An Examination of the Performance and Acceptance of Compact Fluorescent Bulbs and Fixtures in the Residential Market

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ABSTRACT

This paper analyzes sales and returns data from a number of efficient lighting programs Energy Federation, Inc. (EFI) implemented with utility clients and state public benefits charges administrators from 1994 through 2001. These programs promoted sales of compact fluorescent lights (CFLs), hardwire and plug-in compact fluorescent fixtures, to residential customers.

The analysis of over 2,100,000 product sales, and 47,000 product returns, suggests that consumers buying CFLs are satisfied with the products, and experience relatively few problems with them. There are statistically significant variances in return rates between different styles of CFLs. The most popular CFLs, 'bare glass' bulbs such as spirals, triples, and quads, have the lowest ratio of returns to sales. CFLs that either trap heat, such as capsules, or are placed in applications where ambient temperatures are likely to be high, such as reflectors, and products that are dimmable or have multiple light levels, have a much higher ratio of returns to sales.

Compact fluorescent fixtures do not perform as reliably as CFLs - at least at this point in time. Hardwire fixtures appear to present some difficult design challenges which the fixture manufacturing industry has yet to address successfully. As with CFLs, problems are manifested similarly among name brand and more obscure manufacturers. As with CFLs, some types of fixtures are more prone to fail, or to be rejected by customers for some perceived shortcoming, than other types of fixtures.

Plug-in compact fluorescent fixtures have higher return rates than CFLs, but appreciably lower return rates than hardwire compact fluorescent fixtures. The return rates of plug-in fixtures would be much lower if the category of torchieres were excluded. The torchieres return rates are comparatively high principally because of problems unrelated to ballast or lamp performance or reliability – such as difficulties customers encounter assembling the products, and switch failures. For plug-in fixtures, there do appear to be significant differences in product quality among manufacturers.

Introduction

EFI has actively promoted and sold energy efficient products for two decades. In the late 1980's, working with Boston Edison, EFI helped develop and then implement a program to make compact fluorescent lights (CFLs) available to residential customers of the utility at a discounted, or 'incentivized' price.

The direct offer of CFLs to Boston Edison customers was very successful, and the program became a model for a variety of efficient lighting programs EFI worked with utility clients to design and implement throughout the next decade. These programs evolved to include an increasingly wide selection of CFLs, and introduced hardwire and plug-in fixtures. The direct marketing materials became more polished, and for several clients EFI designed

mini and full-sized catalogs, and even on-line (Web) catalogs, featuring as many as 200 different compact fluorescent bulbs and fixtures.

This paper will present and analyze sales and product return data from the largest utility lighting programs EFI has operated since 1994.[1] Information from prior year program sales is excluded because compact fluorescent lighting technology has changed so rapidly and pervasively that the vast majority of products being sold in the late 1980's and early 1990's are no longer being manufactured. Sales and returns history from smaller programs were excluded because of the time and expense that would have been involved including the data in the study, and the conviction that critical sales/returns ratios for products would be unaffected by the decision. Sales and returns from other EFI business units were also excluded because the units' order processing and accounting software does not differentiate the reasons for which customers return products. Also, many of the sales are not to end users, so any feedback on the products' performance is second hand at best.

As is, the data this study reviews is a compilation of more than 504,000 unique transactions (orders/returns), involving aggregate purchases of over 1.81 million integral CFLs, 186,500 hardwire CF fixtures, and 116,170 plug-in CF fixtures, as well as returns of approximately 27,900 CFLs, 13,500 hardwire fixtures, and 5,770 plug-in fixtures.[2] Each transaction is not only linked to a customer, but a specific utility account number as well. Thus, each item returned is associated with a particular sale. This fact gives EFI confidence that the ratios between sales and returns of products are statistically relevant.

The database of information EFI has on consumer purchases and returns of compact fluorescent lighting products is unique. The volume of transactions, length of time over which they occurred, and numbers of products tracked, create a strong composite picture of how compact fluorescent lighting products perform in the consumer market, and are accepted by consumers. However, it is important that several caveats are stated. The author lacked the time, expertise, and resources to explore other factors that might have influenced product sales and returns. One potentially such important factor is the price customers paid to acquire different bulbs and fixtures. The data reveals how many fixture *x's* and fixture *y's* were sold, and how many were returned. The data was not analyzed to compare what customers initially paid for the different fixtures. (Prices for the same products vary from year to year, and program to program, so doing an analysis that incorporated pricing history would be a complex exercise.) Presumably, the more a customer paid for a product, the more inclined s/he would be to return the product if s/he were not 100 percent satisfied with it.

