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Review of European Specification of Requirements for Residential Streets and Park Lighting

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Review of European Specification of Requirements for Residential Streets and Park Lighting

Executive Summary

This review is part of a larger effort to improve outdoor lighting practice in California through the development of an outdoor lighting code and a retrofit luminaire for parking areas and roadway illumination. This paper examines the European Specification of Requirements for Residential Streets and Park Lighting and evaluates its relevance to these objectives.

The European specification establishes specific performance criteria for street and park lighting, including luminance and illuminance values, light pollution restrictions, and minimum lamp efficacies. LBNL compared these criteria to currently available technology used in parking lots in the United States (U.S.), and also to the Illuminating Engineering Society of North America (IESNA) RP-20-98 and California Energy Commission (CEC) draft code for parking lot lighting.

Although the net effect of the European performance standards is to minimize glare, reduce light trespass and light pollution, and limit energy use (all desirable goals), there are a number of aspects of the European specification that greatly limit its applicability to outdoor lighting standards and retrofit luminaires for California. These findings can be summarized as follows:

- **Luminance and illuminance values are inconsistent with current fixture design practice for streets and parking lots in the U.S.** When the European performance standard is applied to available fixtures that are sized to fit HID sources, a discrepancy arises in which the minimum required candlepower to meet specified illuminance levels is actually larger than the maximum allowed candlepower based on luminance restrictions. To make the design functional, the fixture would need to be at least 0.5 m^2 in size, which is inappropriate for most parking lot applications.

- **Single-fixture approach leads to a system where there is essentially no interaction between fixtures.** The European specification directs its requirements to the individual fixture, as opposed to the IES recommended practice for parking facilities (RP-20-98), which controls the performance of the lighting system as a whole. The European approach may be unacceptable in a parking lot installation, as such systems will provide almost no light near the pole when there is a lamp or fixture failure.

- **Differences in physical layout of lighting installations between Europe and the U.S. will affect system performance.** The European specification is tied to a specific geometry, which differs from typical luminaire mounting heights, pole spacing, and road widths used in the U.S. for street and parking lighting. As these variables have a significant effect on candlepower distribution, it may be more appropriate to use the IESNA approach, which allows for greater flexibility in lighting system design.

The analysis also helped elucidate the need to further develop design criteria for parking lot lighting, as visual performance requirements in parking lots differ greatly from those in roadway situations. LBNL raises several important points that should be considered further as standards and retrofits for parking lot lighting are developed. These include:

- **Relationship between vertical illumination and veiling glare.** Vertical illumination is an important part of IESNA recommended practice for parking lots, as it aids in detection of pedestrians. However, vertical illumination is most efficiently produced by the type of light distribution that also produces veiling glare. Before any specific glare reduction measures are implemented for parking lots, it must be determined whether it is possible to reduce glare and still meet the IESNA recommendations on the minimum vertical illuminance.

- **Control of illumination uniformity to meet energy efficiency standards.** The CEC draft standard for outdoor lighting limits energy use (as watts/ft2) in parking lots as a function of the environmental lighting zone, and thus restricts the average light levels for each zone. In contrast, the IESNA recommended practice for parking lots specifies minimum illuminance levels to meet visibility and security requirements for two categories, “basic” and “enhanced security.” To meet these recommended levels in lighting zones 1 and 3 (of the CEC draft standard), a reasonably good control of the uniformity (a ratio of around 5:1) is required.

- **Effects of lamp spectra on brightness and peripheral visibility.** There is currently a great deal of interest in the impact of changes in light spectrum on energy use and visual performance in parking lots, but these issues are not covered in current standards. Further investigation of the relationship of lamp spectra to brightness and peripheral visibility is needed before any light spectrum requirements are included as part of a lighting standard for parking lots.

As a result of this review, LBNL has concluded that the overall intent of the European specification in limiting glare, light trespass, and light pollution should be preserved, but the specific form of the requirements should be adjusted to a system approach for use in California. Possible retrofit strategies for pole-mounted luminaires in parking lots include replacing the fixture or head, changing the optics, or shielding the fixtures. Other types of fixtures, including wall packs and canopy lights, will most likely require fixture head replacement, so the primary issue is to develop a set of target candlepower distributions for manufacturers.

