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Abstract

This paper describes the history, technology development, technology transfer and application of the energy efficient compact fluorescent torchiere. A review of the essential efforts that went into the development of the first commercially available CFL torchiere technologies is described. Also included is a review of the performance issues related to lumen matching capabilities. Furthermore, the paper overviews the critical steps and successes that occurred as this technology made the transition from laboratory to marketplace.

The energy efficient torchiere promises to have one of the single largest energy saving potentials of any DSM program developed to date. This project represents unique spectrum of industry-laboratory collaborations and addresses an important national energy and safety problem.

Introduction

In 1996, the magnitude of the problem of the halogen torchiere started to become widely acknowledged. Estimates claimed that 15 to 20 million halogen torchieres were annually joining the United States' existing torchiere stock of 40 million. (Calwell, 1996; Calwell and Mills, 1996) The energy conservation world soon discovered that this staggering proliferation of 300 W torchieres represented a major step backward in energy efficiency. Torchieres were consuming five times the amount of energy as was being generated by the nation's photovoltaics and wind turbines.1 But when the Consumer Product Safety Commission (CPSC) reported that the hot halogen lamps were directly responsible for at least 100 fires and 10 fire-related deaths, the intense media coverage placed the issue into the consumer consciousness. Stories of the dangers of halogen torchiere-related fires appeared everywhere from exposes on Dateline NBC to articles in the New York Times. (Brooks, 1997) Market pressure for a safer alternative to the ubiquitous halogen torchiere grew as universities across the United States banned the luminaires and CPSC and Underwriters Laboratory reconsidered their prior approval of the torchieres.

The Lighting Systems Research Group at Lawrence Berkeley National Laboratory has promoted pin-based dedicated CFL fixtures through its "Energy Efficient Residential Fixtures" project since the early 1990's. (This project will be described in greater deal in the "Technology Transfer" section). But starting in 1996 the project began shifting nearly all its efforts to address the emerging torchiere problem. Initial studies focused on characterizing the electrical, photometric and thermal characteristics of the halogen torchieres. These studies found that, in addition to being a fire hazard, halogen torchieres were remarkably energy inefficient, generally operating with efficacies one-third lower than was previously assumed. (Page & Siminovitch, 1997a, 1997b) It was determined that torchieres with compact fluorescent lamps (CFLs) could easily lumen match halogen torchieres while completely eliminating any fire hazard with their cool lamp operation. (Page, et al. 1997) These results were shared with the lighting industry and energy conservation community through numerous conference and seminar presentations.

The next project phase focused on developing CFL torchieres through extensive prototyping. Close collaboration with the lamp, ballast, and fixture industry was crucial during this stage. The lamp manufacturers provided valuable insight on the potential of new, high lumen output CFLs while the ballast companies worked to develop components to operate and control the sources. The closest collaboration was with the fixture industry, where issues of optical design, manufacturability, cost and distribution were considered.

Prototype development was linked intimately with technology transfer efforts at all stages. Promising LBNL prototypes were shared with industry partners for manufacturability and cost considerations while industry prototypes were shared with LBNL for photometric characterization and optimization. The end product of these efforts was the market emergence of a variety of safe, energy efficient CFL torchieres by several different companies.

[1] Annual PV and Wind Energy approximately 3.5 billion kWh (NEIC, 1998). 40 million, 300 W halogen torchieres operated for 4 hours per day, 365 days per year approximately 17.5 billion kWh.

Once quality efficient torchieres could be produced in quantity, LBNL's focus shifted to market transformation efforts. Collaborations between LBNL, the fixture industry and the university community were established to organize high level demonstrations of this new technology. Many universities were very interested in purchasing the new CFL torchieres, not only because of the safety issues, but because the luminaires would pay for themselves through energy savings, often within two years. The fixture industry was able make large enough sales (usually 500 to 1000 units) through these university programs to initiate their manufacturing processes. LBNL provided coordination as well as measurement and verification of energy savings at the demonstration sites.

Now, two years after the halogen torchiere appeared on the energy radar screen, CFL torchieres are available in many retail and home stores across the nation. New CFL technologies continue to emerge, promising to enable a next generation of CFL torchieres that are better, brighter and less expensive.

Research & Development

The primary design goal for the energy efficient alternative to the halogen torchiere was to match or exceed the lumen output of the 300W torchiere. This design goal led to a technical development plan for CFL torchieres that involved two distinct phases: 1) the complete photometric characterization of the halogen torchiere, and 2) creative, practical prototyping and optimization of torchieres involving a multitude of lamp and ballast options.

