Energy Efficient Exit Signs

Codes and Standards Enhancement (CASE) Study

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Introduction

CASE Initiatives are a series of Codes And Standards Enhancement (CASE) studies that present arguments for inclusion of specific energy efficiency technologies or practices into existing energy codes. The goal is to assist stakeholders in achieving consensus. This CASE study, which covers energy-efficient exit signs, includes discussions of:

- the technology,
- current practice,
- economics,
- key stakeholders, and
- implementation options and recommendations for inclusion into codes.

Technology Description

Today, exit signs are required in all public buildings. In the 1940s, a growing awareness of the need for clearly marked signs fueled the development of building and electrical codes to ensure clear visibility of emergency departure routes. As a result, facility managers must now meet requirements of the National Fire Protection Association, National Electrical Code, and U.S. Occupational Safety and Health Administration. Although exit signs are mandatory fixtures, facility managers have the freedom to choose from a variety of light sources.

There are more than 100 million exit signs in use throughout the United States, consuming 30 to 35 billion kWh of energy annually. Light sources typically used to illuminate exit signs include incandescent, compact fluorescent (CFL) or light-emitting diodes (LED).

A market data study conducted in 1998 by Rensselaer Polytechnic Institute's Lighting Research Center (LRC), found that 80% of the exit signs sold nationally by 11 manufacturers (that are Energy Star Exit Sign partners)[1] are LED exit signs. Figure 1 shows an example of LED exit sign technology.

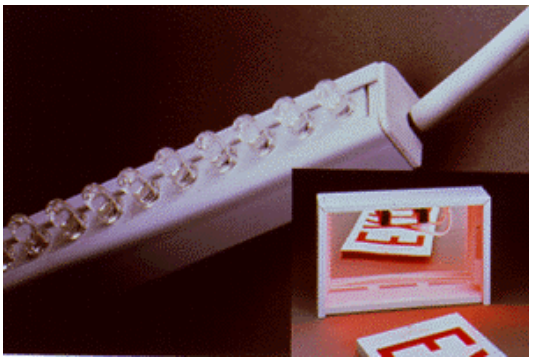

Figure 1. LED Exit Sign

The vast majority of exit signs currently in use, however, are lighted by incandescent lamps. These present high energy and maintenance costs. Exit signs using incandescent lamps consume approximately 24 to 40 watts per sign, or up to 350 kilowatt-hours (kWh) of electricity per year. LED exit signs operate in the 5- to 8-watt range. Compared to an exit sign illuminated with a 13-watt fluorescent source, the LED's energy savings potential is 7 to 10 watts, 24 hours per day (assuming a 2-watt ballast loss in the fluorescent models).

Table 1 compares energy use for typical incandescent, CFL and LED exit signs.

[1] The Energy Star program, administered jointly by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), is a voluntary labeling program designed to identify and promote energy-efficient products.

Table 1. Sign Energy Comparison

Sign Type	Watts per sign	kWh/yr per sign
Incandescent	40	350.4
CFL	10	87.6
LED	4	35

Current Practice

California does not have a standard for exit sign efficacy, and Title 24 does not apply to exit signs. Typical practice in the state before 1995 was to install exit signs illuminated with a 13-watt fluorescent lamp. Worse yet, the installation of exit signs illuminated with incandescent lamps is still allowed.

But over the past five years, current practice has been migrating to LED technology from incandescent technology.

LED Technology Overview

Exit Sign Formats

The method used to illuminate the lettering and background of an exit sign determines its format: matrix, panel, stencil or edge-lit. Matrix signs use arrays of small light sources, usually LEDs, to form the lettering. In the panel format, a translucent panel diffuses a light source; both the lettering and background are luminous. A stencil sign has an opaque panel that conceals the source; the translucent lettering is luminous. Edge-lit signs feature lettering etched into a glass or plastic panel illuminated through its edge; both the lettering and background are luminous.

Factors Affecting Visibility and Readability

An exit sign may be easily visible, but still not be easily readable if, for example, its letters are not uniformly luminous. Factors affecting a sign's visibility include its total luminance, its mounting location, its color scheme, and obstructions and visual distractions including decorations, other signs, and glare from other light sources or windows.

The size and shape of a sign's letters and chevrons (directional indicators pointing to the exit), the uniformity of their luminances, and the contrast in luminances between the lettering and the background affect a sign's readability. The sizes and proportions of lettering are fairly uniform among exit signs because standards are well established; however, the luminances of the letters vary widely among signs.

Luminance contrast between letters and backgrounds also varies widely among signs and a sign may have a different luminance contrast in a lighted environment than in a dark one. Matrix signs and stencil signs usually have better luminance contrast in dark environments than the other formats because only the sign's lettering (and not the background) is luminous.