1. Introduction

The European specification establishes performance standards for luminaires used in lighting residential streets and parks. It has been suggested that these standards may be helpful in designing a retrofit fixture for parking lots as well as in developing a parking lot lighting code for California. The following sections review the major requirements of the European specification as the requirements relate to these goals. Section 2 compares the requirements of the European standard to the performance characteristics of parking luminaires currently available in the U.S. In Section 3, these requirements are discussed in terms of their applicability to parking lighting standards for California. Finally, Section 4 comments on possible retrofit strategies for parking lot lighting, based on the preceding analysis.

2. Comparison of European Standards to Currently Available Technology

2.1 Luminance and illuminance requirements

The luminance and illuminance requirements in the European standard are based on a standard geometry that specifies mounting height, pole-arm length (overhang), and road width. The geometries assumed in calculating luminance and illuminance values for single fixtures in roadways and parks are shown in Table 1.

Table 1. Geometries assumed in specifying luminance and illuminance values

Location	Mounting Height	Overhang	Spacing/mounting height Ratio	Road Width
Roadway	6 meters	1.5 meters	3.5	6 meters
Park	4 meters	0 meters	3.5	3 meters

The European specification restricts the luminance from the luminaire at specified view angles and view directions. These luminance restrictions are detailed below in Table 2. A graphic representation of the luminance values is shown in Figure 1.

Table 2. Maximum allowed luminance from specified view angles (as measured in candela per square meter from horizontal)

View Direction	Maximum Allowed Luminance (in cd/m^2)					
	≤10°	≤20°	≤30°	≤45°	≤60°	≤70°
Across street outward to edge of road	5	300	300	300	300	3000
Across street inward to center of road	5	300	300	3000	6000	N/A
Along the street	5	300	3000	6000	6000	6000

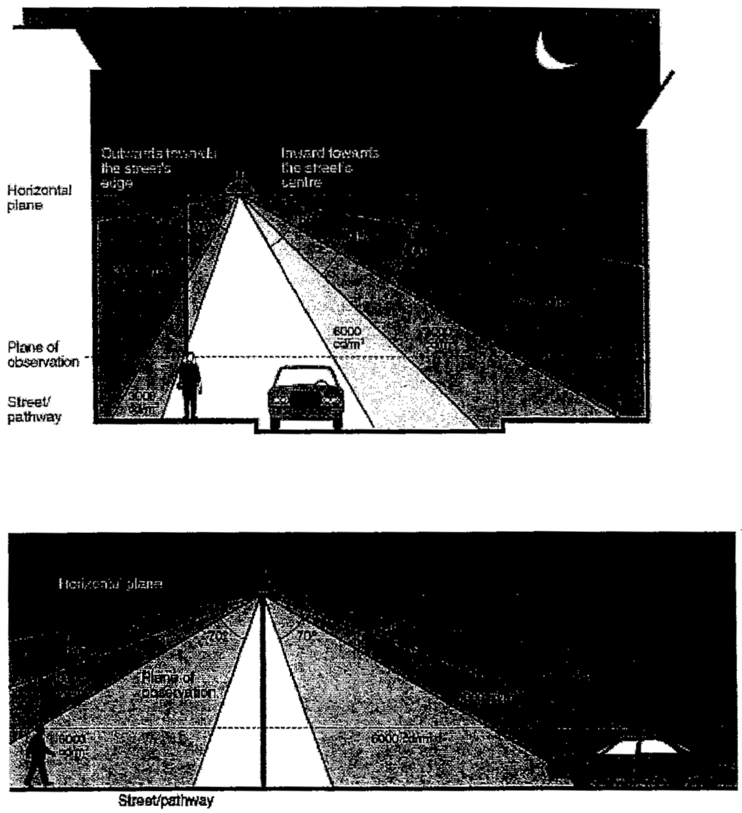

Figure 1. Luminance restrictions at specified view angles and view directions (as depicted in the European specification).

The illuminance requirements for both roadways and parks are specified for a standard spacing to mounting height ratio of 3.5. For roadways, the illuminance is specified only for the roadway itself, while for parks the area includes 1.5 meters from the inside edge of the pole, and 0.5 meters off the far edge of the path. Within these boundaries, the minimum illuminance values for both categories are specified as 10 lux within a radius of one mounting height distance, 2.5 lux within 1.75 mounting height distances, and a minimum of 1 lux at all other measurement points (inside the established boundary). These requirements are depicted below in Figure 2.

