots because this format allows us to visualize both the orientation and the light distribution of the light fixture. The candlepower distribution of a light fixture depends upon reflector design, shielding type, and lamp-ballast selection. It is assumed that the light fixture position is at the crossing of two axes (horizontal and vertical), and that 0° (nadir) is beneath the light fixture. Other angles, which represent the various placements of a photocell as it moves in a circular pattern around the light fixture, are marked on the graph as well.

If the distribution of light is not symmetrical in all directions around the vertical axis, such as for a 2ft. x 4ft. light fixture, candlepower values may be taken in a number of vertical planes through the light fixture (figure A). The planes shown in photometric reports are 0°, 22.5°, 45°, 67.5°, and 90°. The planes most commonly used in lighting practice are 0° or parallel to the lamp axes, 90° or perpendicular to the lamp axes, and at an angle 45° to the lamp axes (figure B).

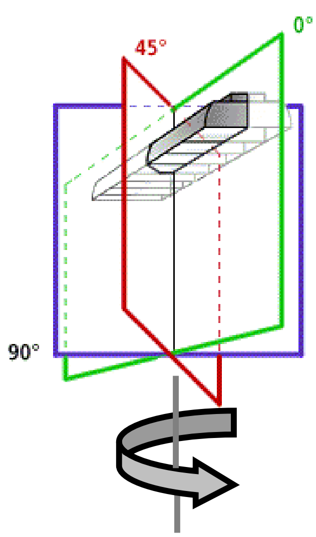


Figure A

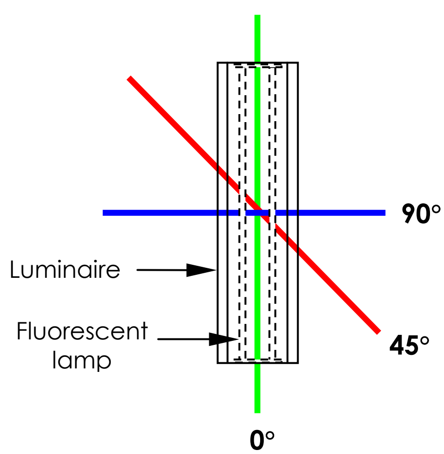
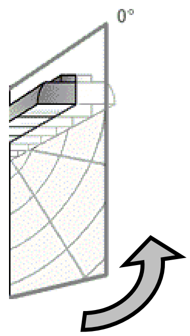
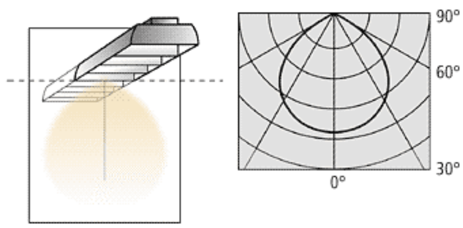


Figure B

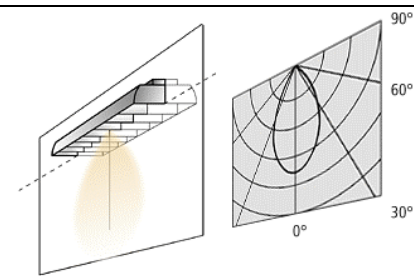
A vertical candlepower distribution curve is obtained by taking measurements at various angles of elevation in a vertical plane through the light center. Unless the plane is specified, the vertical curve is assumed to represent an average such as would be obtained by rotating the lamp or light fixture about its vertical axis.



Candlepower curves can then be plotted for the plane of choice (see figure below). Each lamp and lamp-light fixture combination has a unique set of candlepower distributions. The candlepower distribution of a light fixture depends upon reflector design, shielding type, and lamp-ballast selection.