Ideally, the evaluation of the return and sales data could be complemented by a telephone survey of customers who bought and returned products, and, of customers who bought and did not return products. EFI does enough selective testing of returns to know that customers return products they claim do not work, or are damaged, when there is no evidence to support such claims. Conversely, there are customers who receive products that fail prematurely, or perform so disappointingly that the customers *un-install* them – yet, the

[1] The programs analyzed were operated with utilities, public benefits administrators, and municipal aggregators in the following states – Vermont, New Hampshire, Rhode Island, Massachusetts, New York, Connecticut, New Jersey, Wisconsin, Minnesota, Illinois, Georgia, and California.

[2] Since EFI added compact fluorescent lights as a product line in the mid 1980's, the company has sold, in total, over 6 million CFLs and 800,000 hardwire and plug-in compact fluorescent fixtures.

products are not returned because to do so would be too great an inconvenience, or perhaps the customers no longer have any record of the transactions.

Hopefully, the EFI sales and returns data for compact fluorescent products can serve as a stepping stone in the future to a more comprehensive, rigorous evaluation of customers' experiences using the products.

Compact Fluorescent Lights

The data evaluated in this paper reflects sales of 1,810,138 CFLs and returns of 27,892 products, over an eight-year period. Product returns clearly related to shipping damage, shipping errors, or delivery problems were excluded from the analysis. There were 177 distinct products in the data, supplied by 18 different manufacturers.

This data could be evaluated to test any of a number of hypotheses. The questions that this paper asks, and examines are:

- What is the correlation, if any, between product brands, customer satisfaction, and/or the performance and reliability of the products?
- What is the correlation, if any, between the wattage of products, customer satisfaction, and/or any apparent product performance or reliability issues?
- What is the correlation, if any, between the style of products (i.e., upright/bare glass, encapsulated, reflector), customer satisfaction, and/or any apparent product performance or reliability issues?

Significance of Manufacturer

Even the most ardent supporters of compact fluorescent products must acknowledge that the history of CFLs in the consumer marketplace is a checkered one. Performance claims, particularly regarding equivalent (to incandescent) light output, have ranged from hyperbolic to hilarious. (As recently as two years ago one of the major suppliers of CFLs in the North American market was advertising a 23 watt spiral product as equivalent in light output to a 150 watt incandescent bulb on its product packaging.)

There also are persistent murmurings in both the lighting and energy services industries that CFLs – or, at least, some CFLs - routinely fall short of reaching their rated lifetime hours before failing. These murmurings were given credence by a research project carried out by the Lighting Research Center between 1996 and 1999 as part of their National Lighting Product Information Program (NLPIP). The NLPIP report showed some CFLs tested failed to reach their rated lifetime, particularly when subjected to more rapid on-off cycling than required by ANSI testing standards (NLPIP 1999). Other products continued operating well past their rated lifetime hours.

It is not the intention of this paper to point out who 'has been naughty, and who has been nice.' The returns EFI experiences are certainly an indicator of products' performance and reliability, but they are an imprecise indicator, for reasons discussed above. It is important to understand as well that some CFLs are inherently subjected to greater stress than other CFLs. The mix of products EFI buys from a manufacturer might influence return rates more than the comparative attention to quality given by the manufacturers.

While the CFL sales analyzed are divided between eighteen manufacturers, 95% of the sales were of products supplied by eight manufacturers. Four of these manufacturers are multi-national companies with billions of dollars of annual revenues, and highly respected consumer brands – General Electric, Philips Lighting, Osram-Sylvania, and Panasonic (Matsushita). All make and sell many lighting products other than compact fluorescents. The other four manufacturers – Technical Consumer Products (TCP), Lights of America (LOA), Maxlite America, and Harmony Lighting – are much smaller companies. Their brands are not widely known by most consumers, but they all have an almost exclusive focus on making and selling compact fluorescent bulbs and fixtures.