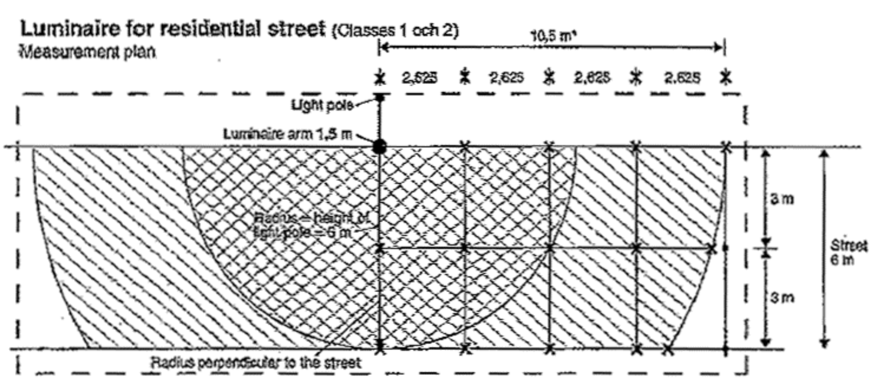

Figure 2. Illuminance requirements for roadways as depicted in the European specification.

Examination of the listed values for maximum luminance and minimum illuminance shows that they are inconsistent with current fixture design practice for streets and parking lots in the U.S. When the European performance standard is applied to available fixtures that are sized to fit HID sources, a discrepancy arises in which the minimum required candlepower needed to meet the specified illuminance levels is actually larger than the maximum allowed candlepower for a single fixture. To explain, the European standards for luminance and illuminance limit both the maximum and minimum candlepower of the fixture via the following two relationships (as derived from standard equations for candlepower and illuminance[1]):

1) Maximum allowed candlepower = luminance x projected area
2) Minimum required candlepower = illuminance x distance^2

LBNL calculated both the maximum and minimum candlepower values for fixtures from one major manufacturer, which are commonly used to light parking lots in California. In Equation 1 above, projected area is the horizontal area of the fixture multiplied by the cosine of the beam angle from nadir. As estimated[2] from drawings on the specification sheets, the luminous openings (horizontal area) for Gardco fixtures range from 0.09 to 0.43 m^2. The smaller sizes (0.09 to 0.13 m^2) are for the smaller lamps (50 to 150 high pressure sodium or metal halide), while the larger sizes are for bigger lamps. For the largest fixture, Equation 1 gives maximum candela limits of 2400 cd at 20° from nadir, 650 cd at 60° from nadir, and 45 cd at 70°from nadir (this is for beam lumens along the street). Equation 2, however, gives a minimum candlepower requirement of 720 cd at 60° from nadir, which is larger than the maximum allowed candlepower for the same beam angle. Additional calculation shows that this discrepancy is much worse for the smaller fixtures. In order to achieve the proper relationship between minimum and maximum allowed candlepower, the fixture's luminous opening would need to be at least 0.5 m^2 in size. Such a large fixture may not be suitable for parking lot applications, as it is inconsistent with current practice.

It is clear that the assumed lamp sizes in the European standard are fairly small, even though the specifications do not explicitly limit the candlepower, the illuminance, or the number of lumens within a narrow range of angles near nadir. For example, the European standard states that illuminances "shall be uniform throughout the measurement area." In American practice, illuminance uniformity is defined in the IESNA's "Lighting for Parking Facilities" (RP-20) as a maximum to minimum ratio of 20:1. If researchers assume a 0.5 m^2 fixture size, the largest permissible minimum illuminance of the paved area is limited by the maximum candlepower restrictions given above to about 5 lux (including overlap from the next fixture). Using the IESNA uniformity ratio, this limits the maximum illuminance in the region from nadir to 20°to 100 lux. For the 6 meter mounting height, the total number of lumens in this region is therefore limited to about 1500 lumens. Outside this region, the total number of lumens is limited to 6650 lumens, so the fixture output can be no more than 8150 lumens. This means that the lamp size for a 0.5 m^2 fixture is on the order of 100 to 150 watts for an HPS or MH lamp.

[1] A) candlepower = luminance x projected area
B) illuminance = candlepower/distance^2

[2] The IES photometric files do not appear to contain accurate information on luminaire size.

