Applying the Latest Technologies for Superior Lighting: New Applications of the *Advanced Lighting Guidelines, 2003 Edition*

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ABSTRACT

Advances in lighting technologies have given lighting designers the ability to save more energy while creating higher quality indoor environments. While it is widely recognized that lighting influences human behavior and sets the mood of many activities, the lighting design community remains eager for direction on how to correctly apply these newest technologies and create better spaces.

This paper uses the *Advanced Lighting Guidelines: 2003 Edition* as the reference for showing how newly created models based on the most current lighting technologies apply to a variety of commercial sectors and building types. The focus is on the design side of commercial building lighting and on presenting examples of real projects with effective lighting solutions. The paper will demonstrate that appropriate efficient lighting is possible using reasonably priced lighting equipment that is readily available.

The paper includes design strategies that result in superior lighting design solutions for many typical building and space types, including private and open offices, grocery stores, big box retail and classrooms. These design solutions improve the indoor environment and reduce energy use. The paper introduces these models and applications and will encourage a discussion of advanced lighting designs. Energy efficiency and market transformation program managers can use these models to provide examples and resources for architects, lighting designers and contractors.

Introduction

The *Advanced Lighting Guidelines* (*ALG*) were first developed in 1991 by the California Energy Commission to dispel myths about new and emerging lighting technologies. The second edition was published in 1993 by a partnership of the California Energy Commission, the Electric Power Research Institute and the U.S. Department of Energy. In 1999, New Buildings Institute (Institute) took stewardship of the *ALG* and in 2001 published the third edition through a multi-client agreement and sponsorship.

The Institute's *2003 Edition* maintains the wealth of information contained in the *2001 Edition* and provides an updated "Applications" chapter (*Chapter 5*), including an array of visual depictions of lighting design solutions for a variety of common lighting problems and space applications.

Lighting design application software was used to create models for evaluation and visual depiction. In most cases, more than one model has been developed to represent different design approaches utilizing combinations of electric light sources, ballasts and luminaires to demonstrate the range of flexibility in technology selection and light distribution characteristics. These solutions are transferable to other lighting applications. The intent of the Applications Chapter is to show advanced design approaches, and it assumes the reader has a base knowledge of standard design practices. While daylighting is an important factor in lighting design, electric lighting solutions are the main focus of this "Applications" chapter.

In addition, this paper shows how the new "super" T8 and T5 fluorescent systems can help achieve beyond-code design.

The beginning of the paper addresses three key areas in planning for an efficient and effective design: lamp/ballast technologies, applying controls and daylighting integration. These are followed by specific application examples from the *ALG – Chapter 5* that are directly transferable into projects.

Foundations to Efficient Design

Lamp/Ballast Technologies

In areas with nationally based codes, standard design practices using low-efficacy ordinary lighting systems will meet most requirements. However, as more stringent codes take effect and voluntary programs promote building beyond energy codes, reducing lighting power 20-25% compared to current practice will be necessary. The models presented are designed to demonstrate extremely low power use. To achieve this, they utilize these especially important technologies:

1. The latest barrier coat, high-lumen maintenance, high-efficacy T-8 and T-5 fluorescent linear lamps. All T-5 standard lamps meet these criteria; only certain T-8 premium lamps comply. The best way to identify T-8 lamps in this category is to look for lamps rated 3100-3200 initial lumens and 95% lumen maintenance at 8,000 hours.
2. The latest energy-efficient electronic ballasts. In the last few years, ballasts have become more efficient. Certain versions of several popular ballast types have now become 7-10% more energy efficient than standard electronic ballasts.
3. The thoughtful use of normal ballast factor/normal light output (NLO), reduced ballast factor/reduced light output (RLO) and high ballast factor/high light output (HLO) electronic ballasts to better match light levels and power to the room needs.
4. Using T-5 twin tube compact fluorescent lamps in wallwashers. This lamp and ballast system remains fairly efficacious, but more importantly produces excellent results in washing walls with even light.
5. A smattering of halogen IR, compact fluorescent and ceramic metal halide luminaires on larger multi-use projects.

The following table shows how more advanced fluorescent technologies used in the *ALG – Chapter 5* compare to a Standard Phosphor T8 System. Some combinations of lamps and ballasts can increase illumination levels 33% while reducing energy use by up to 26%. These options must be evaluated during the design process for the appropriate applications and for economic considerations.