Lumen matching was considered critical because the halogen torchiere's popularity was closely related to their bright "flood of light" and because consumers are typically apprehensive about CFLs being "too dim." Initial calculations showed that a 300 W halogen torchiere with lamp efficacy of 20 lm/W and fixture efficiency of 80 percent (typical) would produce 4800 lm. Producing 4800 lm with fluorescent sources would require 80W to 100W, generally necessitating four CFLs. While technically feasible, this option was considered too expensive when compared to the halogen torchieres that often retail for under $15.

But a detailed photometric characterization of the halogen torchieres showed promise for the CFL alternative. The vast majority of halogen lamps in torchieres had efficacy nowhere near 20 lm/W. In fact, photometrics on a random collection of 300 W lamps obtained from the Stanford University torchiere replacement program found that the average lamp efficacy was under 15 lm/W. Studies based on this and other data found that typical 300 W torchieres produce only 3200 lm, two-thirds of what was previously assumed. (Page & Siminovitch, 1997a, 1997b; Page, Mills and Siminovitch, 1997) Now CFLs in the 50W to 70W range could be used to lumen-match halogen torchieres. This discovery opened the door to torchiere prototype development with a variety of different sources including GE's 55W 2D, Philip's new T-5 circline, two of Osram's 36W F-lamps, Lights of America or Panasonic's double circline, and multiple 26W quad CFLs.

Table 1 presents electric and photometric data on an average 300 W halogen torchiere and two of the early CFL torchieres produced by manufacturers that worked with LBNL: Emess Lighting and Energy Federation Incorporated (EFI). The halogen torchiere gives off a total of 3242 lm at full output, consuming 272 W, while at half power (131 W) it only produces 20% of its original light output because of dimming losses. (Page and Siminovitch, 1997a) The Emess torchiere, based on the two 36W F-lamp design, has both lamps operating at full output to produce 4041 lm while consuming only 64.95 W. At half power, with only one lamp used, the output is 2132 lm and the power is 39.12 W. The EFI torchiere utilizes similar switching for its three-lamp operation of 26 W quad CFLs. The flux ranges from 3708 lm to 1273 lm while the power is between 72.5 W and 26.26 W.

Table 1. Electric and Photometric Data of a 300 W Halogen Torchiere and Two Energy Efficient Alternatives

	Halogen		**Emess**		**EFI**		
	Full	Half	High	Low	High	Mid	Low
Power (W)	272	136	64.95	39.1	72.5	46.79	26.26
Flux (lm)	3242	648	4041	2132	3708	2523	1273
Efficacy (LM/W)	11.92	4.76	62.22	54.53	51.14	53.92	48.48

The Emess and the EFI torchieres more than lumen-match the halogen torchiere while providing a four to five fold increase in efficacy. Additionally, these energy efficient torchieres provide switchable dimming options that do not significantly diminish efficacy, as found with the halogen torchieres. The Emess and EFI torchieres demonstrate to consumers and the lighting industry that a safe and energy efficient alternative to halogen torchieres can be economically produced while matching or improving upon the photometric performance of the luminaire.

Technology Transfer

The development, technology transfer and commercialization of the first generation of energy efficient torchieres into the market place involved a variety of industry, government and university outreach programs. The following is a brief history of the essential activities associated with this transfer program.

Initially, research efforts at LBNL were focused on establishing a vision for market transformation programs related to residential lighting. This required moving state and federal lighting programs away from the short-term approaches offered by screw-based CFL initiatives to a longer-term solution offered by dedicated (pin-based) compact fluorescent fixtures. It was realized that the best way to overcome the technical, institution, and consumer barriers was to develop attractive, high efficiency dedicated fixtures that were designed explicitly for pin-based CFLs.

In the early to mid 90s, this vision led to a research effort that concentrated on the development of an entire range of dedicated CFL fixtures and technologies. The intent of this effort was to show, through example, that high quality, high performance fixtures could perform as well as or better than incandescent technology. A partial objective of these studies was to convince various government agencies and utilities that dedicated fixtures were indeed the best option to obtain long-term market transformation.

Close contact with the lighting industry, including lamp, ballast and fixture manufacturers, was critical in every phase of this initiative for dedicated CFL fixtures. Educating and encouraging communication within the lighting industry still remains a critical function since most residential fixture manufacturers have little or no knowledge of CFLs, ballasting, optics or integration issues associated with these new sources.