Part of the difficulty in applying the European performance standards to American fixtures occurs because of differences between Sweden and the U.S. in the physical layout of roadway and parking lighting. As shown below in Table 3, the European specifications for street lighting are based on standard fixture mounting heights of six meters, which is considerably smaller than the 10 meter mounting height typically used in the U.S. for most street and parking lighting. European roads are also smaller than the typical American road, with lane widths specified as three meters in width instead of 4 meters.

Table 3. Comparison of European and American installation geometries

Standard	Mounting height	Road width
European	6 meters	3 meters
American	10 meters	4 meters

While the limitations on minimum fixture size detailed earlier depend only on the beam angle luminance specifications, the limitations on lamp wattage depend both on the angle specifications and the mounting heights. A four meter mounting height (as used in the European standard for park pathway lighting) would reduce the maximum lumen output to 3600 lumens (50 to 70 watt High Intensity Discharge, or fluorescent), while a 10 meter mounting height would only limit output to 22,600 lumens (a 250 to 350-watt HID fixture).

The conclusion is that the European specifications for luminance and illuminance are not consistent with current practice for post-top or pole mounted fixtures, because of the very large implied size of the source. Although it is possible to build fixtures this large, their cost would increase substantially and the fixtures would likely be considered oversized and inappropriate. Since the overarching goal of the European specifications is to maintain visibility while limiting glare, it may be more suitable to use them as a general guide rather than as an actual specification. This point will be discussed further in Section 3.2.

2.2 Horizontal candlepower

The European specification requires that horizontal candlepower be zero. This is an intrusive light and light pollution restriction, which is currently met in the U.S. by any fixture that has the "full-cut-off" classification. All flat-glass fixtures, such as those made by Gardco and other manufacturers, meet this standard. There is no technological problem with this aspect of the specification.

2.3 Lamp efficacy

Lamp efficacy in the European specification is set at 50 lumens/watt for lamps of less than 45 watts, and 70 lumens/watt for larger lamps. It is not specified whether this is an initial or maintained efficacy. LBNL examined Phillips (2001/2002) and Venture (electronic) catalogs in order to compare currently available lamps to the requirements specified in the European standard. Most (>70 percent) parking lot lighting uses HID sources, which are generally larger than 45 watts. The Phillips catalog lists a metal halide PAR lamp at 39 watts, but the Venture catalog has no lamps below 45 watts. The only standard HID lamp at this wattage is the HPS 35-watt lamp, with initial and maintained efficacies of 64 and 58 lumens/watt respectively.

When LBNL looked at lamps greater than 45 watts, no metal halide lamps below 150 watts have a maintained efficacy of 70 lumens/watt were found. However, most of the initial efficacies for these lamps are above this limit. Table 4 below lists the best initial and maintained efficacies as a function of wattage for MH and HPS lamps as of 2002. The best efficacies for the metal halide lamps are all for vertical operation of the lamp. From the limited information available in the catalogs, it appears that there is approximately a 10-15 percent loss of efficacy for horizontal operation of the lamp, which unfortunately (as far as efficacy is concerned) is the far more common orientation. However, for the bigger metal halide lamps, the efficacies of all but the 150-watt lamps are sufficiently high in the vertical orientation that they should still exceed 70 maintained lumens/watt in a horizontal orientation.

Table 4 also lists the efficacies of standard color HPS lamps (CCT = 2100 °K, CRI = 20), all of which meet the standard for both initial and maintained lumens/watt. Of the improved color HPS lamps (CCT = 2200 °K, CRI = 60), only the 100 and 150 watt 60 CRI lamps meet the initial lumens/watt standard. None of the white HPS lamps (CCT = 2700 °K, CRI = 85) come even close to meeting the standard.

Table 4. Efficacy of Available HID Lamps (in lumens/watt)

	Metal Halide		**High Pressure Sodium**	
Watts	**Initial efficacy**	**Mean efficacy**	**Initial efficacy**	**Mean efficacy**
35			64.3	57.9
50	68.0	44.0	80.0	72.0
70	80.0	51.4	91.4	77.9
100	90.0	59.0	95.0	85.5
125	96.0	67.2		
150	93.3	70.0	106.7	96.0
175	100.0	80.0		
200	105.0	84.0	110.0	99.0
225	84.4	55.1		
250	100.0	80.0	112.0	108.0
300	101.7	81.3		
310			119.4	107.4
320	103.1	82.5		
350	105.7	84.6		
360	100.0	65.0		
400	110.0	88.0	127.5	112.5
600			150.0	135.0
750	96.0	62.4	148.0	132.0
1000	110.0	71.5	140.0	126.0

Fluorescent lamps were not as closely examined, as it was originally thought that they would not be very important for parking lot lighting. However, the recent PIER report[3] on outdoor lighting in California indicates that 9 percent of existing parking lot fixtures have CFL lamps

[3] PIER Outdoor Lighting Baseline Assessment, November 11, 2002.