Table 1-1. System Comparison[1]

Lamp Type	Initial Lamp Lumens	No. Lamps	Ballast	Ballast Factor	System Watts	System Lumens	Mean System Lumens	Relative Lumens @ 8000 Hrs.	LPW @ 8000 Hrs.	Avg. Rated Life (hrs.)	% Lamp Life	% Energy Savings
Standard Phosphor T8	2800	3	3-lamp ISN	.88	87	7392	6653	BASE	76	150000	BASE	BASE
"Super" T8	3150	3	3-lamp ISN	.88	87	8316	7900	119%	91	15000	100%	_
"Super" T8	3150	3	3-lamp ISH	.77	76	7276	6913	104%	91	15000	100%	13%
"Super" T8	3150	2	3-lamp ISH	1.20	78	7560	7182	108%	92	15000	100%	10%
"Super" T8	3150	3	3-lamp PSN	.88	88	8316	7900	119%	90	20000	133%	_
"Super" T8	3150	3	3-lamp PSX	.74	72	6993	6643	100%	92	30000	200%	17%
T5	2900	3	3-lamp PSN	1.03	64	8961	8250	124%	94	20000	133%	26%

NOTES:
ISN = Instant Start Normal Ballast Factor/NLO, ISH = Instant Start High Ballast Factor/HLO, PSN = Programmed Rapid Start Normal Ballast Factor/NLO, PSX = Programmed Rapid Start – Long Lamp Life Ballast/NLO
Lamp Life Ratings at 3hrs/start.
Lamps used for Table: Standard Phosphor T8 = Sylvania FO32/700/ECO, "Super" T8 = Sylvania FO32/841XPS/ECO, T5 = Sylvania FP/841.

Applying Controls

In addition to making lighting convenient to use, controls can dramatically reduce the amount of lighting energy used. High energy costs in parts of the United States and renewed concerns about energy conservation make controls selection one the most important elements of advanced lighting design. Advances in automatic controls offer a number of alternatives. In each of the models, the designer is offered several control options, depending on the priorities of the project.

Table 1-2 shows the rating scale that has been used in each model to help designers make "advanced" choices for applicable lighting controls.

Table 1-2. Lighting Controls Rating Scale for Models

CODE	Explanation
Minimal	This control or combination of controls meets or exceeds modern energy codes, and provides a minimally acceptable level of energy efficiency with savings of at least 5-20% as compared to ordinary manual switching.
Good	This control or combination of controls represents a cost-effective controls salutation, with energy savings of at least 10-30% as compared to manual switching.
Optimum	This control or combination of controls represents an optimal solution in which a minimum necessary amount of energy is used and, in many cases, helps manages demand use (kWh) to save cost and energy.

[1] Information derived from lamp and ballast manufacturer's literature.

Integration of Daylighting

The majority of commercial, industrial, and institutional buildings have windows and, in some case, skylights, clerestories and more extensive daylighting systems. In planning a lighting design for any space, a lighting designer should always first consider the potential of that space to take advantage of the many benefits of daylighting. From a lighting design perspective, daylight can be treated as any other light source and used to compose lighting design solutions with illuminance, luminance, contrast, color and other lighting design elements. The daylighting opportunities can best be described as "Standard, Advanced and Integrated" based on the following scenarios:

1. **STANDARD**: The architecture, building or orientation, fenestration, windows and daylighting opportunities will be "fixed" when the lighting design process starts.
2. **ADVANCED**: The lighting designer has the opportunity to influence some of the building's glazing properties, shade controls and other features to improve the daylighting potential.
3. **INTEGRATED**: An in-depth analysis can be performed to maximize daylighting potential with full integration architectural elements with electric lighting and controls to provide high-quality daylight illumination.

Table 1-3 offers a checklist for evaluating the daylighting potential of a space.

From an energy perspective, the most obvious use of daylight is to permit the dimming or switching of the electric lighting system. However, predicting daylight savings is not easy. The models used in *ALG – Chapter 5* typically address the "Standard Daylighting Opportunities" generally faced by the lighting designer. Further designs evaluations should be explored where appropriate.