Performance Results

Signs using energy-efficient light sources can vary widely in power characteristics, visibility and readability. *Specifier Reports: Exit Signs*, a report by the National Lighting Product Information Program (NLPIP), identifies performance concerns. Understanding these concerns will help specifiers select products that save energy and can be seen in clear-air and smoke conditions. The report identified these issues:

- **Luminance.** All the compact fluorescent and one LED replacement kit had letter luminances greater than the luminance of the host sign. The electroluminescent, incandescent, and two LED kits had lower letter luminances than the host sign.
- **Luminance Contrast.** For all but two of the 57 signs and kits, the luminance contrast between the background and the lettering was greater than or equal to 0.90.
- **Readability.** Readability was reported as the number of subjects unable to discern the orientation of the sign

from 150 ft (46 m) in a dark corridor. Readability was poorest for the radioluminescent signs.

- **Visibility in Smoke.** Visibility in smoke was reported as the distance in feet at which the luminance of a sign would drop below 0.21 candelas per square meter in uniform, medium gray smoke in a room with no other light. Visibility for the fluorescent products ranged from 31 to 41 ft (9 to 12 m); for incandescent products visibility ranged from 21 to 26 ft (6 to 9 m); for LED products visibility ranged from 22 to 33 ft (7 to 10 m); and for electroluminescent products visibility ranged from 11 to 22 ft (3 to 7 m). The luminances of the radioluminescent products were too low for NLPIP to accurately apply the computer calculations.

  These results should be taken as indicative of relative visibility, rather than absolute visibility, because different types of smoke and different smoke densities will change the critical distances.

Life and Failure Rate of Technology

Manufacturers' estimates of the life of LED lamps range from 50,000–438,000 hours. It is quite possible that the actual life is longer. One manufacturer claims that 80–100 years is a reasonable expectation, and notes that some manufacturers claim their LEDs can last up to 570 years (May and Listwa).

The lighting industry typically offers a "rated lamp life" based on a standard test method that documents the number of lamps failing to operate. Rather than fail, though, LEDs begin to "fade away," but continue to operate. Thus new test methods need to be developed that will measure the useful life of LEDs. This is an active topic of discussion between the semiconductor and the lighting industries (Conway 2000).

A survey that PG&E conducted of exit sign distributors found skepticism about any lengthy estimates of LED life. Distributors are somewhat uneasy providing a product whose warranties are for periods longer than their experience with the lamps. None of the distributors interviewed indicated any evidence of LED signs having any greater failure rates than other types of exit signs, but many noted that the signs have just not been around long enough.

Some suppliers pointed out that there are essentially "two tiers" of LED exit signs. "The difference between the top tier and the lower tier is still wide but there is comparability across all of the top tier," said one supplier. A few suppliers also indicated the "lower tier" was populated with "off-shore" brands. Some manufacturers traced failures of exit sign products in the early 1990s to poor manufacturing quality control, particularly at the point in the assembly process where LEDs were soldered onto a socket board (Conway 2000).

Defects and failures were reported to be very rare, but in our study those that were reported tended to be attributed to circuit board defects or a mismatch between LEDs and the circuit "drivers." This could result in a premature decline in light output so that even though the lamps would last many years, they could be visually ineffective after only a few years. LRC suggests that the component mismatching problem could be solved by creating "modular packages of LEDs to make it easier for sign and signal designers to incorporate this relatively new light source … [and] give appropriate design guidelines for system uses (lamp, housing, and controls) and for electrical circuit design" (Conway et al. 1997).

The major "defect" with the first two generations of LEDs was relatively rapid degradation of their light output. The third generation of LED lamps seems to degrade more slowly than the earlier LEDs. E Source reports that newer LED lamps (made of AlInGaP[2]) operate at about 85% of their original output after about 20,000

[2] Aluminum, indium, gallium and phosphorus.

hours (Krepchin 1998). Agilent Technologies, the manufacturer of newer diodes, only claims about 80% of original output after 10,000 hours and just under 75% after about 100,000 hours (Agilent Technologies 1999). This compares favorably with the performance of the older AlGaAr[3] LEDs, which were at about 50% of their original light output after the same amount of time (Krepchin 1998).

Compact fluorescent lamps (CFL) need to be replaced every couple of years, and incandescent lamps every four to nine months. LEDs may only need replacement every 10 to 15 years (or longer). Since LED exit signs last so much longer than the alternatives, persistence of energy savings is not an issue. In addition, this technology does not need commissioning.

Availability

There are at least 28 U.S. manufacturers of LED exit signs that meet the U.S. EPA/DOE Energy Star specifications (Krepchin 1998). The Energy Star Exit Sign Web site lists 12 manufacturers and hundreds of products, although not all Energy Star-compliant products are listed on the Web site.[4]

PG&E conducted a survey of 36 lighting distributors and manufacturers' representatives who sell exit signs in the California market. Nine companies were eliminated from the results because they either were unresponsive on the issue of price or their responses lacked clarity on price or other key issues. Each respondent was asked their price per unit for 100 economy LED exit signs. They were also asked the number sold last year, two years ago and five years ago.

