Expanding the Market for Visually Effective, Highly Efficient Exit Signs

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ABSTRACT

Although the power demand of a conventional incandescent exit sign is only 20 to 40 watts, the total annual energy expenditure for the 100 million exit signs estimated to be installed in the United States is of the order of 17 to 34 TWh. Using exit signs illuminated by lower wattage light sources would conserve a significant amount of energy, and avoid the associated air pollution. By developing a product performance specification for exit signs, the authors and sponsors of this market transformation project have promoted the widespread use of new, energy efficient and visually effective exit signs. The specification was developed through structured interviews with more than 40 key market players, the testing and evaluation of existing products, human factors experiments on visibility, two specifiers roundtables, and a designers workshop. Early market response to the specification, which was introduced in 1996 through a federally sponsored, voluntary, product labeling program, has been encouraging.

Key words: Exit signs, performance specification, market transformation, product labeling.

INTRODUCTION

Most buildings in the United States are required by building codes to have exit signs to mark the means of egress. Most of these signs are self-illuminated and are operated for 24 hours per day, 365 days a year. Although the power demand of conventional, incandescent exit signs is only 24–40 watts [1)], the total annual energy consumption for exit signs nationwide is estimated to be 17–34 TWh. New exit signs illuminated by much lower wattage light sources can conserve a significant amount of energy. The goals of this project were to:

1) Develop a product performance specification for visually effective and energy efficient exit signs,
2) Build the consensus needed to launch products meeting the specification into the lighting market, and
3) Create a protocol for testing conformance with the specification.

THE MARKET IN THE UNITED STATES FOR EXIT SIGNS

We obtained market information from an extensive literature search, United States census data, directories of manufacturers and in-depth interviews with 46 key players in the market. Sales of emergency egress products for new and for renovated buildings combined are valued at approximately US$250 million annually in the US, of which we estimate conservatively that exit signs may account for US$75 million. The US Environmental Protection Agency states that 100 million exit signs are presently installed in buildings in the United States (US EPA 1996). US EPA also reports that "as of August, 1997, 143,752 new, non-incandescent exit signs have been installed" in buildings by participants in the voluntary US EPA Green Lights Program (US EPA 1997).

Manufacturers told us that the average age of the signs that their new products replace is three to ten years old. Our interviewees noted that from 20% to 70% of all signs presently in buildings would not function properly in an emergency, due to inoperable lamps, dead batteries, and other electrical problems. Our literature search located reports of incidents where loss of human life was attributed at least partially to failure or lack of exit signs, improper placement of exit signs, or poor directional information