LBNL's dedicated fixture research development efforts concentrated on the most popular and high use luminaires in the home. These fixtures included recessed downlights, portable table and floor lamps (torchieres), surface mounts, and exterior fixture types.

The primary methodology in developing market entries and technology transfer involved:

- fundamental development of advanced high efficiency fixture geometries
- development of technical information on fixture performance
- dissemination information and research findings through conferences and seminars
- development of technical papers
- involvement in industry interaction

All of the material that is developed in the energy efficient fixture laboratory is public in nature. Furthermore, the objective of the laboratory is to make this material available rapidly to the industry via publications, industry seminars and seminars conducted at utility and government agencies. The vast majority of the industry partnerships, transfers and market entries have occurred as a result of these public forums.

The development, transfer and commercialization of the energy efficient torchieres were reflective of this diverse technology transfer effort. Currently there are three to four manufacturers with products that have interacted with LBNL on torchiere and fixture development issue associated with the use of CFLs. Because of LBNL's efforts to encourage technology transfer from the lab to the manufacturing community, the United States will see number of other small and large manufacturers enter the market which have had direct involvement with the lab. For example, one of the larger portable fixture manufacturers employed a fixture geometry that was based on one of our earlier prototype efforts as a pin-based replacement for torchieres. The high performance fixture was their first market entry and has seen extensive use on college campuses.

In another example, LBNL worked with senior management of the one of largest importers and manufacturers of torchieres in this country on the evolution of their first energy efficient product. The interaction with this particular manufacturer was conducted over the telephone and involved advice, guidance and preliminary assessment on how to use efficient lamp-ballast technology. This type of assistance accelerates the development and transfer of information to quickly bring new market activity for efficient fixtures and CFL technology.

In terms of the product development side of the transformation process, our early efforts first concentrated on the development of high performance torchiere optics for novel high efficiency sources. High performance in this case refers to lumen output, efficacy, and fixture efficiency. Our fundamental objective was to set the first industry "standard" for energy efficient torchieres.

Knowing the actual performance of the lamp gave us an informed starting point for setting realistic goals for lumen matching. Without detailed preliminary testing and research before developing an alternative fixture, the consumer could be dissatisfied with the new technology.

Once we completed the development of the lumen-matching torchiere prototype designed as a residential model, we made the information widely available to the lighting industry. The information attracted the interest of a number of manufacturers within the fixture, lamp and ballast industry. During this product development and transfer period, an essential technology transfer and "market development" opportunity was established with Stanford University that allowed us to bring a large end user and initial market to the table.

Market Development

To encourage large-scale production of efficient torchieres we looked for demonstration sites that could purchase and use a large quantity of torchieres, ideally, locations where many halogen torchieres could be replaced with the new efficient torchieres. A wide range of initial demonstration sites was considered such as private residences, low-income housing, dormitory rooms and small offices. After closely investigating each of these options it became clear that university residence halls would be a perfect demonstration site for this new technology. Our initial surveys showed that it is fairly common of to find halogen torchieres in more than half of the dorm rooms. In some cases, halogen torchieres accounted for almost half of a residence hall's line power load.

Not only were universities a good target because of the number of existing torchieres, but also because the university could completely or partially subsidize the cost of the new efficient torchieres and still save money since the payback time is under two years. Purchasing efficient torchieres also decreased liability for the universities. By eliminating halogen torchieres on campus and offering efficient torchieres instead, the university would eliminate a major fire hazard.

Once it was decided that universities should be the first place to demonstrate this technology, several contacts were developed via talks and seminars with the housing offices of major universities across the country. Once the university community was introduced to efficient torchieres, many universities approached LBNL and the fixture manufacturers to organize installation programs. Between May 1997 and January 1998, energy efficient torchieres were installed in several universities including Stanford, Brown, Harvard, and Rice, and also in military housing at Bowling Air Force Base. LBNL was closely involved in the efficient torchiere programs at Stanford University, Rice Universities and Bowling Air Force Base. Due to differing needs and funding situations, a unique installation program was developed for each site.

Stanford University hosted the first torchiere demonstration program, installing 500 efficient torchieres in their residence halls during May 1997. Stanford decided to ban halogen torchieres the next semester and wanted to offer their students a replacement. It was decided that a "swap" program would work best in this situation.