Based on the responses, the current average price of an economy model LED exit sign is approximately $44.[5] This makes the incremental price difference from comparable incandescent signs about $20. Most suppliers indicate that comparable CFL exit signs are no longer available from the major manufacturers.

Suppliers who serve mainly the industrial and institutional (e.g., schools) market pointed out that their customers require die-cast signs for the superior ability to withstand "rough" treatment. However, they claim they can no longer get die-cast signs with incandescent lamps. They are all LED now.

According to the suppliers surveyed, LED signs now have at least 78% of the market, compared to 43% two years ago and 20% five years ago. Of the nine suppliers who sold at least 1000 units last year, seven indicated that at least 95% of their exit sign sales are LED (the other two said 75% and 90%, respectively).

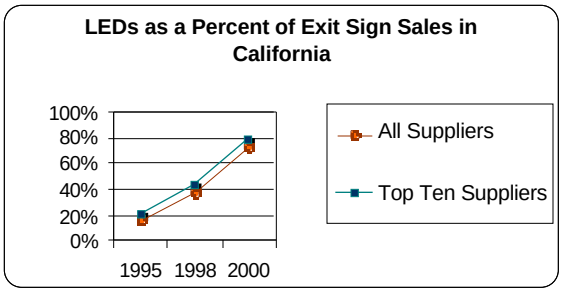

Figure 2. LED Share of Exit Sign Market

Energy Star-labeled exit signs are typically not sold in retail stores. Manufacturers need to contact the EPA to find a representative or distributor.[6]

[3] Aluminum, gallium and arsenide.

[4] U.S. EPA Energy Star Exit Sign Web site: http://yosemite1.epa.gov/estar/consumers.nsf/content/exitsigns.htm

[5] This is an average of all valid price responses weighted by sales volume. The unweighted average price is $52.

[6] See the Energy Star Exit Sign Web site (http://yosemite1.epa.gov/estar/consumers.nsf/content/exitsigns.htm) or call 1-888-STAR-YES for a complete listing.

Economics

The first cost of LED exit signs has fallen so dramatically in the past three years that they will soon be directly competitive with incandescent exit signs; they already cost less than CFL exit signs. Up to this point, the argument for using LEDs was based on overcoming the higher initial first costs through energy and maintenance cost savings within a year or two. Since exit signs are required in virtually every nonresidential building in the state and must be lit 24 hours a day, 365 days per year, switching to LEDs wherever possible will result in significant and secure energy savings.

This section of the report details the energy costs and other costs and benefits of LED exit signs compared to the alternatives. Although switching to LEDS will result in significant savings, the recommendations at the end of this report focus on performance indicators and not on LED exit signs specifically. Eventually there could be new alternatives that would meet the same threshold of performance and efficiency.

signs (EPA 1998a). In Table 3, which shows typical exit sign costs, we used EPA's maintenance costs but updated other numbers. We conservatively estimated the life of LED signs to be 10 years (see discussion in Life and Failure Rate section above), we used an energy cost more in line with current California electricity prices, and we adjusted the typical wattage for LEDs to be closer to what we found available.

The annual cost of operating an incandescent exit sign is approximately $35. The annual operating cost for an LED exit sign ranges from $2.50–$3.50. Primarily because of maintenance and energy costs, in that order, the simple payback period for LED signs versus incandescent signs is less than one year.

At the rate LED exit sign costs dropped from 1995 to 1998, E Source predicted that LED signs would soon be cheaper than incandescent types. In the case of commodity signs with battery back up, the price increment has already fallen to the point that the payback period is less than eight months. LED signs are already cheaper than CFL signs.

Installation costs for new LED exit signs

Table 2. Exit Sign Typical Costs and Performance

Fixture	Typical Wattage	Life (yrs.)	Annual Energy Costs @$0.10/kWh)	Maintenance Costs	First Cost (mtl. only)	Life Cycle Cost 1 yr.	5 yr.	10 yr.	15 yr.
Incandescant	40	0.8	$35.00	$19.50	$25.00	$80	$298	$570	$843
CFL	10	2	$8.75	$9.50	$60.00	$78	$151	$243	$334
LED	4	10	$3.50	$0.00	$45.00	$49	$63	$125	$143

Costs

In 1998, the EPA reported first costs of $55 for incandescent exit signs, $60 for CFL exit signs,[7] and $85 for LED exit

are the same as for CFL or incandescent exit signs according to R. S. Means cost estimating guide widely used in the industry. Therefore, installation costs were ignored in our analysis.

Table 3 provides maintenance cost data compiled from six different sources. The "Frequency" column lists estimates of required frequency of "bulb" replacements. The "Labor" and "Parts" columns are self explanatory, with the exception that the

[7] EPA's estimated first costs include labor. We assume installation labor to be the same for all three technologies, so used only the cost of the signs themselves. In another report, EPA estimated the cost of CFL exit signs to be exactly equivalent the cost of LED exit signs (EPA 1998b); we found LEDs to cost less than CFLs now.

sources did not provide information about how complete the replacement was. For example, it is not clear whether the sources assumed CFL ballast replacement or just lamp replacement.