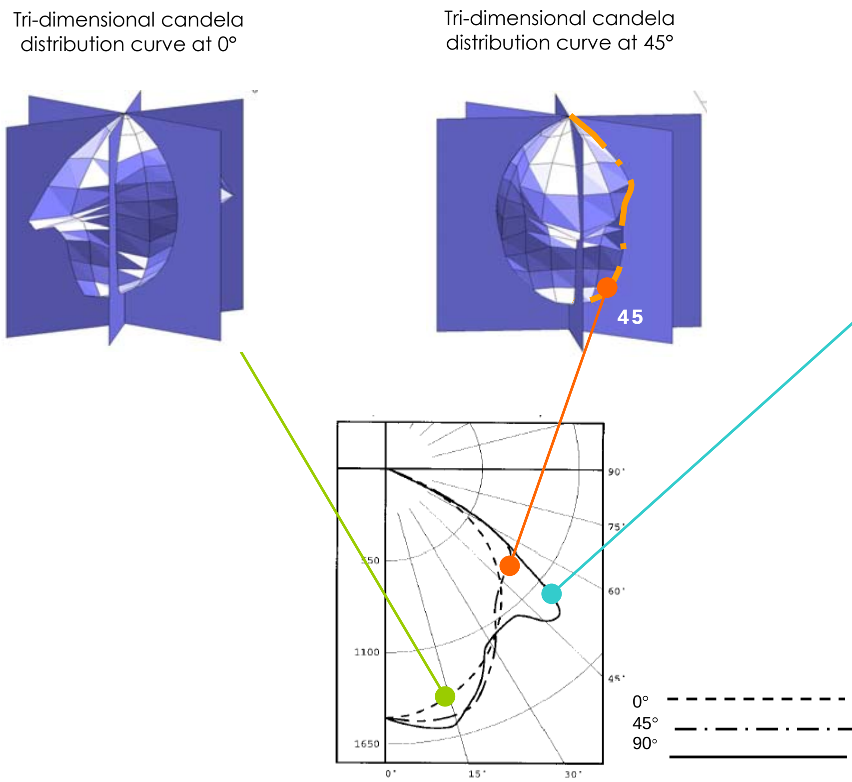


Candlepower curve *perpendicular* to the lamp axis of a 2ft. x 4ft. light fixture.

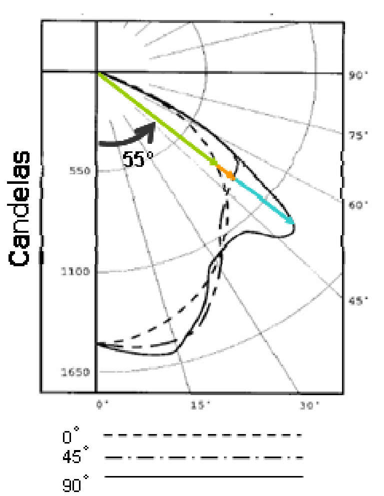


Candlepower curve *parallel* to the lamp axis of a 2ft. x 4ft, light fixture.

If the distribution of the light is symmetrical in all directions around a vertical line, as with most recessed incandescent downlights, then only one candela distribution curve is necessary. In fact, only one half of that curve is usually shown, with the missing half implied to be an exact match. This is done primarily to simplify the reporting. If, however, the distribution of light is not symmetrical in all directions around a vertical line, candela values will be taken in more than one vertical plane through the light fixture but are shown in the same plot as in the illustration below. Only half of the curve for each plane is shown if the candela distribution is symmetrical within the plane (Lighting Reference Manual, 1994).



From the candela distribution curve, we can roughly estimate the luminous intensity at a certain angle. For example:



- On the 0°-plane (parallel to the lamp axis), the candela value at 55º falls between 550 and 1100 candelas (cd) and is about 700 cd.
- On the 45°-plane, the candela value at 55º also falls between 550 and 1100 cd and is about 800 cd.
- On the 90°-plane (perpendicular to the lamp axis), the candela value at 55º falls between 1100 and 1650 cd and is about 1300 cd.

b) ***Candela Distribution Summary***

The candlepower distribution curve provides a good reference when trying to visualize how light will emerge from a light fixture. However, it is difficult to obtain exact candela values just by looking at the polar plot. The candela distribution summary is a table that provides candela values measured at different angles.

If we would like to find candela values at 55° and 65° at the 0°, 45°, and 90° planes, we can find them easily by identifying the plane and finding the values at 55° and 65° on the first column, which represent the angles measured from nadir. For example:

- On the 0°-plane, the candela value at 55° is 656 cd, and at 65° is 274 cd.
- On the 45°-plane, the candela value at 55° is 868 cd, and at 65° is 329 cd.
- On the 90°-plane, the candela value at 55° is 950 cd, and at 65° is 216 cd.

