Why Compact Fluorescent Lamps Are Not Ubiquitous: Industrial Organization, Incentives, and Social Convention

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This paper challenges the prevailing assumption that energy efficiency achieved through advanced technology is always a "win-win" situation. It suggests that industrial organization, retail incentives, and social convention are additional reasons for the slow adoption of compact fluorescent lamp (CFL) technology. These additional barriers, in turn, lead to new areas for policy research and recommendations in pursuit of improved energy efficiency.

Introduction

Compact Fluorescent Lamps (CFLs), for all of their advantages over standard incandescent, are not ubiquitous. To understand why this is so, a firm was established by the author in July 1993 with the sole purpose of distributing CFLs. The findings presented here are based in part on this experience, and in part on research into industrial organization, diffusion of innovation, and finance. They suggest that while most of the common reasons for the slow adoption of CFLs (high up-front cost and fixture incompatibility) are important, looking at how industrial organization constrains the diffusion of innovation, corporate financial incentives, retail incentives, and alternative aspects of consumer perception could lead to an alternative policy agenda for promotion of energy efficiency. The findings also suggest that those groups and individuals interested in advancing an energy efficiency agenda should abandon the sanguine view that energy efficiency adopted through technology advancement is necessarily a "win-win" situation.

After summarizing the comparative benefits of CFLs, this paper reviews and critiques the common explanations for the slow adoption of CFLs and then presents four additional explanations. The paper concludes with recommendations for new policy directions for overcoming these barriers to the proliferation of CFL technology.

Comparative Benefits of CFLs Do Not Match Their Market Performance

The comparative benefits of compact fluorescent lamps (CFLs) over incandescent are well known. Gadgil and Rosenfeld (1990), making conservative assumptions, project consumer savings of $33.00 per lamp for switching from 900-lumen incandescent lamps to equivalent CFLs. Additional consumer benefits include reduced risk of bums from touching the lamp, and reduced time and risk associated with changing incandescent bulbs, since CFLs last up to ten times as long as incandescent. Environmental benefits arise from lowered energy generation requirements for equal amenity; each CFL, over its lifetime, saves roughly 200 kg (440 lbs) of coal used to generate electricity. And electric utilities benefit since it is cheaper to transfer saved electricity to new demand than it is to build new power plants. These cost savings are passed along both to ratepayers and shareholders. CFL technologies are proven and some lamps carry one-year guarantees. With all of these advantages, one might expect CFLs to roll right over their primary competition: the century-old standard incandescent.

But they aren't. After more than half a decade on the market, CFLs are still a niche player in lighting sales. Roodman (1993:62) reports 1992 CFL sales of 38 million units in the U. S., 28% of the world total. On a worldwide basis, CFLs accounted for less than 2% of lighting sales volume; and in the United States, only 1% (Rasky 1993:13). CFL sales are certainly increasing, up 23% from 1991 to 1992, but this high percentage increase is partly due to the relatively small numbers sold. It would take 18 years at the same growth rate for CFLs to achieve just a 33% market share. CFLs are nowhere near their potential market penetration.

Common Explanations for the Slow Adoption of CFLs

The most common reasons for the slow rate of adoption of CFLs are consumer reticence based on high initial price, poor coordination among utilities, manufacturers, and retailers, and lack of compatibility with many existing fixtures. Each of these will be discussed individually.

High Initial Price

A recent survey of seven domestic CFL manufactures (Electric Power Research Institute [EPRI] 1992:A11-12) asked what they believed to be the "two top problems or barriers" to a conversion to "effective and efficient" lighting systems. Every list included the price differential between CFLs and incandescent, often describing the problem as consumer misconception over first cost versus operating cost. Roodman (1993:62) suggests that initial price is the primary problem, revealing the seemingly incongruous behavior of consumers in the following statement: "Although the CFL's price, at $15-20 per bulb, discourages most consumers, its efficiency and longevity more than cover this expense in most situations." Another EPRI (1993) survey of consumers also identifies price as a key deterrent to CFL sales.

A common explanation for this seemingly short-sighted calculation is that, in fact, people are short-sighted. More education is needed, the argument goes, so that people can make the proper calculation, and see the wisdom in buying a CFL (Rasky 1993:13; EPRI 1993).

While relatively high initial price appears to be a valid barrier, the general solution of education on capital cost versus operating cost may not yield the expected result. The education suggested appears to involve showing consumers that over enough time, CFLs will pay off. Yet it is not uncommon for consumers to make purchases that are more expensive initially, but are expected to pay off over time. This is the logic behind the practice of "buying quality," and is manifested in the marketplace in the wide range of prices one can pay for the same type of good. Further, it does not make sense that people will occasionally act irrationally *en masse* toward a particular commodity. Why is there logic to society-wide buying decisions regarding televisions or computers, but not lighting? Rather, we should suspect a social custom or issue that is not immediately apparent motivating consumer behavior, or some other factor altogether (see the section on Social Convention of Leaving Bulbs Behind Reduces Buying Incentive). Finally, if consumer education were indeed a primary barrier to rapidly expanding CFL sales, one would expect manufacturers and distributors to educate the public through advertising, as they do so frequently when other innovative products are introduced. This, of course, is not happening.