Design Applications

The designs offered demonstrate concepts in lighting applications that employ energy-efficient strategies without compromising good lighting practice. The models provided enable lighting designers to consistently improve upon the energy standards of ANSI/ASHRAE/IESNA Standard 90.1-01 and state and local energy codes and standards as defined by Lighting Power Density (LPD). The technologies used in these designs are readily available today.

In addition, the figure below provides further considerations for advanced lighting design.

The Examples Are Not Exemplary

The *ALG - Chapter 5* models used were developed from experience and, to a certain extent, from plans available in current or recently completed projects. They are meant to represent real projects with real lighting solutions. The fundamental concept behind the models is to demonstrate that appropriate lighting can be created using reasonably-priced lighting equipment that is readily available. This does <u>not</u> mean that the designs are exemplary. Other lighting designs might easily be better when taking into account specific project needs and budgets.

Table 1-3. Daylighting Potential

	Opportunity	Evaluation
STANDARD	"Fixed" architecture, building orientation, and windows. Focus on lighting and controls.	Can daylight provide any useful illumination during occupied hours? If so, can some electric lighting be dimmed or turned off in response? If so, can the electric lighting be circuited to facilitate either manual or automatic control of the lights?
ADVANCED	Building glazing properties and glare issues can be influenced. Focus on quantifying daylighting contribution and glare management.	For windows, recommend external shading devices or internal window controls such as blinds to allow occupants local adjustments to avoid discomfort. For skylights or roof monitors, recommend the use of diffusing glazing materials and/or baffles or louvers to diffuse the sunlight. Work with the design team to evaluate the impact of changes in glazing performance on occupant discomfort. Can the occupant's activities be repositioned so that they will not be bothered by the potential glare sources? Work with the design team to evaluate the potential glare sources through windows or skylights, such as white or bright reflective surfaces that may reflect sunlight into the space.
INTEGRATED	In-depth analysis of daylighting potential.	Evaluate if there are ways that the quality, distribution or amount daylighting can be improved during pre-design and schematic design phase. Utilize modeling software to evaluate full integration of daylighting, electric lighting, controls, and building characteristics such as: 1. Placing windows closer to ceiling or wall surfaces to get better distribution. 2. Raising the ceiling plane to allow higher windows. 3. Increasing the visible light transmission of the windows to allow more daylight into the space. 4. Positioning reflective surfaces, either internally, or externally to direct more daylight deeper into the space. 5. Increasing the reflectance of important interior surfaces that will help distribute the daylight deeper into the space.

Private Offices and Small Work Rooms

Lighting private offices and small workrooms is one of the most common and basic lighting tasks. The same design strategies can be applied to mailrooms, examination and treatment rooms, small meeting rooms and a variety of other small spaces.

These advanced lighting design approaches considerably reduce lighting power below code minimums, yet provide a quality lighting system. The main purpose is to provide illumination to a task surface such as a desktop. The designer has several luminaire choices, including recessed basket "indirect," suspended indirect and recessed parabolic. The average ambient light level for each strategy is between 20 and 30 footcandles.

Task lighting exceeding 50 footcandles on work surfaces is accomplished with under-cabinet task lights or portable lighting using compact fluorescent technology.