Vertical

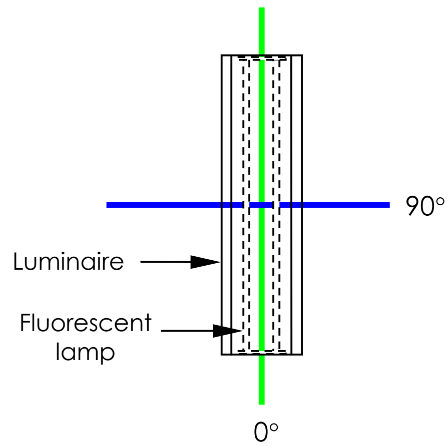
Angles from Nadir	0.0	22.5	45.0	67.5	90.0
0	1491	1491	1491	1491	1491
5	1480	1491	1512	1527	1537
10	1448	1483	1527	1559	1575
15	1406	1460	1524	1565	1573
20	1351	1425	1490	1459	1459
25	1288	1376	1370	1334	1319
30	1211	1309	1245	1166	1186
35	1124	1209	1088	1108	1154
40	1026	1066	989	1081	1148
45	917	925	938	1116	1280
50	795	782	900	1166	1283
55	656	656	868	940	950
60	489	528	668	619	662
65	274	327	329	283	216
70	83	104	95	58	55
75	29	31	27	27	27
80	12	13	12	13	13
85	4	4	5	4	5
90	0	0	0	0	0

According to the minimum luminous intensity minimum criteria set by the SCLP, this light fixture does not qualify for open office plans because it exceeds 300 cd at 55°. It does, however, qualify for other applications where a maximum of 600 cd at 65° is acceptable.

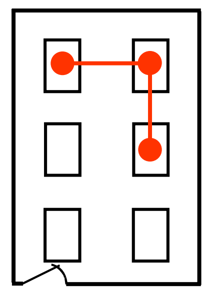
c) ***Spacing Criteria***

Photometric reports also provide spacing criteria (SC) or mounting height ratios (S/MH). As discussed in Section II-M these ratios are used to calculate the maximum recommended installation spacing to obtain an even pattern of light on the surface below the light fixtures. If we refer to our photometric report sample (see a portion of it below) we find that the SC for that particular 2x4 troffer is 1.2 for both the 0° (along the length of luminaire) and the 90° (across the length of luminaire) planes.

```
TOTAL LUMINAIRE EFFICIENCY =       67.0 %
TOTAL REFLECTANCE OF PAINT =       86.9 %
LUMINAIRE EFFICACY RATING  =       FP55
COST OF LIGHTING           =       4.36
CIE TYPE - DIRECT
PLANE                : 0-DEG   90-DEG
SPACING CRITERIA     :   1.2      1.2
PLANE                : 0-DEG   90-DEG
LUMINOUS LENGTH      :44.938   20.813
```



With this information the lighting practitioner can find the appropriate spacing to install an array of luminaires.

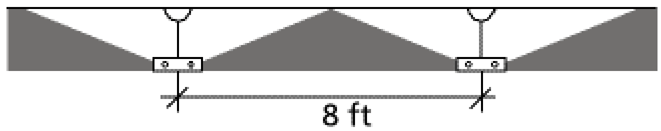


Equal spacing along and across, as seen in the example above, is not usually typical for this type of light fixture, however. Often the spacing at 90° is greater than the spacing at 0°allowing further spacing across. SCLP requires that the distance between walls and adjacent light fixtures should not exceed one-half of the light fixture spacing criteria. This will help prevent the so called "cave effect" where the upper part of a room looks dark and gloomy as shown in the example below.

Photo: Lighting Research Center
Resource Collection

There is usually no spacing criterion for pendant light fixtures. Manufacturers, however, provide spacing recommendations that if implemented will help ensure uniform lighting at the work plane and uniform ceiling brightness.

Reprinted Courtesy of the Illuminating Engineering Society of North America



Following the manufacturers' recommended spacing distances for suspended luminaires will help achieve a degree of uniformity on the illuminated ceiling. Note that the distance is measured from the center of the luminaires.

F. Installing the Lighting Equipment

It is important to follow manufacturer guidelines and construction and electrical safety codes when installing lighting equipment. SCLP requires that all lighting fixtures be installed according to manufacturers' spacing criteria (for direct and recessed light fixtures) and spacing recommendations (for linear suspended light fixtures).

G. Commissioning the Lighting System After Installation

Some important steps in commissioning a lighting system after installation include verifying that the lighting fixtures have been installed properly, making sure the actual light levels meet the design levels, and aiming accent lights.