(presumably wall packs associated with apartments, etc.), and that another 6.5 percent have straight or u-tube fluorescent lamps (such as canopy lighting in gas stations that illuminate the parking area). These percentages are significant enough to warrant further consideration. The efficacy of straight and u-tube fluorescents is generally better than 80 lumens/watt maintained, so these lamps all meet the European standard. All the CFLs are below 45 watts, and their efficacies range from 54 to 65 lumens/watt maintained, and 63 to 76 lumens/watt initial, so these lamps also meet the standard.

3. Applicability of European Requirements to Parking Lot Standards for California

3.1 General comments

As it currently stands, the European specification has limited applicability to an outdoor parking lighting standard for California. The European specification was meant to apply to roadways and parks, and as such only addresses pole-mounted and post-top types of fixtures. There are a substantial number of parking lots that are closely associated with buildings, and are lit by wall or soffit mounted fixtures. Furthermore, the single-fixture approach used in the European standard is tied to a specific physical layout. This is fundamentally different than that of IES recommended practice for parking facilities (RP-20-98), which controls the performance of the lighting system as a whole and allows for greater flexibility in mounting heights, locations, spacing, and candlepower distributions. In the European standard, there is essentially no interaction between fixtures, which may be unacceptable in a parking lot installation as such systems will provide almost no light near the pole when there is a lamp or fixture failure. Some of these problems can be resolved by changing the specific levels of the requirements, but the best approach would be to convert the restraints of the European regulations to a system specification as used by IESNA. The following sections discuss the European requirements and suggest ways they can be adapted to this approach.

3.2 Luminance restrictions

Because the luminance restrictions in the European standard are based on a standard geometry, using different mounting heights and spacing will have a significant effect on luminance. If the European requirements are to be adapted for use in California, it is important to understand the basis for the luminance restrictions so the original intent of the specifications can be preserved. Unfortunately, the intent of the restrictions in the European standard was not explicitly stated. However, it is possible to examine the restrictions in terms of their effects. For example, bright sources of light can cause discomfort and disability glare. There are several formulas for calculating discomfort glare under different conditions. Regardless of which formula was used, researchers found that the calculated levels of discomfort for the European standard varied over a very wide range as a function of the view angle, and therefore it did not seem likely that control of discomfort glare was the basis for the restrictions. Further examination of the standard suggests that the luminance restrictions are intended to meet two goals: 1) to reduce veiling (disability) glare, and 2) to reduce light trespass.

3.2.1 Veiling glare

The eye is not perfectly transparent. When light from a bright source enters the eye, a small fraction of it is scattered to other angles. This scattered light reduces visibility in the same fashion as a veil of light over the entire scene, and is therefore called veiling glare. The level, or luminance, L_v, of this veiling glare can be computed from the formula:

$L_v = 10 * E_v/\Theta^n$, where for $\Theta < 2$, $n = 2.3 - 0.7 * \log_{10}(\Theta)$ and for $\Theta \geq 2$, $n = 2$.
E_v = the vertical illuminance at the plane of the observer's eye.
Θ = angle in degrees between the glare source and the line of sight.

Figure 3 below gives a graphic representation of how veiling luminance is calculated.

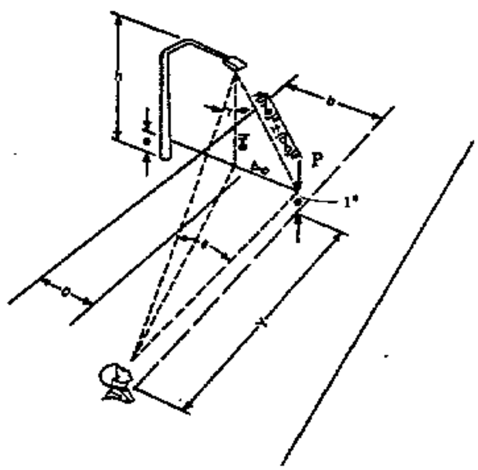

Figure 3. Method for calculating veiling luminance as shown in IESNA RP-8-98 (recommended practice for roadway lighting).