Figure 2-1. Advanced Lighting Considerations

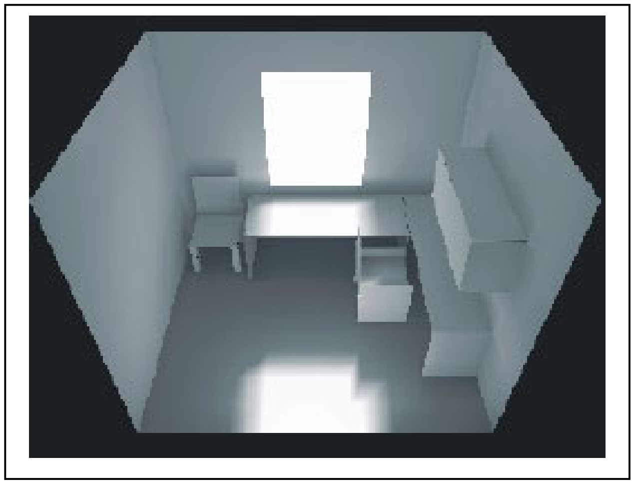
- **Daylighting:** Window height should match ceiling height, if possible, to maximize the depth and distribution of daylight penetration into the space. Windows facing north have the best daylighting performance. Consider toplighting for top floors and single-story buildings.
- **Glazing:** As a general rule, the visible light transmission of glazing should be as low as possible without appearing too dark reflective. Shading coefficients should be selected to balance the heat gain and solar radiation with the visible transmittance of around 0.5 is a good starting point. Transmittance can be as high as 0.8 when there are two daylight sources.
- **Shading:** For optimum daylighting, the window should be equipped with horizontal or vertical blinds for individual control of direct sunlight and/or external glare sources. Perforated density shades or other shading systems can also be used.
- **Direct Glare:** Proper orientation and shading devices should naturally be considered to minimize glare. North-facing windows produce minimal direct glare. Windows facing east, south and west should have exterior shading to minimize sun penetration. Window glass above 7 ft. should have a second set of blinds controlled separately from the view window area (below 7 ft.). The recommended luminaires do not produce direct glare.
- **Reflected Glare:** Recessed indirect fluorescent luminaires direct light downward from the ceiling plane. Perforated metal "baskets" allow a gentle glow of downward light while shielding a direct view of the lamps and minimize reflected glare. Alternative suspended indirect "uplights" reflect light off the ceiling to provide uniform ambient light that has low glare. The other proposed option, lensed troffers, requires acrylic prismatic lenses to obscure the lamp images and limit luminous intensity (and therefore glare) at viewing angles above 60 degrees. White finishes on the inner reflective surfaces reduce the reflected view of lamps, as sometimes seen with metallic finishes. Quality task light that minimizes veiling reflections must be specified.
- **Luminance of Room Surfaces:** The luminaire options recommended all diffuse light well. Suspended indirect luminaires better illuminate upper walls, improving perception of brightness in the room. Encourage use of highly diffuse, reflective, light-colored ceiling and wall surfaces.
- **Other:** The primary work area and computer monitor should face 45 degrees away from the window to minimize glare on the monitor while still allowing a view out the window.

Power density. Current U.S. energy codes and standards permit at least 1.1 W/sq. ft. for lighting office space. Utilizing ceiling-mounted and under-cabinet task lighting, the models shown have lighting power densities ranging from 0.73-0.89 W/sq. ft., well below the standards. 24W CFL table lamps add 0.22 W/sq. ft. each.

Controls. The "base case" control strategy should include separate manual switches for the overhead and task lights, with an automatic shutoff device (occupancy sensor) on the overheads. For spaces <u>with</u> windows, also provide the overhead lighting system with a dimming ballast and automatic daylighting controls. For spaces <u>without</u> windows, also provide a manual dimmer. Occupant lighting level preferences will likely result in reduced energy consumption.

Private office with windows. A common problem in offices with single windows is the high "punch" of daylight that happens on south-facing walls in the winter. The light levels can exceed 2,000 footcandles in the center of the room, creating a very high contrast to task light levels. A properly designed shading system is necessary.

Figure 2-2. Worst Case Solar Condition



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Strategies. The models used a 12 ft. x 9 ft. (108 sq. ft.) typical office with an "L" furniture configuration. An example shown here uses a partial task/ambient lighting design using a high performance overhead "recessed indirect" perforated metal basket luminaire with two F32T8 "super" lamps and a single normal light output energy efficient (NLO/EE) electronic ballast (BF = 0.88), using about 55 watts. There is also an under-cabinet luminaire with a F25T8 lamp that draws about 24 watts. Using only two overhead lamps, ambient light levels are barely met, but the under-cabinet light ensures adequate task lighting levels.

The ballast factor dictates the level of ambient light from the overhead luminaires. This example provides 20-30 footcandles throughout the room at a power density of 0.73 W/sq. ft., including task lighting.

This should be considered a minimum light level for this application. Lighting levels can be increased by using a high light output (HLO) ballast, which will yield light levels of 25-40 footcandles with a power density of 0.94 W/sq. ft.