Commissioning is very important when using lighting controls. Proper commissioning calibrates lighting controls to ensure that lighting systems will perform as intended. Occupancy sensors are used the most in small commercial applications. The following section will provide useful guidelines when specifying and commissioning occupancy sensors.

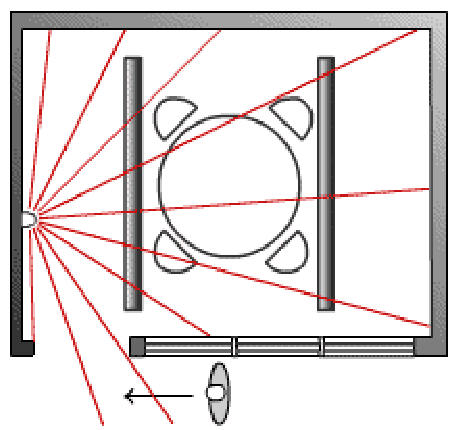
The performance of any motion sensor is based upon four characteristics:

- Sensitivity: the degree to which the sensor can detect motion in the space (may be adjustable).
- Field of view: the angle of view of the occupancy sensor, determining both the coverage area and the coverage pattern (fixed by manufacturer).

- Coverage area: the physical limits of the sensor's ability to detect motion (affected by sensitivity setting).
- Time delay: the amount of time that elapses before the light fixtures are turned off (may be adjustable).

When specifying occupancy sensors, the type of sensor and the coverage pattern should be matched carefully with the area. If the sensor has a coverage pattern that goes beyond the limits of the room, and it is located near a window or a door, passers-by can trigger it, even though the space itself is not occupied. An occupancy sensor should be located so that it will detect all occupants within the intended coverage area only.

Adapted from DELTA Portfolio:
Prudential HealthCare



Due to its coverage area and location, the occupancy sensor shown here detects motion outside the room and turns the lights on each time a person passes by.

Either infrared or ultrasonic sensors are effective for detecting large body motions such as walking. However, for detecting small body movements in a room such as writing, typing, or turning pages in a book, ultrasonic sensors are more effective.

In individual offices and other small spaces, occupancy sensors can be used in place of a standard wall switch. They are mounted and wired in a manner similar to standard switches. Options include dimming, manual on and/or manual off switching and three-way switching.

A manual on/automatic off occupancy sensor does not turn light fixtures on unless someone touches the switch, but will turn the lamps off automatically when no motion is sensed. These are good choices in rooms with daylight, since no electric lights may be needed during the day.

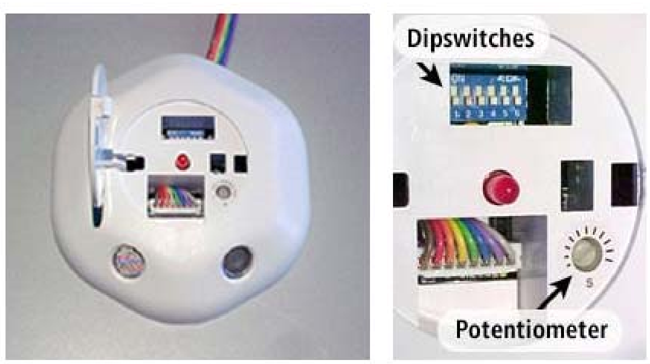
Because HID lamps have a re-strike time, occupancy sensors are not used to turn these lamps off. However, with the use of multilevel ballasts, occupancy sensors can be used to lower light levels without turning the lamps completely off.

If a motion detector switches a fluorescent lamp too frequently, the life of the lamp may be reduced. In these cases, it is important to select a lamp/ballast system that is best suited to delivering long lamp life. Time delay should be set at an appropriate level for the occupancy rate.

Although occupancy sensors are typically used to switch lights off when a room is not in use, they may also be used to dim a lighting system when no motion is detected in a space. A common application for this is a hallway in a multi-unit residential facility where people may feel uncomfortable entering a dark hallway from their apartment.

It is important to make sure that occupancy sensors are properly commissioned once installed in a space. Commissioning typically involves adjusting (with a potentiometer or dipswitch) the amount of time that elapses between the sensors perceiving no motion in the space and the light fixtures being turned off or dimmed. Normally a lighting professional will want to allow at least a five minute period between the time no motion is detected in a space and the lights are switched off or dimmed.

Photos: Courtesy of The Watt Stopper



Commissioning devices (potentiometer and dipswitches) located on the front of this ultrasonic occupancy sensor.

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