Central Hudson and FacilitiesNet.com did not directly provide any of the information listed in Table 3, but we were able to calculate the dollar figures based on other data they provided.

As can be seen from the table, the relative costs and frequencies for replacement are quite comparable across sources. One exception to this is FacilitiesNet.com, which gave no data on CFLs, but estimated the cost of incandescent exit sign maintenance much higher than any other source.[8] The average annual incremental cost of maintaining incandescent exit signs over maintaining LED exit signs, without including FacilitiesNet.com, is $29.21. With FacilitiesNet.com, it is $45.17. The average annual maintenance cost increment for CFLs over LEDs is $15.25.

Table 3. Comparative Maintenance Costs

	Business	Incandescent		
Source	Type	Labor	Parts	Freq.
US Energy	mfctr	$ 24.33	$ 16.50	
Central Hudson	IOU	$ 33.00	$ 4.00	
E Source	Indepnd.	of $24.00 incremental		
	evaluator	over LEDs		2-8 mo.
Facility Mgt.	Indust.			
	Assc.			4 mo.
EPA Green Lts	Federal	Total of $19.50		
				.8 yrs.
Facilities Net	Assc.	$ 91.00	$ 18.00	
	Web site			
	Business	CFL		
Source	Type	Labor	Parts	Freq.
US Energy	mfctr	$ 8.33	$ 10.00	
Central Hudson	IOU	$ 10.42	$ 12.00	
E Source	Indepnd.			
	evaluator			1-2 yrs
Facility Mgt.	Indust.			
	Assc.			1+ yrs.
EPA Green Lts	Federal	Total of $9.50		
				2 yrs.
Facilities Net	Assc.	-	-	-
	Web site			
	Business	LED		
Source	Type	Labor	Parts	Freq.
US Energy	mfctr	$0.00	$0.00	
Central Hudson	IOU	$ 1.50	$ 3.00	
E Source	Indepnd.			
	evaluator			10+ yrs
Facility Mgt.	Indust.			
	Assc.			100 yrs.
EPA Green Lts	Federal	$0.00	$0.00	
				25+ yrs.
Facilities Net	Assc.	$0.00	$0.00	
	Web site			

[8]Where no data appears in the table, the source did not provide the data or did not provide enough information to calculate the missing data.

Benefits

Table 4 shows the costs and savings to a typical building owner of various exit sign technologies. The table includes maintenance costs and lamp replacement costs for a typical lifetime.

Table 4. Exit Sign Annual Cost Comparison

	Incandescen	Fluorescen	LED
Current watts	4(	1	1.6
Burn hours/year	876(	876(	876(
Cost per kWh	$0.0	$0.0	$0.0
ANNUAL ENERGY COST:	$28.0	$11.9	$1.1
Hourly Rate	$18.0(	$18.0(	$18.0(
Replacement time (mins)	2	2	2
Yearly replacements	2.9	0.9	none
ANNUAL LABOR COST:	$21.7	$6.7	none
2 lamps per	2@$2.7	2@$4.8	none
# replacements/ year	2.9	0.9	none
ANNUAL LAMP COST:	$15.9	$8.7	none
TOTAL ANNUAL COST:	**$65.73**	**$27.41**	**$1.16**

At the rate LED exit sign costs dropped from 1995 to 1998, E Source predicted that LED signs would soon be cheaper than incandescent types. In the case of commodity signs with battery backup, the price increment has already fallen to the point that the payback period is less than eight months. LED signs are already cheaper than CFL signs.

According to the suppliers in the PG&E survey, LED signs now have at least 78% of the market, compared to 43% two years ago and 20% five years ago. Of the nine suppliers who sold at least 1000 units last year, seven indicated that at least 95% of their exit sign sales are LED (the other two said 75% and 90%, respectively).

Statewide Analysis

Since exit signs are always operating, the energy saved is a simple function of the number of inefficient units replaced by more efficient ones. We estimate that there are approximately 80,000 exit signs installed in new construction in California each year.[9] There are an equal number being installed as replacements or in renovations and additions in California, according to our estimates. We assume that exit sign sales will remain constant at 160,000 per year over the period of the analysis (2001–2012), and that of the 80,000 installed in retrofits, three-fourths replace incandescents and one-fourth replace fluorescent signs for the next 10 years— after which there would be none left to replace.

If 78% of the signs sold are already LED exit signs, as the PG&E survey indicates, then an appliance standard requiring the efficiency level of LED signs would only affect the other 22% of sales. In the following analysis, we assume that the natural growth of LED exit sign's market share would result in LED's having 85%, 90% and 95% of the market in the next three years, so the potential savings would shrink accordingly. We further assume that, absent a requirement in the Appliance Standards (Title 20), the natural market share for LEDs would stabilize at 95%.