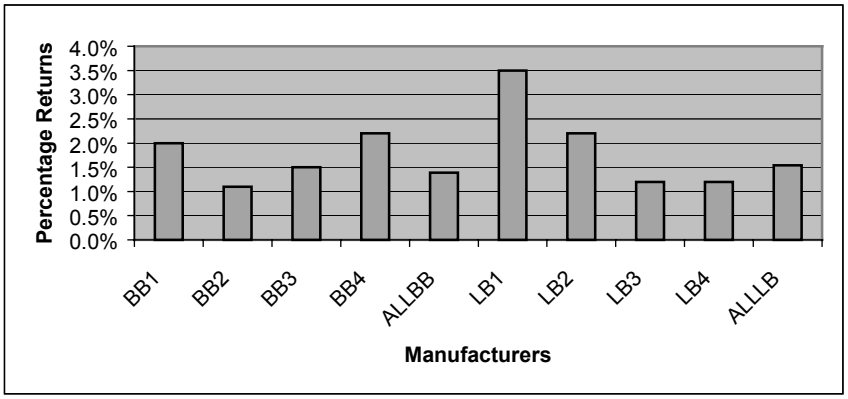
Table 1 shows total sales and returns of the Big Brand (BB) products, and the Little Brand (LB) products.

Table 1. Sales and Returns of Big and Little Brand CFLs

Manufacturers	Sales 1994 – 2001	Returns 1994 - 2001	Percentage Returns
Big Brands - GE, Philips, OSI, Panasonic	909,036	12,612	1.39%
Little Brands - TCP, LOA, Maxlite, Harmony	832,787	12,860	1.54%

As the column graph in Figure 1 reveals, there is a fair amount of variation in return rates within the big and little brand categories. This might indicate that there are significant differences in the performance and reliability of different manufacturers CFLs. However, there are potential mitigating factors, unrelated to quality, which could explain the differences. LB1 had fewer sales than other 'Little Brand" manufacturers, and a comparatively high percentage of their products were dimmable units, or reflectors. The 'Big Brand' manufacturer with the highest return percentage (2.2%) supplies EFI with the majority of the encapsulated CFLs that we sell. Dimmable, reflector, and encapsulated CFLs have higher return rates than other styles of CFLs – which sell in much higher volumes – as will be discussed below.

Figure 1. A Comparison of Return Rates between 'Big' & 'Little' Brand Manufacturers



If any conclusion can be drawn from these data, it is that there is no overwhelming evidence to suggest that consumers experience significantly higher problems, or are more dissatisfied with the performance and quality of some of the second tier CFL manufacturers,

than is the case with first tier manufacturers. This conclusion is one the author embraces in some respects, and resists in others. 'Big Brand' manufacturers essentially have ceded not only production of consumer model CFLs to the factories that have been making 'Little Brand' products (with a few exceptions), but also much of the design and engineering work involved in making CFLs. Over 80 percent of CFLs manufactured in the world in 2001 were produced in China. That said, major brand companies, in the author's opinion, are more cautious in rushing new products to market, more rigorous in complementing factory quality control processes with additional quality checks of their own, and perhaps more insistent on the use of high quality components. While EFI believes many smaller brand CFL products are quite good, and reliable, there are many off brands in the market EFI would not feel comfortable selling.

Significance of Wattage

When EFI first started promoting CFLs in the mid 80's, options were limited. The staple products EFI was selling to energy service companies, contractors, and consumers, were an array of modular 7w, 9w, 13w, and 22w magnetically ballasted compact fluorescents, some Philips 18w 'Earthlight' capsules, and some Panasonic 15w encapsulated CFLs. These products were large, heavy, and produced inadequate light – in comparison with standard 60, 75, and 100-watt incandescent bulbs they typically replaced. Evaluations of these early programs not surprisingly revealed that customers' were disappointed in the quality of the CFLs installed in their homes, and in particular, with the poor light output of the products.

In the past year or two there has been a marked trend in the CFL industry toward the production and sale of low wattage CFLs (e.g., mini-spirals, mini-capsules). Often these products, which range from 7 to 13 watts, are sold in multi-packs, sometimes with as many as six bulbs to a package. It is difficult to imagine that many customers will find so many satisfactory uses for products that realistically are suitable replacements for 25w and 40w incandescent bulbs.

Table 2 shows sales and returns of CFLs according to wattage ranges.