Using the European luminance restrictions, the calculated veiling luminance for a 0.5 m^2 sized fixture is approximately constant (0.03 to 0.12 cd/m^2) for view angles from 45° to 70° from the horizontal. This suggests that veiling luminance is the basis for the restrictions corresponding to these particular angles. The veiling luminance produced by a fixture depends upon its candlepower (luminance multiplied by area) and mounting height. At a fixed luminance, a larger fixture produces more glare. At a fixed angle, increasing the mounting height increases the distance to the observer and thus decreases the glare. In order to allow for flexibility in design, the restrictions need to be placed on the veiling glare itself, and not the luminance or candlepower of the fixture. This could be achieved by basing the future California standard on the type of recommendation used by the IESNA.

The IESNA recommendation is in the form a ratio of veiling luminance to average luminance, and is given as a range and not as a fixed upper limit. The average luminance can be estimated from the "preliminary design" estimate of 10 lux (for basic parking lot lighting) or 25 lux (enhanced security lighting), and the average pavement reflectance of 7 percent. Using these values to convert the ratios to veiling luminances results in an estimated range of 0.07 to 0.2 cd/m^2 for basic parking lot lighting, and 0.2 to 0.6 cd/m^2 for enhanced security. The IESNA basic classification is about two times the range used in the European specification, and the enhanced security classification is about five times the range (even given the very large fixture size used in the calculation). Before any specific glare reduction measures are implemented, it should be determined whether it is possible to reduce glare and still meet the IESNA recommendations on the minimum vertical illuminance. Vertical illuminance aids in detection of pedestrians, and is therefore an important part of the IESNA parking lot recommended practice. Vertical illuminance is most efficiently produced by light that also produces veiling glare. A study would be useful to show what levels of vertical illuminance are possible for any given level of glare.

3.2.2 Light trespass

Light that falls off the boundary of a site and interferes with another person's use or enjoyment of the off-site area is called obtrusive light, or *light trespass*. This is to be distinguished from *light pollution*, which refers to light that escapes into the sky and causes problems with astronomical viewing. In the European standard, the lower luminance restrictions (5 cd/m^2 and 300 cd/m^2) listed in the European standard are for view angles and directions that place the observer off the road. Thus, these restrictions are essentially a way to reduce light trespass. In adapting the European standard to California, the specifications could be translated into a luminance restriction at the boundary of the parking lot, but it would no longer be a fixed angle restriction, as parking lot sizes and mounting heights vary. One option is to limit luminance at a specified distance from the parking lot, which could be a function of the lighting zone designation. Again, further clarification is needed on the rationale for the particular luminances chosen, before deciding on the actual form of the requirements.

3.3 Illuminance levels

The European specification lists only one set of illuminances for all conditions. Furthermore, its illuminance levels were designed to meet the needs of the residential road or park user. In a parking lot, where illuminance requirements may vary depending on the context, a single set of illuminances may not be appropriate. For example, the IESNA recommendation RP-20 lists two light levels for parking lots, one for basic lighting and one for enhanced security. The minimum levels specified in the European standard are slightly lower than those recommended by the IESNA as suitable for "basic" lighting needs, and significantly lower than those recommended for "enhanced security" needs.

The CEC has further differentiated illuminance requirements based on the Commission Internationale de l'Eclairage (CIE) definition of four environmental lighting zones, ranging from parks (dark) through rural and urban (low and medium lighting) and up to limited areas of high illumination levels (such as adult entertainment zones). The CEC draft standard for parking lots limits the wattage/ft^2 (input power to the ballast/lit area) as a function of the lighting zone. Although this is not a strict illuminance requirement, there are practical limits on the efficacies of the sources and fixtures, so this is effectively a restriction on the average light levels of the parking lot for each of the four zones.

The effect of power restrictions on illuminances is demonstrated below in Table 5. The first two columns give the environmental zone designation and the proposed power allowance. Columns 3 to 5 give the calculated illuminances, assuming typical ballast losses of 10 percent, and a 50 percent coefficient of utilization (CU), which is the fraction of light from a lamp that actually falls on the work plane (this is due to light loss within the fixture, absorption by dirt, and light going outside the work area). A mean lamp efficacies of 60, 85 and 110 lumens/watt was also assumed. The lowest value in the table is the minimum lamp efficacy that meets the CEC draft standard. The next two values are the approximate maximum efficacies from Table 3 for MH and HPS lamps, respectively, of 400 watts and below. This is only a rough calculation, in that the CU may be lower than 50 percent if the installation has to meet the cut-off requirements as well as the IESNA requirements on vertical illuminance.