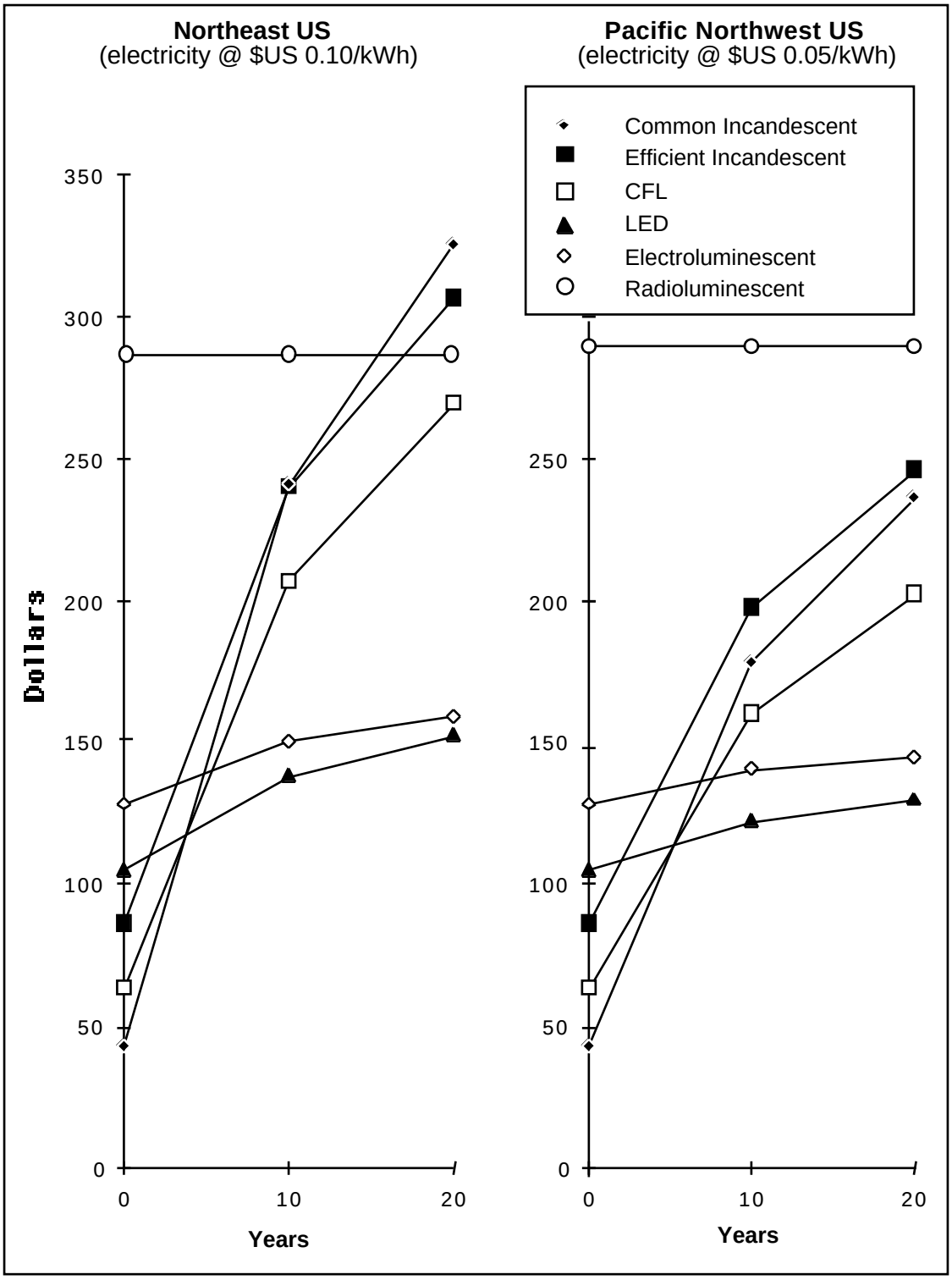

Figure 1. Life Cycle Costs of Exit Signs for Two Areas of the US, by Type of Light Source [2].

on exit signs (Willey 1971; Bell 1979; Anon. 1983).

The cost of an exit sign varies by type of light source, the materials used to form the body of the sign, the quality of the battery and associated circuitry, and the sophistication of any self-diagnostic devices. Broadly, the market for exit signs can be divided into two parts: one dominated by first cost, in which the products use incandescent lamps in a weak metal or plastic box and have no diagnostic capability; the other part of the market is characterized by products designed with a longer-term view of operating and maintenance costs, using more energy efficient light sources, substantial construction materials and sophisticated diagnostic technology. Interviewees predicted that incandescent light sources would continue to dominate the first cost part of the market, unless the cost of LED signs decreases dramatically. The life cycle cost analysis for the major types of exit signs shown in Figure 1 helped the sponsors determine which types of signs would be suitable for inclusion in their market transformation programs.

Table 1. Market Barriers to the Adoption of Energy Efficient Exit Signs.

Customer	Barriers/Concerns	Possible Solutions
Owners	First cost is the major factor. When energy efficiency is considered, the product must have a short payback period: "Use the cheap stuff —why exceed the minimum?"	• Increase demand for efficient signs, to increase volume of production, and reduce costs. • Introduce a building energy code requirement that would eliminate the most inefficient and least visible signs.
	Reliability of products is important, because they are liable for safety of occupants.	• Test products objectively and make results accessible to specifiers. • Initiate labeling program.
Developers	Prefer to use products with which they are familiar because it takes time and effort to select reliable new products.	• Demonstrated use by peers. • Model specifications. • Initiate product labeling program.
Installers	Want to be sure products are independently listed and comply with all code requirements.	• Bring qualified new products to the attention of fire marshals and code officials.
-		• Initiate product labeling program.
Designers	Some want unobtrusive, stylish products: "All they want is a bronze face." Others choose the highest illuminance: "Signs are to show people how to get out of the building; I don't care how much energy they use."	• Demonstrate that energy efficient signs can also be visually effective and aesthetically pleasing. • Encourage manufacturers to introduce more efficient designs at reasonable costs.