Table 2. Comparison of Sales and Returns of CFLs by Wattage Range

CFL Wattage Range	Products Sold	Products Returned	Percentage Returns
Under 15 watts	40,418	1,416	3.5%
15 watts - 17 watts	588,976	8,748	1.5%
18 watts - 21 watts	550,472	6,916	1.3%
22 watts - 25 watts	504,646	7,330	1.5%
26 watts - 29 watts	39,363	982	2.5%
> 30 watts	86,493	2,500	2.9%

The table shows that both higher and lower wattage CFLs see significantly higher return rates than 15-watt to 25-watt CFLs, the products best suited to legitimately replace 60 watt and 75 watt incandescent bulbs. The higher return rates of the high wattage bulbs might be explained by a) the larger average size of the products creating 'fit' problems in many household fixtures, and b) the disproportionately large number of three-way and dimmable

bulbs represented in this category. These products, as will be discussed in the next section, encounter more problems - early failures - than one-way CFLs.

For the lower wattage CFLs, such explanations do not hold. For example, there are no low wattage three-way CFLs, and dimmable CFLs also are invariably higher wattage products. The higher return rates for lower wattage CFLs are most logically explained by the simple fact they do not produce enough light to meet customer expectations and requirements.

Significance of Product Styles

The third hypothesis to explore was whether there were significant variances in problems experienced with different style categories of CFLs. Was the style of a product a more likely indicator that a product might be returned, than its manufacturer?

In Table 3, the 1.81 million CFLs EFI sold are grouped into five style categories.

Table 3. Comparison of Sales and Returns of Different Style CFLs

Category of Style	Sales 1994 – 2001	Returns 1994 – 2001	Percentage Returns
Bare Glass, Upright	1,348,541	13,894	1.0%
Encapsulated	232,254	6,408	2.8%
Controlled	120,156	3,967	3.3%
Horizontal	57,592	1,487	2.6%
Reflectors	51,825	2,136	4.1%
Total CFLs	1,810,368	27,892	1.5%

The rationale for grouping all CFLs into these particular five style categories is that products within these categories share certain characteristics that make them comparatively homogeneous to other products within the category, and different from other products outside that category. The differences relate to either the technical designs of the products, or to the applications for which they are most suited for use.

The overwhelming majority of CFLs EFI sells are 'bare glass, upright" products. These are the quad, triple, or double quad ("oct") tubes, as well as the spirals and mini-spirals that have dominated CFL market sales the past two years in the United States. These have the lowest return rates, which is not surprising, if one understands a little bit about compact fluorescent lighting technology. These CFLs have the advantage of being compact, and present fewer 'fit' problems than other styles. They have no glass or plastic covers blocking light transmission, and trapping heat. Of the nearly 1,350,000 bare glass style CFLs EFI sold in the programs reviewed for this study, only 1 in 100 were returned.

'Horizontal' style CFLs are predominantly 20w, 22w, and 30w T-9 circlines, and products using GE's 38-watt 2-D lamp. These products are designed for use in table lamp applications, with the ballast/adapter fitting between a table lamp harp, and the lamp encircling the harp. These are high light output products, and table lamps present almost ideal applications for CFLs in general, and horizontal products in particular. Heat build up is not an issue, and light distribution from horizontal bulbs is more optimal than from "A" style incandescent bulbs (Page, Praul and Siminovitch 1997). Return rates for this category are higher than for bare glass CFLs, but lower than for other categories. These are not the easiest

products to install for the average consumer, so "fit problems" are listed as a reason for returns more frequently with these bulbs than others.

Overall returns for the reflector category are higher than for any other category, with premature product failure the most prevalent reason customers return reflectors. Size and fit issues account for some reflector returns EFI sees as well. Return rates are higher for R-40 reflectors than for R-30 reflectors (about 5% vs. 3%), which would most likely be attributable to a size/fit problem. Thermal related stress is probably the single most common cause of compact fluorescent lighting product failures – both bulbs, and fixtures – so it is not surprising to see reflectors with a returns to sales ratio over four times as high as that of bare glass CFLs.

Encapsulated products have a return rate of 2.8 percent, which is about half the return rate for reflectors, but still is nearly three times greater than the return rate for bare glass CFLs. Encapsulated CFLs generally create their own thermal challenges, by trapping heat from the phosphor-coated lamps within an outer layer glass enclosure.