Table 5: Power allowances and estimated maximum average illuminances for environmental zones at three different efficacy levels

Zone	Power allowance	Lux (60 lpw)	Lux (85 lpw)	Lux (110 lpw)
1	0.04	12	16	21
2	0.06	17	25	32
3	0.08	23	33	43
4	0.20	58	82	107

The European specification requires that illuminances be above 10 lux near the fixture, but can be less farther away. Ten lux is lower than the lowest value in table 5, so this portion of the European specification should easily meet the proposed CEC power restrictions.

In contrast to the CEC draft standard, the IESNA recommendation RP-20 specifies minimum illuminance levels that are required for visibility and security. These levels are independent of the area classification, as the IESNA does not recommend different light levels for different zones. The IESNA recommended levels can be met in zones 1 and 3 as long as there is reasonably good control of the uniformity of the illuminances (5:1 or so), as it is the minimum illuminance that is controlled by RP-20, and the average level that is specified in the draft CEC standards.

The CEC levels were partially modeled on meeting the IESNA recommendations[4]. Since the European specifications are less than the IESNA recommended minimum levels, they are unlikely to be acceptable. One question that remains to be answered is whether lower light levels can be used if the light source is white. Although there is currently a great deal of interest in this issue, it is not discussed in the European specification (see section 3.5)

3.4 Light pollution

The CEC draft code agrees with the European specification in banning direct uplight. The IESNA system already specifies illuminances and veiling glare, but it does not control light pollution, or near horizontal light. The European light pollution constraint could easily be added to an IESNA style of specification, but there is some uncertainty as to whether this would actually reduce overall sky glow. The European approach to the control of light pollution is a special case, in that it is a ban on any direct light at or above horizontal from the light fixture.

[4] However, examination of Figure 4 (p.20) of the California Outdoor Lighting Standards report (Eley Associates, 6/6/02) shows what appears to be a significant discrepancy in the location of the minimum luminance point. This means that the validation of the CEC levels may not be correct and so the CEC levels may not be appropriate.

The only way a lighting system can have no direct light above horizontal is if each of the individual fixtures produces no direct light above horizontal. In this particular case, the system approach used by the IESNA would have to be a restriction on the fixtures themselves, as is used in the European approach.

However, a recent series of papers by David Keith[5] has called into question the utility of limiting only the direct uplight. Keith notes that the total uplight is the sum of the direct component, plus the reflected components from the road surface and its surrounds. His calculations over a large sample of test installations indicate that the indirect light is actually an important fraction of total uplight[6]. The amount of reflected uplight tends to be larger for cut-off style fixtures (which control direct uplight) than for semi cut-off or non cut-off fixtures (which do not control direct uplight). Keith's work would again suggest a system approach where total uplight, included the reflected component, is limited. In this respect, the European standard may actually be counterproductive.

3.5 Lamp characteristics

3.5.1 Lamp efficacy

With regard to lamp efficacy, the European specification is slightly more demanding than the current CEC draft recommendations. The proposed CEC standard also has an efficacy restriction, but it is 60 initial lumens/watt for lamps greater than 100 watts. As such, it does not apply to fluorescent lamp fixtures. Both the European and CEC standards unequivocally eliminate halogen and standard incandescent lamps, which currently comprise about 10 percent of the lamp count in parking lots (PIER NBI 11/02 report). The European standard also eliminates small metal halide lamps, whereas the draft CEC standard does not. Eliminating small metal halides may not be a good idea, as there are advantages to the white light that these lamps emit as compared to the yellow light that HPS and LPS (low pressure sodium) lamps emit. The improved color HPS lamps also pass the CEC standard (white HPS lamps do not). As color rendering and brightness issues may be significant for outdoor lighting, and parking lighting in particular, it appears that the CEC recommendation is more appropriate.