PARTICIPANTS, BARRIERS, DISTRIBUTION AND MANUFACTURING

The market for exit signs is complicated, involves many participants, and numerous processes. Primary players include those who: determine what is necessary (code-making organizations, testing laboratories, building inspectors, and fire marshals), supply the equipment (manufacturers and electrical distributors), specify what should be installed (architects, electrical consultants, electricians, building contractors, energy service companies, facility managers, and designers) and pay for what is installed (building owners and developers). All these people interact to determine which exit signs get installed. The market is also influenced indirectly by utility rebates, new knowledge from research and product testing, and lobbying of code makers and regulators by manufacturers' trade associations. From the interviews, roundtables and workshop we identified several significant market barriers to the increased use of energy efficient exit signs, along with some possible solutions, summarized in Table 1.

We found that some of the concerns of owners, developers and installers potentially could be met by a labeling program based on a published specification which would ensure that the products would be energy efficient, visually effective and reliable. We considered it unlikely that any labeling program would do much to change first cost, unless the program would generate intense competition among energy efficient technologies.

DEVELOPING THE SPECIFICATION

Table 2 summarizes our "Performance Specification for Energy-Efficient and Visually Effective Internally-Illuminated Exit Signs." For several earlier versions of this specification we interviewed market players and conducted roundtables, asking respondents if they would find the specification useful and acceptable in their work. With their input we revised the specification until it was as stringent as possible, given these sponsor-imposed restrictions:

• Optimize both the energy-efficiency and visual effectiveness of exit signs, in clear atmospheres. The specification should not address visibility in smoke-filled atmospheres.

• Comply with or exceed the requirements of the National Fire Protection Association Life Safety Code 101 (NFPA 1966) and the testing standard of Underwriters Laboratories, Inc. (UL 924), both used widely in the US. Many local jurisdictions adopt these requirements.

• More than one manufacturer should state that it would be technically and economically feasible to produce a sign that would meet the specification, within six months of publication.

• More than one type of light source could be used to meet the specification.

RATIONALE FOR THE PERFORMANCE REQUIREMENTS

Input power demand was the primary focus of the specification, but we balanced this objective with the life safety concern of providing visually effective performance. After evaluating commercially available exit signs, we concluded that a power demand of five watts per face per sign would be the lowest possible wattage that could be specified if good visual performance was to be achieved by at least two types of light sources. This can be achieved at least

Table 2. A Performance Specification for Energy-Efficient and Visually Effective Internally-Illuminated Exit Signs

CHARACTERISTICS	PERFORMANCE REQUIREMENTS
Energy Efficiency	
Input power demand	Less than 5 watts per face
Visibility	
Letter size and letter spacing	As in current NFPA 101, Life Safety Code, 5-10.2
Luminance contrast	Greater than 0.8
Average luminance	Greater than 15 candelas/meter^2 measured at normal (0°) and 45º viewing angles
Minimum luminance	Greater than 8.6 candelas/meter^2 measured at normal (0°) and 45º viewing angles
Maximum to minimum luminance	Less than 20:1 measured at normal (0°) and 45° viewing angles
Reliability	
Manufacturer warranty for failures due to materials and manufacturing defects	Replacement of defective parts for 5 years from date of purchase

with LEDs, and also with high efficacy compact fluorescent light sources.

The use and placement of exit signs in the US usually falls under the rules (building codes and life safety codes) adopted by local governments, and is not subject at this time to federal mandate. Federally owned and operated buildings have their own set of regulations. Thus for visibility, the constraint that the specification should comply with UL 924 establishes the legend form, size and spacing, because this is the standard that is most widely adopted. Larger legends with greater intercharacter spacing would be visible at greater distances, but previous work shows that exit signs conforming to UL 924 are readable by most people at 100 ft, the maximum distance anyone would be from an exit sign, so long as the emergency egress installation conforms with the NFPA Life Safety Code 101 (Collins and Goodin 1991; Boyce 1994; Boyce and Mulder 1995).