Most encapsulated products consume between 12 and 18 watts. Higher input wattages create more heat, placing more stress on thermally sensitive electronic components in the CFLs' ballasts. There has been a trend in recent years to make CFLs look more like conventional "A" or "G" style incandescent bulbs. This trend is rooted in the belief that if CFLs look more like what the average consumer assumes a light bulb should look like, they will have greater commercial appeal. This may be an astute marketing judgment, but the unfortunate ancillary result of this trend is higher sales of low light output bulbs that fail more quickly on average than un-encapsulated models.

"Controllable" CFLs are either dimmable, or three-way, producing three distinct light levels when used with a three-way switch in a portable fixture, or, in one instance, include a photocell. These products come in all sizes and styles – from spirals, to triples and "octs," to T-9 circlines and 2-D CFLs. All of them have 'companion' models that have simple on/off switching.

Controllable CFLs have the second highest return rate for CFL products EFI has sold. This is not an altogether surprising finding. Electrical circuit ballast designs for these CFLs are more complex than for one-way products; complexity increases the probability for problems. Lamps also operate under greater stress, dealing with more frequent switching - which will wear down cathodes - and fluctuating current. Also, controllable CFLs, as is true of reflector CFLs, are more expensive than most bare glass, or simple encapsulated products. Consumers are probably more likely to return products whose performance they are not satisfied with, if they paid $10-$20 for them, as contrasted with bulbs they might have bought for $3-$6 (after rebates).

Compact Fluorescent Fixtures

EFI has worked actively with clients over the past decade to promote greater residential use of compact fluorescent lighting fixtures. These efforts have encountered many obstacles, not the least of which has been a dearth of products appropriate for the consumer market. EFI has been the first customer for many fixtures featured in programs EFI has helped design and implement for clients. EFI has worked with manufacturers in many instances to identify products that both EFI and clients – primarily utility companies - believe have market potential broader than simply catalogs or directly marketed programs.

This is particularly true of plug-in, or portable floor and table lamps, and for 'families' of hardwire fixtures – e.g. matching flush-mount, off-the-ceiling, and wall sconce fixtures. Some large, established manufacturers that EFI has worked with for many years, that have traditionally produced and sold hundreds of different models of incandescent fixtures, now also have catalogs exclusively devoted to compact fluorescent fixtures, many of which first appeared in programs implemented by EFI.

Twenty manufacturers supplied the 186,500 hardwire fixtures sold in the programs whose data is analyzed in this paper.[3] Fourteen manufacturers supplied the 116,170 plug-in fixtures. Six manufacturers supplied both hardwire and plug-in models, so the total number of fixture suppliers represented in the study is twenty-eight.

Hardwire Compact Fluorescent Fixtures

Many of the same issues that affect the performance and reliability of CFLs impact the performance and reliability of compact fluorescent fixtures. Some people within the energy service industry – and 'influencers,' whose opinions often impact the industry – believe that compact fluorescent fixtures should perform better, and more reliably than CFLs. Fixtures can be designed to take advantage of the strengths of compact fluorescent lamps, such as their tremendous efficacy, and to minimize their weaknesses, such as the susceptibility of some key components to fail if subjected to high temperatures. In theory, this is true; in practice, at least for the overwhelming majority of products sold into the residential or consumer market, it is not.

Almost all compact fluorescent hardwire fixtures in the market are essentially incandescent fixtures with CFLs in them – absent the 'adapter(s)' that allows the bulb(s) to screw into a medium base Edison socket, as opposed to a pin-based lampholder(s). Customers have consistently experienced more problems with hardwire fixtures than CFL, to judge by the returns of products EFI has received. While customers of large public benefit charge funded programs EFI has operated return 1.5 CFLs for every 100 they purchase – either because they are unhappy with some characteristic of the products, or, the bulbs have failed prematurely – they return nearly 7.3 out of every 100 hardwire CF fixtures they buy.

To be sure, there are factors other than performance or reliability that can account for the higher fixture returns. The fixtures cost more than the bulbs, so customers have a greater incentive to return them if they are dissatisfied in any respect with the products. A fixture failure is also a much greater inconvenience and problem for a customer than a bulb failure. Bulbs can easily be replaced, either with other CFLs, or with an incandescent product. If a fixture ballast fails, the average consumer is going to be without light for some period of time, and may well need to pay an electrician to have the failed product removed, and a new product installed.