3.5.2 Color and light spectra

The European specification classifies luminaires into those sources with color rendering indices (CRI) of 79 or less (all standard HPS, comfort HPS, LPS, and some MH) and CRI of 80 or more (white SON and the remaining MH), but does not include any restrictions based on these classifications. The recognition of car colors may be an issue in a parking lot, but color rendering is not currently covered in the IESNA parking lot lighting specification. The lamp spectra can also affect brightness, and peripheral visibility, both of which may be issues in parking lot lighting, and neither of which are covered in current standards. It should be noted that a CRI of 80 is quite high, and is not met by the quartz metal halide lamps made by Venture

[5] Keith, David M. "Roadway Lighting Design for Optimization of UPD, STV and Uplight." Journal of the Illuminating Engineering Society. Volume 29, No. 2: 15-23.
[6] Direct uplight was less than 20 percent of total uplight for the sample "best" semi-cutoff and cutoff fixtures, and ranged as low as 0.3 percent. Direct uplight is 0 percent for full cut-off fixtures.

lighting, although it is met by the ceramic lamps made by Phillips as well as the better quality fluorescent lamps. Since the European specifications do not put any actual restrictions on lamp spectra, the discussion of the potential implications (including energy savings) of changes in light spectrum is deferred.

4. Discussion of Possible Retrofit Strategies

The European specification only addresses pole and post-top mounted fixtures, and is focused on source efficacy, glare, light trespass, and light pollution control. For pole and post top fixtures, the source is almost always a HID lamp. The source efficacy provision of the European specification would ban all mercury lamps, and many metal halide lamps. As white light is perhaps desirable, it seems more reasonable to stick to the CEC efficacy proposal, which is set slightly lower and would ban the mercury lamps, but not the metal halide lamps. Companies such as Venture lighting make a selection of metal halide lamps that can run on mercury ballasts. For wattages where there is an equivalent metal halide replacement, retrofitting a fixture would simply mean swapping lamps. The main issue here is that of enforcement, and it might require restrictions on lamp availability.

As noted earlier, it is probably not practical to meet the exact wording of the European specifications on luminance and illuminance, but it may be possible to develop standards, and retrofits, that fit the spirit of the specifications in improving lighting quality. A light fixture can be retrofitted by replacing the fixture or head, by changing the optics, or by shielding the fixture. For pole mounted fixtures it appears that pole arms generally come in a few standard sizes, with the fixture heads bolted on to the pole. In the case of a standard pole arm size it seems likely that retrofit would be nearly as simple as disconnecting power, unbolting the old fixture head, bolting on the new fixture head, and reconnecting power. This retrofit would allow a very wide flexibility in candlepower distribution for the new fixture. About the only thing it does not provide that an entirely new fixture would provide is control over fixture height. A similar strategy may be possible for post-top mounted fixtures as well.

Every manufacturer has their own style of fixture, so a retrofit kit for the optics would probably need to be designed by the manufacturer of the fixture. This would be less flexible than a new head, or considerably more expensive, as the existing head design constrains the size and location of the optics relative to the lamp.

The last choice, shielding of the lamp, is really only applicable to retrofits designed to eliminate light pollution, as the shield can have only a minor effect on the candlepower distribution inside the shield angle (by redirecting light striking the shield into this angular range). Shields are, for the most part, only applicable to pole-mounted fixtures, as many post-top area lights would be difficult to shield. Furthermore, it would be aesthetically inappropriate to apply a shield to a globe or other decorative style of post-top fixture. Again, it should be noted that every manufacturer has their own style of fixtures, so a shield designed to attach to the fixture itself would be most easily designed by the manufacturer of the fixture. In fact, some manufacturers already produce shields that can convert an existing fixture into a cut-off type.

Since a shield is a fairly simple device, it is possible that shields could be designed to mount to the pole arm instead of the fixture. Shields could then be made in a limited range of sizes to accommodate the more common non cut-off fixtures. The downside of this approach is that the shield is unlikely to be optimized for a particular fixture, and it may not complement the aesthetics of the fixture. The upside of this strategy is the relative low cost and wide applicability.

A fair amount of parking lot lighting is accomplished by wall or canopy fixtures. Although the European standard does not address this fixture style, the general principles of glare control are equally applicable. Because parking lots attached to a building come in an extremely wide variety of shapes, glare and light trespass control would require some flexibility in the availability of candlepower distributions. This again, is a problem that would require some research into what is both available and desirable. Retrofits for wall packs, floodlights and canopy lights will most likely require fixture head replacement, so the issue may be to develop a set of target distributions for manufacturers.