The value of the energy savings varies dramatically depending upon the actual rate for energy. Since market prices are in flux and the California Energy Commission is currently creating estimates for them, we used some simplifying

[9] Based on information from surveys performed by the Heschong Mahone Group, the Nonresidential New Construction Baseline (RLW), and F. W. Dodge data being analyzed by Quantum Consulting for NRNC program penetration.

assumptions for our estimates. A more precise estimate should be used to develop the final potential savings analysis. We estimated energy prices for the medium commercial and industrial sectors to $0.10/kWh. These estimated prices hold for all years of the analysis.

Table 5 shows the potential energy savings and capacity savings for a requirement that would result in all new exit signs sold in California meeting the efficiency level of LEDs, based on the above assumptions.

Table 5. Statewide Energy Savings Potential

Year	GWh/yı	MW	$ Millions
2000	9.9	1.1	$ 1.0
2001	16.7	1.9	$ 1.7
2002	21.2	2.4	$ 2.1
2003	23.5	2.7	$ 2.4
2004	25.8	2.9	$ 2.6
2005	28.0	3.2	$ 2.8
2006	30.3	3.5	$ 3.0
2007	32.5	3.7	$ 3.3
2008	34.8	4.0	$ 3.5
2009	37.1	4.2	$ 3.7
2010	39.3	4.4	$ 3.9

Key Stakeholders

Exit sign manufacturers are, of course, one of the key stakeholders with an interest in the energy efficiency of exit signs. The national association representing exit sign manufacturers is the NEMA Emergency Egress Committee. Lithonia Emergency Systems is the largest manufacturer of exit signs in the United States, and has been involved with the Energy Star Exit Sign program since its launch in 1996.

Other important stakeholders include exit sign distributors, building owners and tenants, and lighting designers and contractors.

Implementation Strategies and Recommendations

Currently, the California Building Energy Efficiency Standards (Title 24, Part 6) exempts from the calculation of total watts per square foot of lighting any required exit signs that have an efficacy greater than or equal to 40 lumens per watt and a power factor greater than 90%. CFL exit signs are exempted from the calculated lighting wattage, while incandescents and LED exit signs, both of which operate at about 15 lumens per watt,[10] must be included.

Compared to standard incandescent exit signs, LED exit signs, with a lower number of watts per square foot, essentially provide a credit in the lighting power density (LPD) calculation. But because CFLs have an efficacy that exempts them, they essentially provide an LPD credit compared to either incandescent or LED exit signs. We suspect that there are few, if any building departments in California that are aware of this distinction. Our experience suggests that exit signage is often not counted in the lighting power densities of nonresidential new construction permits.

ASHRAE Standard 90.1–1999 requires that exit signs operating at or above 20 watts per sign shall have a minimum source efficacy of 35 lumens per watt. Standard incandescent exit signs will typically operate at about 22 watts with an efficacy of 13 to 15 lumens per watt. LED signs operate at about the same efficacy, but a much lower wattage.

Another important element of the Title 24 code development process will be the determination of what non-energy performance specifications need to be included as minimum qualifying criteria. One alternative is to simply reference UL 924, the Underwriter Laboratories' Standard for Emergency Lighting and

[10] Some of the newer LEDs operate at 20–25 lumens per watt.

Power Equipment. This has the advantage of simplicity and avoiding a potential controversy within the CEC's standards development process on issues that are not purely energy-efficiency related. However, the UL 924 standard may not be restrictive enough. Some manufacturers attack it as allowing patently inferior products to qualify (Gilbert 2000). Even those who praise UL 924 for bringing some quality control to the industry support the "tougher" (but voluntary) set of energy and visibility specifications used by the Energy Star Exit Sign program. The Energy Star specifications were developed by the LRC (Conway et al. 1997).

The minimum visibility of signs is required through the state's adoption of the National Electrical Code and reference to NFPA 101. The Commission should specifically reference these standards so that its energy efficiency standard does not push the market to produce and supply signs that may not perform well in regard to visibility.

Some states have adopted a requirement that exit signs flash during a fire alarm. If this requirement were adopted in California, it would effectively leave the choice as one between incandescent lamps and LEDs since CFLs cannot meet that requirement.

Add LED Exit Signs to the Appliance Efficiency Standards

Our recommendation for LED exit signs is that performance standards be adopted within the Appliance Standards (Title 20) that *effectively* require LED exit signs given the current state of the competing technologies. This approach is appropriately technology neutral in that any advances in technology that might conceivably allow another light source to meet the same criteria will be permissible.

This approach also has the advantage of cutting through any confusion that might exist at building departments about including exit sign energy in the building LPD. To further remove that potential for confusion and eliminate an inappropriate bias toward CFL exit signs, we recommend that the Commission specifically state that any lighting energy for required exit signs need not be included in the lighting power density under the building standards (Title 24).

Creating an Appliance Standard for exit signs has the further advantage of centralizing the enforcement and education efforts (focusing on distributors rather than building inspectors). While the Commission has agreed with the building community not to revise the Title 24 Building Standards more often than once every three years, an Appliance Rule-Making can be inaugurated at any time the Commission receives a petition. In fact, it might be possible to include highly efficient exit signs within a currently active Appliance Rule-Making.