[3] EFI also sold over 20,000 solar lighting fixtures – almost all models to provide landscaping or pathway lighting – supplied by three different manufacturers, in the evaluated programs. Sales and returns information about the solar lighting products was excluded from this study.

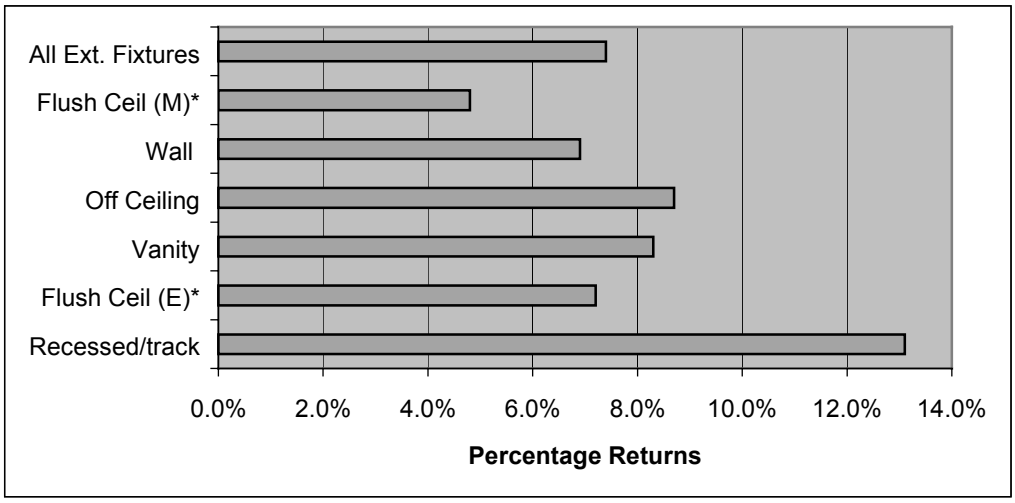
Table 4. EFI 'Program' Sales of Various Interior and Exterior Hardwire Fixtures

Interior Fixtures	Units	Exterior Fixtures	Units
Flush Ceiling	86,038	Ceiling	1,523
Off Ceiling	6,096	Post Top	3,501
Wall	4,964	Wall Mounted	57,227
Recessed/track	7,253	Wall Mounted w/photocell	18,041
Vanity	2,008	Landscape	344
Total Interior Fixtures	106,359	Total Exterior Fixtures	80,292

Even taking these factors into consideration, it seems significant that compact fluorescent hardwire fixture returns exceed CFL returns by a factor of nearly five. Fixture return data was analyzed to see if there were any patterns that might point to specific design or technical issues being responsible for poor product performance and/or reliability.

If 'follow the money,' was the Woodward and Bernstein mantra during their Watergate investigation, the mantra with compact fluorescent lighting products is 'follow the heat.' The author investigated whether the return data supported this premise, and while it appears to, the data is less conclusive than thought.

Figure 2. Return Percentages of Various Interior Fixtures



* (M) magnetic ballast fixture; (E) electronic ballast fixture

If thermal problems affecting electronic ballasts were the primary cause of product failures - and, premature product failures were the primary reasons customers returned products - the lines in the bar graph in Figure 2 should get progressively longer. Residential recessed cans generally will present the most difficult operating environment for compact fluorescent lamps and ballasts, due to the high ambient temperatures that can build in the fixtures, particularly as there is little unimpeded air space above the fixtures.

Flush-mount ceiling fixtures, installed directly against a ceiling, create/confront almost equal thermal challenges. The ballast or ballasts typically are installed directly beside, or within, a lamp(s). A diffuser cover is screwed or otherwise fitted into or onto the pan, in such a fashion that there is little or no ventilation. For magnetic ballast fixtures, this is not necessarily a problem, as the ballasts are simple, and their components are not extremely sensitive to heat. (They do not operate as well in cold temperatures as electronic

ballasts). For electronic ballasts, with a number of heat sensitive components – particularly, capacitors – heat is a problem. EFI has experienced a number of documented early failures of these types of fixtures in multi-family housing and new construction programs. [4]

Electronic ballast flush-mount fixtures have experienced a 50 percent higher return rate than hybrid flush-mount fixtures EFI sells. (Hybrid fixtures use magnetic ballasts with quick start lamps.) Further, EFI saw return rates of ceiling fixtures of one of its major suppliers drop from 17 percent to 6 percent when it moved the ballasts in their fixtures above the pans, isolating them from the lamps. The redesign also provided at least some ventilation in their fixtures.