Figure 2-3. Private Office 1 – Direct/Task-Ambient Strategy

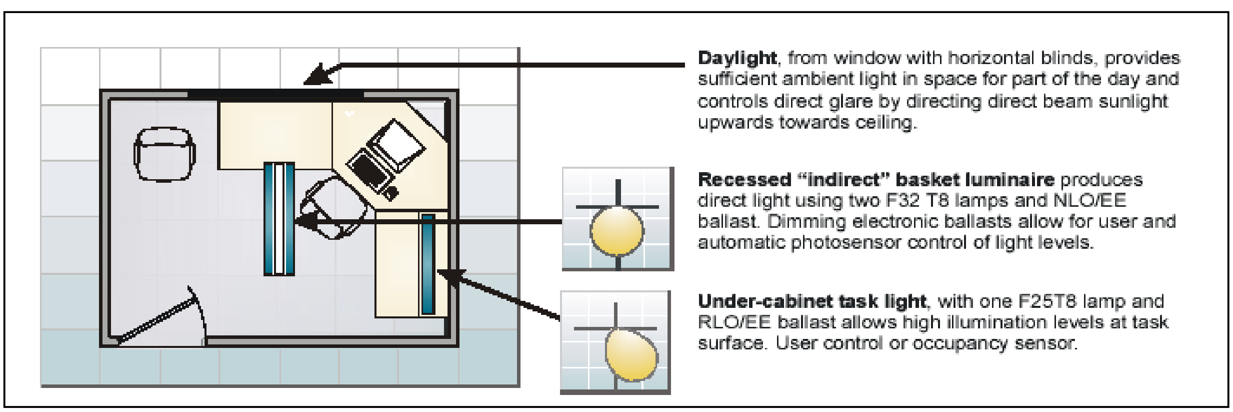

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Figure 2-4. Private Office 1: Grey Scale Rendering

Advanced Lighting Guidelines, Chapter 5 – Applications, pg 5-10

Open Plan Office Areas

Significant energy savings can be realized because of the large percentages of people working in open office configurations. Chapter 5 shows three designs for advanced approaches to considerably reducing lighting power below code minimums. These designs provide good illumination on task locations, with lower ambient light levels in the non-task areas.

The overhead lighting system examples provide mostly "ambient" light of at least 20 footcandles, and preferentially between 25-40 footcandles. Currently, the most common options are direct (troffer) luminaires and suspended luminaires. Troffers are inexpensive, scalable and easily configurable to furniture and transit area floor plans.

However, troffer lighting systems generally do not illuminate the ceiling and upper walls very well. Suspended lighting systems offer an alternative, allowing indirect, semi-indirect or direct/indirect lighting to increase visual comfort. Of these, indirect "uplighting" systems are reasonably inexpensive and able to compete in cost and performance with parabolic or basket troffers. Ceiling heights should be at least 9 ft.-6in. or higher in open areas for most applications.

Power Density

Current U.S. energy codes and standards permit at least 1.1 W/sq. ft. for lighting open office space. Utilizing suspended indirect luminaires with F54T5HO lamps or direct/indirect luminaires with FO32T8/800 "super" lamps and electronic ballasts with under-cabinet task lighting, the models shown have lighting power densities ranging from 0.81-0.89 W/sq. ft., well below the standards.

Controls

Most energy codes require automatic shut-off of the overhead lighting system. Override controls are necessary for local control, and separate switching zones should be included for daylight areas. Daylight dimming can be applied for increased energy savings of 10-50%.

Daylighting

Can be introduced via sidelighting (proper glazing and window treatments are required) and toplighting. Spaces with daylighting should utilize daylighting dimming controls.