The Standard should at least include the minimum performance criteria of "standardized" (such as UL 924) testing, either directly or by reference. The CEC should also consider a higher level of performance specification such as the one adopted for the U.S. EPA/DOE Energy Star Exit Sign program. This higher level seems not difficult for the industry to meet. For example, three years ago over 95% of the exit signs reported on by the LRC's National Lighting Product Information Program had a luminance contrast at least 80% higher than that required by UL 924 (Conway and Boyce 1997).

There are circumstances in industrial occupancies where it may be necessary to use an exit sign that eliminates the chance of an arc, either from an AC source or from a battery. These requirements can be met with alternatives such as photoluminescent signs, electroluminescent signs, or radioluminescent signs (relying on tritium). The Appliance Standard could be written to specifically apply only to signs requiring an electrical input from a DC or AC source.[11]

[11] Anyone concerned that this might

Potential language for the Appliance Standard could borrow heavily from the current Energy Star Exit Sign specifications. The Commission should consider the following:

- New electrically powered and internally illuminated exit signs must meet the following performance criteria:
  - Input power shall not exceed five watts per face.
  - Letter size and spacing shall comply with NFPA Life Safety Code 101.
  - Luminance contrast shall be greater than 0.8.
  - Average luminance shall be at least 15 candelas/meter_ measured at normal (0°) and 45° viewing angles.
  - Minimum luminance shall be greater than 8.6 candelas/meter_ measured at normal (0°) and 45° viewing angles.
  - The ratio of maximum luminance to minimum luminance shall be less than 20:1 measured at normal (0°) and 45° viewing angles.

Testing procedures for determining exit sign performance corresponding to the above criteria are included in the Appendix to this report. These were developed by the LRC for the Energy Star Exit Sign program. Note also that the Energy Star Exit Sign specifications require a five-year manufacturer warranty.

inadvertently push the construction industry to move to photoluminescent, electroluminescent or radioluminescent signs, need only look at the dramatically higher first cost of these signs to realize that a cost-conscious building industry would not use them needlessly.

Bibliography

Agilent Technologies. 1999. Projection of long term light output performance for AS AlInGaP LED technology. Application Brief I-007.

Conway, K. U.S. EPA Energy Star: A specification for energy efficient and visually effective internally illuminated exit signs. Lighting Transformations Program, Lighting Research Center, Rensselaer Polytechnic Institute. (Downloaded 6/15/2000).

Notes that to meet the EPA Energy Star Exit Signs criteria, the signs must use 5 watts or less per face, have a luminance contrast > 0.8, average luminance > 15 cd per square meter, and a minimum luminance > 8.6 cd per square meter.

Conway, K. 2000. Personal communications. (August and September).

Conway, K. and P. Boyce. 1997. Expanding the market for visually effective, highly efficient exit signs. *Right Light* 4.

The typical age of exit signs at replacement is 3 to 10 years. At 1997 prices (approximately $45, $65, $85 and $105 for common incandescent, CFL, efficient incandescent, and LEDs, respectively), the payback period for LEDs at electricity prices prevalent in California, is less than three years. Tests performed by the National Lighting Product Information Program (NLPIP) in 1995 showed that 95% of the LED exits signs tested (57 of 60) had a luminance contrast at least 80% better than the UL 924 standard.

Conway, K., Y. He, P. Boyce and A. Bierman. 1997. Optimizing the use of LEDs in signs and signals for visually critical applications. *CIE LED Tutorial Workshop and Symposium.*

Of the 108 exit signs NLPIP tested in

1997, 97% (105 of 108) performed at least 80% better than the UL 924 standard.

Environmental Building News. 1994. Revolutionary New Exit Signs. *Environmental Building News* Volume 3, No. 3 (May).

Reports that LED exit signs have been on the market since 1985, but initially cost as much as $200 apiece. There are approximately 100 to 150 million exit signs in United States. Converting those would save over 30 billion kWh of electricity per year. (California represents about 1/10 of the market.) At least one manufacturer discussed offering 25-year warranties for all their products.

Boyce, K., T. Shields, and G. Silcock. 1999. Toward the characterization of building occupancies for fire safety engineering: Capability of people with disabilities to read and locate exit signs. *Fire Technology* Vol. 35, No. 1 (First quarter 1999).

Results of testing show that, for people with visual impairments, LED signs are the easiest to see and read, even in smoky conditions.

Fetters, J. 1998. Signs of the future. Maintenance solutions. Trade Press Publishing Corporation (October).

LED drive circuit design is the key to long-life exit signs. New red LEDs have the highest efficacy—nearly 25 lumens per watt. If future fire codes require exit signs to flash (some states' codes already do), LEDs and incandescents could meet that requirement easily, but CFLs cannot. Using very conservative rates for electricity and demand charges (2.59¢/kWh and $12.258/month, respectively), each exit sign should save $13 per year ($5 and $8, respectively). They make the point that this is swamped by the maintenance cost savings.