This author's assumption that high operating temperatures destroy key electronic ballast components and are the primary culprit in compact fluorescent fixture failures can be challenged, however, by the relatively high return rates that EFI has experienced for several types of fixtures where operating conditions should be much more benign – particularly wall sconces, off-the-ceiling fixtures, and exterior fixtures.

While the return rates of off-the-ceiling fixtures are quite high, these fixtures are on average more than twice as expensive as flush-mount units. They also clearly are an important decorative feature of any room in which they might be placed, while the flush-mount units, although generally very attractive, are for the most part visually unobtrusive. EFI is largely reliant on customers to indicate why they are returning products, so statistics on off-the-ceiling fixtures returns are not a 100 percent reflection of operational failures with products. As noted previously, EFI's selective testing of returned fixtures suggests that some customers will return fixtures because they simply decide they do not like the appearance of the fixtures, either before they are installed, or after they are installed and lit – even if they note the reason for the return is 'product failed' or 'product does not work.' EFI has not encountered any extensive failures of these products – most of which are 'hybrid' products – in any large multifamily retrofit or new construction projects, where operational failures are virtually the only reason fixtures are returned.

Wall sconces have return rates of slightly less than 7 percent, which places them just below the median for all hardwire fixtures. This is somewhat perplexing. They are not particularly expensive, in comparison with other compact fluorescent fixtures EFI sells. Thermal stress should not affect them, as all of them allow for easy heat dissipation through the open top of the fixture.

Exterior fixture return rates present a curious story. While overall returns for exterior hardwire fixtures are similar to return rates for interior fixtures, the return ratio for exterior fixtures with photocells is over twice the return ratio for fixtures without photocells –12.2 percent vs. 5.7 percent. For many years EFI sold predominantly fixtures without photocells. In 1999 most of EFI's utility clients decided to adopt the ENERGY STAR specifications for CFLs and fixtures, and only rebate products carrying the ENERGY STAR label. The specifications for outdoor fixtures required them to have photocells.

Many of the exterior floodlights, wall lanterns and post top fixtures EFI has sold the past three years were initially (and probably still are) manufactured in models supplied without photocells, so EFI believes this is a fairly generic problem, rather than something that can be ascribed to the quality, or lack thereof, of particular manufacturers. EFI sold 14,216 exterior fixtures without photocells supplied by a particular fixture vendor, and had 664 returned (4.7%); EFI sold 12,556 fixtures with photocells, supplied by the same

[4] New construction and multi-family product sales and returns are not part of the data analyzed in this paper.

manufacturer, which are almost identical in all other respects to the fixtures without the photocells. Through the end of 2001, 1,501 had been returned (12.0%). The addition of photocells to exterior fixtures may not inherently cause problems, but photocells do add design and electrical complexity to the fixtures, and complexity often contributes to higher incidences of problems in the field. The fixtures also can present installation challenges, particularly to unsophisticated consumers, who may put matching wall lanterns in locations where the light from one fixture triggers the other fixture to turn off.

Plug-In Compact Fluorescent Fixtures

Plug-in compact fluorescent fixtures are a relatively new product category. There have been simple desk lamps available for the past ten years, if not longer, but only several models of table lamps – which never found sales channels where they sold successfully, and thus were quickly discontinued – and no floor lamps. Around 1997-98, compact fluorescent torchieres began to appear in the market, as a somewhat belated response to the frightening proliferation of inexpensive and dangerous electricity guzzling halogen torchiere floor lamps.[5] These fixtures were promoted very aggressively by utilities supporting demand side management initiatives in the Northeast, Midwest, and along the West Coast because of the substantial energy savings they provided, at little cost. In recent years programs EFI is implementing have added a variety of table lamps, and several non-torchiere style floor lamps. These programs remain the primary sales channels for these products.