Figure 2-5. Open Office 2 – T-5HO Uplighting Strategy

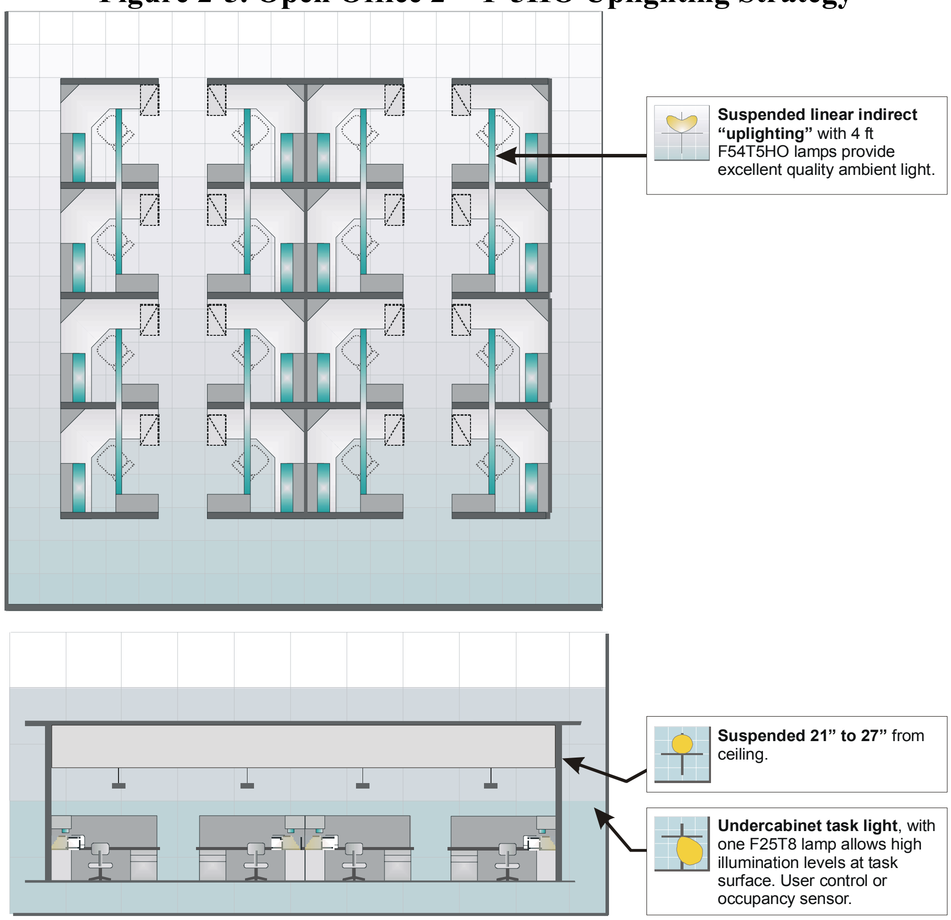

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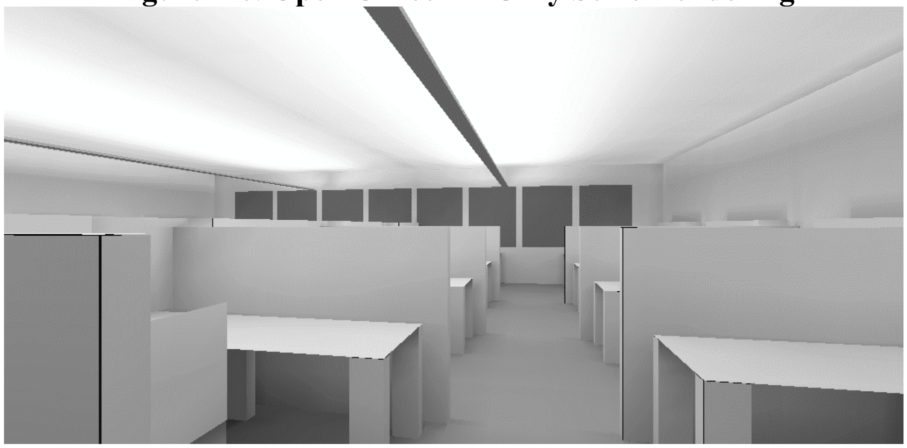
Figure 2-6. Open Office 2 – Gray Scale Rendering



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Big Box Retail Stores

The growth in the big box retail market makes it a significant area for lighting energy efficiency. Energy codes typically allow approximately 1.8-2.0 W/sq. ft. Because big box stores lend themselves well to the use of skylights and relatively efficient electrical lighting equipment, substantial energy savings are possible.

Increasing the integration of electric light and daylighting is a design priority. While almost all electric light fixtures have a photometric report allowing the designer to accurately predict the lighting levels from any given design, it has only been recently that designers have used photometrics for common skylights.

Now it is possible to describe the light characteristics of skylights and light well combinations in the same manner as electric light sources, and some photometrics are freely available from public funded research (PIER Report 500-03-082 A-15 at http://www.energy.ca.gov/reports/2003-11-17_500-03-082_A-15.pdf).