Gilbert Industries, Inc. 2000 (download date). Reliability debate. http://www.gilbertinc.com.

Argues that LED exit signs are so much more reliable that other kinds of exit signs ought to be made illegal through codes. Requested that the NFPA require light sources for exit signs to have a mean time to failure of ten years or longer. NFPA is not confident that there is a valid test procedure to establish mean time to failure. Article indicates that some LED exit sign manufacturers have made mistakes that led to quick reduction in brightness and even catastrophic failure. They contend these problems can be fixed by specifying which LEDs may and may not be used for exit signs.

Krepchin, I. 1998. Improved LEDs set for exit sign market. E Source. (September).

Reports that the first introduced LED exit signs were expensive, and light output was uneven and degraded more quickly than was acceptable. Now that the prices are down and performance is up, LED exit signs have relatively short payback periods comparable to other exit sign technologies.

Lighting Research Center. Transforming the exit sign market: An Energy Star case study. Rensselaer Polytechnic Institute.

Provides life-cycle cost data and market share data. 83% of respondents' sales were in LEDs, with the next closest (incandescent) at 11%. In California, the LCC savings in five years (compared to incandescents) would be $158, and in ten years, $519.

Lighting Research Center. 1994. Specifier reports: exit signs. Rensselaer Polytechnic Institute (November).

Lists manufacturers of exit signs, both LED and other technologies. Incandescent exit signs use approximately 25–40 watts per sign, or up to 350 kWh of electricity per year (compared with 2–10 watts per sign for LEDs). Updates to this report are available through the LRC web

site, http://www.lrc.rpi.edu.

Marktech Optoelectronics. 2000. LED alphabet soup… What does it all mean? http://www.marktechopto.com.

May, C. and L. Listwa. September 2000 (download date). Winning with LED exit sign technology. http://www.facilitymanagement.com.

LED exit signs eliminate uneven illumination common to incandescent and CFL exit signs. They also help facility managers by providing "virtually maintenance-free operation."

NFPA. Life Safety Code 101. National Fire Protection Association.

Section 5-10 lists the requirements for "Marking of means of egress," and describes allowable characteristics of exit signs. Section 5-10.3 provides the specifications for illuminating exit signs.

Ouellette, M. 1993. Visibility of exit signs: Construction practices. National Research Council Canada.

Rea, M., ed. 2000. The IESNA Lighting Handbook, Ninth Edition. Illuminating Engineering Society of North America.

Light-emitting diodes are improving in efficacy, but still are in the 20–25 lumens per watt range, compared to CFLs in the 40 LPW range.

Suozzo, M. and J. Thorne. 1999. Market transformation initiatives: Making steady progress. American Council for an Energy Efficient Economy.

Reports that LEDs were incorporated into exit signs in the mid-1980s in an attempt to increase reliability and visibility, and to save energy. Non-energy benefits, such as improved visibility and reduced maintenance, were instrumental in facilitating wide market acceptance. Of the exit signs sold by companies who are Energy Star partners in 1998, 83% were LED exit signs and about 70% carry the Energy Star label. As of 1999, only about a quarter of new exit signs continue to be illuminated by incandescent lamps. ASHRAE Standard 90.1R and many state codes already specify energy-efficient exit signs.

Suozzo, M., J. Benya, M. Hydeman, P. DuPont, S. Nadel, and R.N. Elliott. 1997. Guide to energy efficient commercial equipment. American Council for an Energy-Efficient Economy.

Underwriters Lab. 2000. *UL 924 Standard for Safety for Emergency Lighting and Power Equipment: Scope.* http://ULStandardsInfoNet.ul.com.

U.S. Environmental Protection Agency (EPA). Energy Star Exit Signs. 2000 (information downloaded in 2000 from http://www.archlighting.com). Current EPA Energy Star Web site: http://yosemite1.epa.gov/estar/consumers.nsf/content/exitsigns.htm.

Reports that LED exit signs can save between $15 and $20 in electricity costs per year per sign. New LED lamp designs have longer lamp life than other technologies. They last an estimated 15,000 to 100,000 hours compared with high wattage incandescent lamps that last an average of 4000 hours. (One source estimated LED lamp life to be over 150 years.) This provides additional savings and maintenance costs. Their potential marketing cost savings from being Energy Star partners helps to lower the overall cost of LED exit signs compared to other technologies. Also lists manufacturers of LED exit signs.

U.S. Environmental Protection Agency (EPA). 1998a. Selecting and specifying energy-efficient exit signs. U.S. EPA (January).

Compares the life-cycle costs of incandescent, CFL and LED exit signs. As of the date of the paper, the estimated first costs were $55, $60 and $85, respectively. The total five-year

operating costs plus initial costs for the three technologies were $340, $194 and $109, respectively. The U.S. EPA Web site also lists 12 manufacturers and nearly 300 products that fit the Energy Star exit sign criteria.