Plug-in, or portable, lighting fixtures have become an increasingly important source of illumination in residences. Many people like the indirect lighting these products can offer, as well as the ability to move the products to specific areas in rooms where lighting is most required. These fixtures are generally quite adaptable to compact fluorescent technology. They do not trap heat, and ballasts can be isolated from lamps, and the high temperatures lamps create. Shades or 'bowls' help diffuse and/or refract light in desired directions, and hide the actual lamps from view.

Table 5. Sales and Return of Plug-In Compact Fluorescent Fixtures

Plug-In Compact Fluorescent Products	Product Sales	Product Returns	Percentage Returns
Desk Lamps	30,245	982	3.2%
Floor Lamps (not torchieres)	5,312	219	4.1%
Table Lamps	29,862	1,365	4.6%
Torchieres	46,340	3,062	6.6%
Under Cabinet	4,411	139	3.2%
All Plug-In Fixtures	116,170	5,769	5.0%

[5] Lawrence Berkeley Laboratory (Michael Simonovitch, project leader) was instrumental in helping to develop this technology. Chris Calwell, working with the National Resources Defense Council at the time, played a critical role in highlighting the energy wastefulness of halogen torchieres, and safety hazard they posed. EFI, collaborating with Guan Fumin, a leading lighting expert in China, and Linsey Marr, a Harvard senior doing her thesis on the problem of halogen torchiere use on campus, developed one of the world's first compact fluorescent torchieres. Harvard eventually bought 6,000 torchieres from EFI, installing them in all undergraduate dormitory rooms and suites.

As Table 5 demonstrates, return rates for compact fluorescent plug-in fixtures have been appreciably lower than return rates for hardwire fixtures. Returns are much higher for the torchieres than the other types of plug-in fixtures. There are several likely explanations for this. Most of the compact fluorescent torchieres that EFI sells offer continuous dimming; those that are not dimmable, have three-way switching. Controllable ballast circuitry is more complex than circuitry that simply needs to operate a lamp at a set current.

EFI has had many compact fluorescent torchieres returned because of problems with components other than lamps and ballasts. For several models, particularly some three-way units, switch failures are the single greatest reason customers list for returning products. Some dimming units also experience problems with switches. Customers sometimes strip insulation from wires when they try to assemble torchieres. Getting a six-foot fixture into a box that is easy to ship, and which can ship for less than the cost of the product itself, is complicated. Manufacturers need to add more wire than is optimal to allow pole sections of the torchieres to be laid out in a box. Customers find no simple way to 'stuff' the wire into the pole sections, and sometimes catch the wire as they thread the top pole section into the torchiere bowl.

There are variations in compact fluorescent torchiere return rates between different suppliers. The most 'reliable' two brands are actually manufactured by the same company (one brand is privately labeled). These brands have a return rate of only 4.6 percent. Three other brands that EFI sells have a collective return rate average of 8.1 percent - with switch failures responsible for a significant portion of the differential rate.

EFI has two major suppliers of table lamps, and with these products, there also appear to be evident variations in product reliability. EFI has sold 12,120 table lamps supplied by one of the two manufacturers, and had only 215 returned (1.7%). EFI sold 12,659 table lamps supplied by the other manufacturer, and had 1,129 returned (8.9%). For other plug-in fixture categories, sales to returns ratios have been fairly uniform among all suppliers.

Summary

Analysis of EFI's large database of compact fluorescent product sales and returns suggests that CFLs, by and large, have achieved a measure of acceptance from consumers who buy and use them. They also are performing reliably, although certain types of bulbs appear to encounter significantly higher problems than other types. Thermal issues, and complex ballast circuitry, are more likely determinants of a product's performance, than which company manufactures the product.

Hardwire compact fluorescent fixtures have return rates nearly five times the return rates of CFLs. While the goal of promoting greater use of compact fluorescent hardwire fixtures in residences to insure energy savings persist is laudable, there is evidence that the products currently in the market too frequently fail to meet consumers' standards for performance or reliability. The same design and technical issues affecting performance and reliability of CFLs seem to apply to CF fixtures, although the correlation is less pronounced.

Plug-in compact fluorescent fixtures generally have been more reliable than hardwire fixtures, although there appear to be significant variations in quality among different manufacturers. These variations in manufacturer quality were not nearly as evident with CFLs or hardwire fixtures.

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