Luminance contrast is, along with legend size, one of the most important determinants of visibility. UL 924 specifies a minimum luminance contrast between exit sign legend and background of 0.5 in a completely dark room. For a given legend size, the higher is the luminance contrast, the greater is the visibility of the legend. While a luminance contrast of 0.5 meets the UL 924 standard, luminance contrasts higher than 0.8 in a dark room are quite common in commercially available exit signs (Boyce 1994). For example, of the 60 energy efficient exit signs evaluated by the National Lighting Product Information Program in 1994 and 1995, all but three had a luminance contrast of 0.9 or greater (Boyce 1994, Bierman 1995). So, to stimulate the continued production of high performance products, the authors and sponsors agreed that the minimum luminance contrast would be greater than 0.8.

The minimum average luminance of the legend or background also is important for visibility. The results of Boyce (1994) and Bierman (1995) can be used to show that at an average luminance of 15 cd/m^2, about 95% of observers can detect the orientation of the word "EXIT" at 100 ft. This percentage would increase as observers approach the sign. Thus we set a minimum average luminance of 15 cd/m^2 for sign legend or background.

The average of the measured luminance points does not indicate the extremes of the range of luminances present. Thus a minimum luminance is specified to eliminate the possibility of having an average luminance which meets the specification but which contains some very low luminance points. The minimum luminance of 8.6 cd/m^2 at any measurement point on the sign legend or the background is taken from proposed revisions of UL 924.

Luminance uniformity increases the visibility of an exit sign, especially when it is viewed at a distance. A minimum average luminance and a minimum luminance at any measurement point are not enough to eliminate a few high luminance measurement points. Limiting the ratio between maximum and minimum luminances to less than 20:1 for the measurement points on the legend or the background prevents non-uniform luminance. This value came from a draft Canadian Standard Association standard for exit signs (CSA 1995).

The average luminance, the minimum luminance and the maximum to minimum luminance ratio are specified at two angles, normal to the face of the sign and at 45º, because exit signs may have to be viewed from several different angles. We assumed that the worst case viewing angle would be 45º from the normal to the face of the exit sign because exit signs can be mounted either parallel or perpendicular to a wall. Some light sources, such as LEDs, are strongly directional. To meet the performance requirements, this characteristic must be carefully incorporated into the optical design of an LED sign.

It was difficult to propose any measurable reliability characteristics that would apply generically to several types of light sources. Instead, we proposed a three-year manufacturer warranty. Input from various key players in the market persuaded the sponsors to adopt a five year requirement, which should be a sufficient period of time for most manufacturing defects to be discovered, especially defects in light sources and electrical circuits.

We also drafted a testing protocol, and used it on a trial basis to evaluate twelve exit signs of various styles and incorporating several light sources. The final protocol is appended to the specification documents so that manufacturers can self-certify their signs, or so that anyone could bring a sign to an independent laboratory for testing (US EPA 1996a).

RESULTS: WORKING IN A RECEPTIVE MARKET

The US exit sign market was dynamic and open to improvements. Specifiers were seeking lower cost signs, but did have an interest in visual performance and reliability. There was a distinct and rapid trend toward signs that use LEDs as a light source, but the prevalence of low-cost signs using incandescent lamps obviously would remain a stubborn barrier unless the costs of signs using other light sources decreased. Exit sign manufacturers were receptive to the US EPA's proposal to initiate a national, voluntary product labeling program. Manufacturers sought ways to introduce new products to customers and to fill the gap in demand caused by the decline of electric utility incentive programs. Several manufacturers expressed a business interest in retiring their old, less efficient product lines, especially those that cost as much or more than newer technologies to produce, maintain and operate.

Although code and standard change is a slow, consensus-based process, the individuals we interviewed were sincerely concerned about life safety. Many influential market players, such as insurance companies, code officials and fire marshals, were unwilling and unable to demand installation of products that would exceed the minimum building and life safety codes; however, they indicated that they would support more stringent requirements if these were adopted by national organizations.

Evidence of feasibility and public support that we gathered helped US EPA decide to launch an Energy Star Exit Sign Program, in cooperation with the US Department of Energy. Eight manufacturers became Charter Partners in June 1996 by signing a voluntary memorandum of understanding. By September 1996 four more joined, and the manufacturers began to label and advertise Energy Star products. As of September 1997, most major manufacturers of exit signs had joined the program, bringing the number of Partners to 28. At a recent lighting trade show the manufacturers promoted Energy Star products by prominently displaying the program logotype, and by providing prospective customers with educational brochures.