U.S. Environmental Protection Agency (EPA). 1998b. Lighting upgrade manual: EPA's Green Lights program. U.S. EPA. (September).

Of the exit sign technologies EPA analyzed, LEDs stand out as the clear life-cycle winner. Self-luminous lamps use radioactive material which then have a very high disposal cost. Their first cost is twice that of LEDs, though their annual energy costs are zero. Electroluminescent signs also have high first costs and high annual maintenance costs (besides being extremely poor performers visually). CFLs have a relatively very short life, higher maintenance and energy costs, and cost roughly the same as LEDs to purchase. Although LEDs cost about $40 more than incandescent lamps, they last at least 25 times as long, have roughly $25/yr less maintenance costs, and only use about 1/8 as much energy as incandescent lamps do.

U.S. Department of Energy (DOE). 2000. Buyer tips: DOE procurement. U.S. DOE (July 6).

In recommendations to buyers of equipment for federally-owned buildings, DOE says that CFL exit signs require replacement of lamps roughly every two years while LED lamps only have to be replaced every 10 to 20 years. They also advise that manufacturers' warranties cover replacement of defective parts for at least five years from the date of purchase. They note that this is an Energy Star Exit Sign requirement.

Appendix A

Test Methods for Exit Signs

Conditions for testing

Testing shall be conducted in clear (non-smoke) conditions.

All measurements shall be made in a stable ambient air temperature of 25°C ± 5°C.

All voltages shall be provided within ± 0.5% by a constant voltage power supply.

Prior to input power or photometric measurements, the Exit Sign Model shall be operated at the rated input voltage for a period of 100 hours. In addition, Exit Sign Model with an internal battery shall be operated from the battery for one-and-one-half hours, the minimum period of emergency operation specified in NFPA 101, Life Safety Code, 5-9.2.1, and then recharged for the period specified by the sign manufacturer.

All of the light sources in the sign must produce light throughout the first 100 hours of operation, before any measurements are taken, in order to meet the requirements of this specification.

Input Power Measurement

The input power of the Exit Sign Model in its entirety shall be measured with an appropriate True RMS Watt Meter at the rated input voltage that represents normal operation. For an Exit Sign Model that includes a battery, the battery circuit shall be connected and the battery fully charged before any measurements are made.

Photometric Measurements

Each of the photometric characteristics of the sign shall be measured at three voltages:

- The rated input voltage, which represents normal operation.
- A voltage corresponding to the minimum voltage provided either by the internal battery or a remote emergency power source after one minute of operation, as applicable.
- A voltage corresponding to the minimum voltage provided by the internal battery after the marked rated operating time or at 87.5% of the rated emergency input voltage for signs intended to be connected to a remote emergency power source. The level of illumination of the exit sign shall be permitted to decline to 60 percent of the initial illumination level by the end of the emergency lighting time duration.

All measurements shall be taken with less than 0.01 footcandles of external illumination on the face of the Exit Sign Model.

The luminances shall be measured from two viewing angles: 1) from normal (0°) to the face of the exit sign, and 2) from 45° to the face of the exit sign.

Luminance Measurement Positions

The positions where the luminances for the legend and background of the exit sign are to be measured are shown below.[12] For instances in which Exit Sign Model has a directional indicator, the positions where the luminances for the directional indicator and its background are to be measured are also shown below.[13]

Measurement of Exit Sign Luminance

The luminances for each numbered position in the legend and directional indicator shall be measured over a circular area as large as possible while maintaining at least a 1.6 mm distance between the perimeter of the circular area and the adjacent border. The positions for measuring the luminances of the background shall lie within 25.4 mm of the legend and directional indicator but no closer than 1.6 mm to the border.

Luminance Calculations

- *Average luminance of the legend or background of the legend, whichever is higher, and where applicable, the directional indicator or its background, whichever is highe*r. For each, the mean of the luminances of all the positions measured.
- *Luminance contrast ratio:*

  $$\text{Contrast} = \frac{Lg - Le}{Lg}$$

  Where,

  Lg is the greater luminance and

  Le is the lesser luminance.

Either the variable Lg or Le may represent the legend or directional indicator, and the remaining variable shall represent the respective background.

- *Minimum luminance of the legend or background of the legend, whichever is higher, and where applicable, the directional indicator and its background, whichever is highe*r. For each, the lowest luminance of all the points measured.

- *Luminance uniformity of the legend or background of the legend, whichever is higher, and where applicable, the directional indicator and its background, whichever is highe*r. For each, the ratio of the highest luminance of any position measured to the lowest luminance of any position measured.

[12] "Measurement of exit sign luminance" in NFPA 101, Life Safety Code, Figure A-5-10.3.3.

[13] Found in Figure 40.9 "Directional indicator luminance measurement points" in UL 924, Standard for Safety: Emergency Lighting and Power Equipment, May 9, 1995.