Stanford conducted a room-by-room survey and inspection in every residence hall to assess their halogen torchiere problem and identify potential sites CFL torchieres. The University decided to focus its efforts on the residence halls with the most torchieres per student. In each of those halls a "swap" date was set and non-graduating students owning torchieres were encouraged to exchange their old torchieres for efficient torchieres because the halogen fixtures would become illegal in the fall.

Stanford's Housing Office, Resident Advisors, and LBNL's Lighting Systems Research Group worked together to organize the swap events. Over a three-hour period in each of the chosen residence halls, students arrived with their old halogen fixtures and traded them for the new, efficient torchieres. A few students were skeptical of the new technology so they were allowed to bring the new torchiere back to their rooms to try it out before turning in their halogen torchieres. After a short trial period, every student gladly traded an old halogen fixture for the efficient torchiere.

For one of the swap dates, Stanford and LBNL Public Relations departments arranged a high profile event with a pre-recorded speech by Secretary of Energy Federico Pena and substantial media coverage to publicize the unveiling of this new technology. This was a key step in receiving widespread acceptance of the efficient torchiere beyond Stanford's campus.

Monitoring devices were placed on approximately ten percent of the torchieres distributed. These devices were collected after one month and offered very pertinent data on how often and how long the students used the torchieres. Preliminary data shows that the CFL torchieres are on for an average of four hours per day when school is in session. Once this data is fully analyzed, numbers on the energy savings due to the new torchieres will be calculated and can be used in educational materials for other universities, utilities, and other possible targets for energy efficient torchieres.

The second major torchiere installation occurred at Rice University in Houston, Texas. This was a very different program than the one used at Stanford because instead of swapping torchieres with the students, Rice's objective was to install an efficient torchiere as a furniture item in each dormitory room on campus. This approach would ensure energy savings after the individual students more out of the dormitories because they would leave the CFL torchieres behind.

Rice decided to ban halogen torchieres starting in the 1997 fall semester and, like Stanford, wanted to offer their students an alternative to make the ban as effective as possible. Rice wanted to avoid the situation encountered at Yale when halogen torchieres were banned but no alternative was offered to student. Hundreds of halogen torchieres remained on campus because the students simply hid their torchieres during room inspections. (New York Times, 1997) Rice University's primary goal was to make the campus housing safer and more energy efficient. By banning halogen fixtures and installing efficient torchieres, they could accomplish both of these goals. Rice University has installed 1000 CFL torchieres, and over the next several semesters, they plan to place an efficient torchiere in each dormitory room on campus.

Another demonstration program involving LBNL occurred at Bowling Air Force Base in their housing quarters. Several hundred efficient torchieres from two different manufacturers were installed at the air force base. In this program, a selection of officers of a variety of ranks were chosen to receive one or more efficient torchieres (depending on how many halogen torchieres needed to be displaced in their residences). The efficient torchieres were distributed at a special ceremony at the Base introducing the new technology.

Monitoring devices were placed on 40 of the torchieres distributed at Bowling Air Force base. Since this is the first project venturing outside of universities, the information gathered by these devices will provide very useful information on how often and how long torchieres are used in different types of residences.

Conclusion

It is our hope that high performance torchieres will be the "Trojan Horse" of CFLs into the residential marketplace. Certainly this market transformation effort will require more care and insight than earlier DSM programs that left many of today's consumers unhappy and dissatisfied with CFLs. This new opportunity will require leadership, particularly in partnerships with industry and the education of consumers. Government and state agencies are also in a unique and critical position to ensure the future success of these new technologies. Important steps must now be taken to sustain the success and guarantee the future the wide spread application of this technology into the market place.

Specific action items to be considered include:

1. encouraging the market use by setting example in federal and state housing (military housing, public housing)
2. sponsoring high visibility demonstrations
3. providing information and disseminate success stories
4. working with utilities to insightfully encourage the technology
5. developing rational and well thought out performance recommendations
6. working with and developing positive and supportive relationships with industry

Ironically, the halogen torchiere has potentially opened the door to the residential market for CFLs. There are tens of millions of halogen torchiere owners in America and many of them have a very real fear of the fire hazard posed by halogen torchieres. But they have come to depend on the bright, high quality indirect light they get from their torchieres and are not ready to give them up. These consumers may now consider bringing a CFL into there homes for the first time, as CFL torchieres prove to be the only acceptable alternative to a luminaire they have become accustomed to.

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