In addition, recent reports prepared on behalf of the California Energy Commission PIER program found up to a 6% increase in sales from daylighting in retail. (Heschong, 2003) These extensive studies will draw increased market attention and demand for effective and efficient lighting applications that integrate with daylight.

Lighting Strategy

The model uses a combination of sources. Ceramic metal halide pulse-start downlights, 272 watts (w/ballast) with 20% uplight onto the ceiling, reducing the perceived glare of the luminaire, and contributing reflected light to help reduce shadows. Suspended, continuous strip, open one-lamp luminaires with T8 lamps, electronic ballasts and reflectors are used to illuminate products on shelving in the aisle areas and featured sales areas. High ballast factor (BF = 1.15-1.2) ballasts are needed to achieve appropriate light levels. Compact fluorescents illuminate seasonal merchandise in lower ceiling heights. The total lighting power density for this model is 1.53 W/sq. ft.

Figure 2-7. Big Box Retail

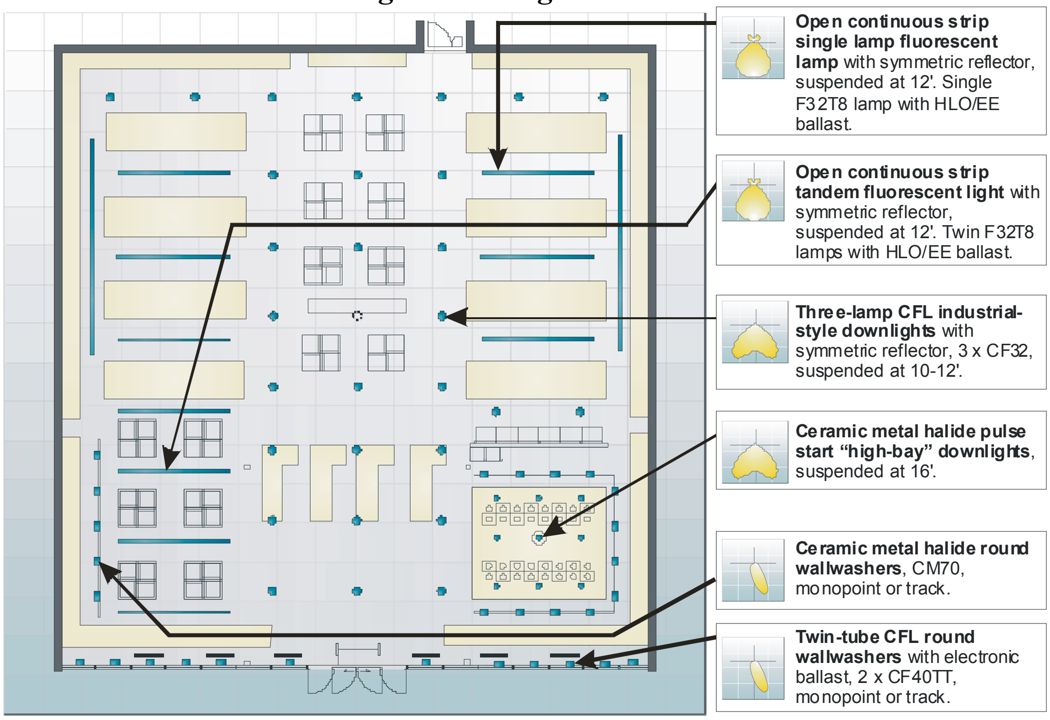

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Figure 2-8. Big Box Retail: Gray Scale Rendering

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Summary

It is the goal of the *ALG - Chapter 5* to stimulate discussion among experienced lighting design professionals and to educate those just beginning on balancing lighting energy decisions with quality lighting applications. Advances in technologies will continue to give the lighting professionals choices in meeting the needs of the users and code requirements. It is imperative that the "human factor" always be the first criteria for all advanced lighting designs.

The next edition of the *Advanced Lighting Guidelines* is in the planning stages and will continue to be the leader in providing the foundation to advanced lighting design practices.

References

Heschong, Lisa 2003 *Productivity Report on Retail* California Energy Commission "PIER" publication. www.energy.ca.gov/pier/reports/500-03-082.html

Advanced Lighting Guidelines – 2003 Edition. www.newbuildings.org/lighting.html