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

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Lighting Research Center

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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.

Space Type	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.

10 lumens **350 lumens** **750 lumens**

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.

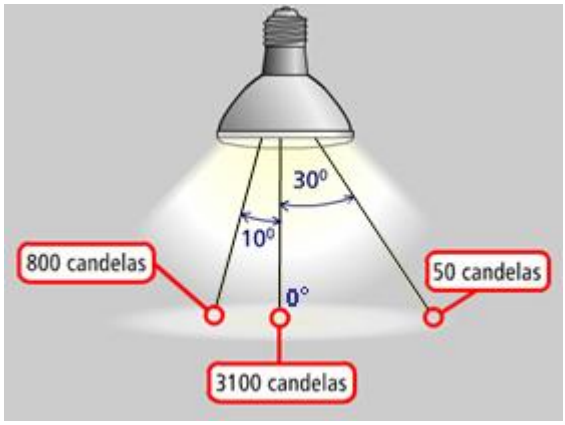
The following table shows a few examples of initial and mean lumen ratings for some commonly used lamps:

Lamp	Initial Lumens	Mean Lumens
60-W A19 incandescent	890	755
135-W A21 energy-efficient incandescent	2485	2110
34-W T12 cool white fluorescent	2650	2280
32-W T8 4100 K, CRI 85	3000	2850
26-W Quad CFL, 4100 K	1800	1550
54-W T5 HO 4100 K	4400	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
75-W MR16 Spot	14,000
75-W PAR38 Flood	3,150
75-W PAR38 Spot	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

Angle	Mean CP
0	541
10	535
20	520
30	490
40	445
50	385
60	313
70	233
80	152
90	110
100	108
120	96
140	78
160	55
180	46

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

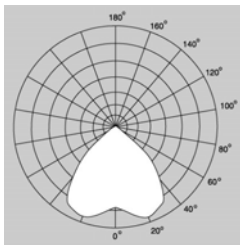


Photo: Courtesy of OSRAM SYLVANIA

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

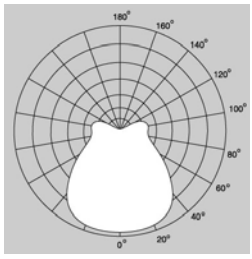


Photo: Randall Perry

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

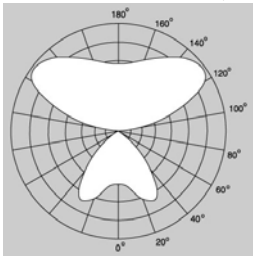
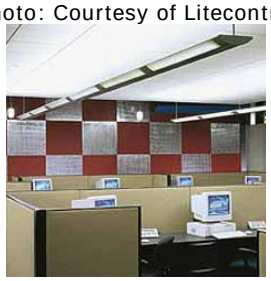


Photo: Courtesy of Litecontrol



Indirect lighting: 90-100% upward

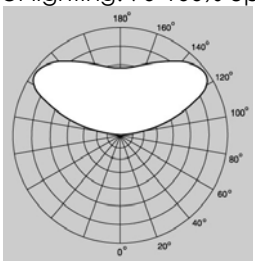


Photo: Courtesy of Litecontrol

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

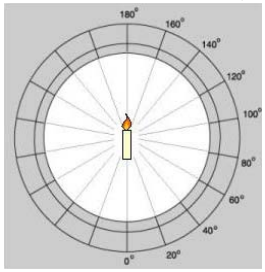


Photo: Courtesy of Kichler Lighting