The two other sponsors of this endeavor have each introduced programs to complement and support the Energy Star program. One is conducting a competitive incentive program designed to provide matching funds for innovative research and development of energy efficient lighting products in New York State, including exit signs. Another is increasing specifiers' awareness of and access to the Energy Starexit signs by providing information and product demonstrations at a regional lighting design center in the Pacific Northwest, and supporting electronic information links to manufacturers and distributors.

To stimulate demand for Energy Star products, and thus help lower the per unit cost, we are communicating through trade publications and through on-line media to interest procurement collaboratives and large-volume purchasers to adopt the Energy Star specification (Conway 1996, EEPC 1996, LRC 1997, US EPA 1996b). So far, the US Federal Energy Management Program, which applies to government buildings nationwide, encourages the purchase of Energy Star exit signs, and the US Postal Service has announced a procurement contract with a single manufacturer for more than 16,000 units (USPS 1997). Several major electric utilities are considering incorporating the Energy Star specifications into their product incentive pre-qualifications.

CONCLUSIONS

The Energy Star labeling program and the other programs implemented by our sponsors appear to be successfully increasing the creation and use of visually effective and energy efficient exit signs. It is still too early to know if this is a true market transformation, one that will persist in the market without any support from sponsors; however, our recent interviews with purchasers of Energy Star exit signs have elicited strongly positive comments about the performance of the signs. Surprisingly, both manufacturers and specifiers have approached us to ask about a more stringent specification, the energy saving potential of emerging lighting technologies, especially LEDs, being the stimulus for this interest. We believe that the initial success of this market transformation effort is due to:

- Listening carefully to manufacturers, specifiers and customers from the start of the project.
- Exceeding but not contradicting established product specifications and codes.
- Developing a technically justifiable and testable specification.
- Building consensus throughout the process.

Fortunately, alternative technologies were available for use in exit signs and the manufacturers were interested in trying them. It is much easier to work with a market trend than to initiate or counter one! We hope that this paper might inspire program developers in other countries to emulate this process for exit signs or for other lighting applications that are ripe for market transformation.

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ENDNOTES

1) Prior to the introduction of exit signs with high luminous efficacy, conventional exit signs in the US used one or two incandescent lamps, usually 12 (nominal) watts apiece. Some used two lamps in case one lamp burnt out prematurely; other signs had larger housings and face plates than those used today, and needed two lamps for even light distribution. Both "A-line" and tubular incandescent lamps were used. Some signs used a single 40 watt "A-line" lamp. Many of these older signs are still operating in US buildings, and many manufacturers still offer signs that use two 12 watt incandescent lamps.

2) For this comparison, we used a software program developed by the US Department of Commerce, National Institute for Standards and Technology, entitled "Building Life Cycle Cost, BLCC version 4.0, 1993. The graphs show the cumulative cost (initial cost of the exit sign plus the cost of electricity used to operate the sign year-round for 24 hours per day) for ten, and for twenty years, in two states with differing electricity rates. Electric utility customers in the Northeast area pay some of the highest rates in the US, while customers in the Pacific Northwest pay some of the lowest rates. The first cost of the signs is shown by the symbols positioned on the vertical axis. We arrived at these costs by averaging bids submitted by six electrical distributors for 50 units of each of several models of each type of exit sign. The "common" incandescent exit sign is a widely-used commodity grade product that draws 23 watts of active power. The "efficient incandescent" sign uses miniature incandescent lamps. The active power for the other types of signs is the calculated average of the signs that were tested by Boyce (1994) and Bierman (1995). Radioluminescent signs do not require any power input. Other assumptions for the analysis include a base date of January, 1996, a commercial discount rate of 12 percent, and an inflation rate of three percent. For the exit signs using incandescent and fluorescent lamps the annual recurring costs are calculated as:

- (number of lamps in sign) x (annualized replacement factor) x (cost per lamp).

Electroluminescent and radioluminescent signs do not require any lamp replacements. We assumed that no replacements of LEDs would occur. We did not include any labor costs for maintenance or lamp replacement.

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