Poor Utility CFL Promotion

Many authors also cite poor coordination among utilities, manufacturers, and retailers in marketing CFLs. This barrier stands only if we accept the above contention that people will not pay market prices for CFLs. While there is no doubt that utilities can benefit from the dissemination of CFLs, so too can consumers even without utility intervention. That is, if the CFL market were to perform consistent with its comparative advantage over incandescent, there would be far less need for utility involvement.

There is no immediately apparent reason to expect utilities to take a lead in distribution efforts of CFLs. Indeed, lighting manufacturers in the EPRI survey expressed the concern that utility involvement in CFL distribution programs could increase their product supply uncertainty (EPRI 1992: l-l). Here, however, it appears that the manufacturers protest too much. Planning for dissemination of a new technology is difficult under any circumstances, yet projections are always made. By now, manufacturers should be able to predict demand relatively accurately.

Fixture Incompatibility

This is a common point-of-sale issue and returned item problem: either the ballast is too wide or the lamp too long. While this is typically viewed as a "CFL problem," it also could be seen as a fixture problem. Many fixtures are relatively inexpensive and easy to produce in mass quantities from molds. These molds could be recast to support CFL dimensions on relatively short notice if the fixture industry thought CFLs were becoming an important part of the lighting market. The fact that fixture manufacturers, who are intimately aware of the lighting manufacturing industry, and who should rightly be considered followers/facilitators of innovation in lighting products, are *not* producing CFL-compatible fixtures should hint that they do not expect future significant growth in CFL market share.

Additional explanations of why CFLs have not been more widely adopted include color quality and lack of ability to dim. And it can be argued that CFL technology is simply low on the S-curve that describes adoption of innovation over time. Color quality and lack of dimming do not seem fatal, however, and few S-curves have a tail as long as that which characterizes the adoption of the CFL relative to its incandescent competition. Indeed, if CFL promoters are ever to realize an S-curve at all, much work remains to be done. One important area which has yet to receive serious attention concerns industrial organization.

Additional Explanations for the Slow Dissemination of CFL Technology

To summarize, the first two commonly expressed reasons for slow dissemination of CFL technology mentioned above focus on demand-side issues, and the third on a technical supply-side issue. Following are three additional *non-technical* supply-side reasons for the slow dissemination of CFL technology, as well as one additional demand-side issue.

Lighting Industrial Structure Slows Diffusion of Innovation

Kenichi Ohmae, a leading analyst of industrial strategy, believes that a firm's first task in developing a strategy is to pay "painstaking attention to the needs of customers," including the firm's "willingness to rethink, fundamentally, what products are and what they do, as well as how best to organize the business system that designs, builds, and markets them" (Ohmae 1988:149). Two important points can be drawn from this quote. First is the importance of customer feedback. American firms today are sensitive enough to this issue that bringing it up in a business strategy context approaches triteness. Second, and less transparent, is the importance of organizing all aspects of a firm around the two issues of sources of value to customers and what products the firm offers.

In the case of lighting, it appears that neither of these two issues is addressed properly with respect to the diffusion of CFL technology. CFLs are new, innovative products with the potential to radically restructure the lighting industry. Yet CFLs have been introduced and are sold by an industrial structure designed to deliver products which have remained essentially unchanged for most of this century. It is a wholly inappropriate mix of innovative technology with a static distribution system.

The first and most obvious manifestation of this problem arises from the oligopolistic nature of lighting manufacturing, which is dominated by three firms. Oligopolistic structures have been shown in theory and practice to slow innovation and set up barriers to entry in order to protect strategic position. In the case of lighting, the "Big Three" manufacturers share the seemingly conflicting incentives to innovate technologically in lighting, but at the same time not to push the market in fundamentally different directions that might threaten their oligopolistic profits. While the latter motivation is understandable from an economic perspective, the R&D focus bears more elucidation. The importance of maintaining vibrant energy-efficient lighting R&D draws from the potential threat that one of the firms could develop a technology so advanced that it could act aggressively and conquer market share sufficient to justify breaking the oligopoly. Only technological parity can maintain the market structure. Further, there are always potential threats from other technology companies that may seek a foothold in the lighting industry.

Rapid adoption of CFL innovation is slowed to a crawl by a system of manufacturer-supplier relationships that supports the oligopolistic autonomy of the manufacturers, the broad line of lighting products the Big Three offer, and the profit motives of the wholesalers. The Big Three deal with only a handful of extremely large wholesalers, who can carry the varied and extensive lighting product lines they manufacture.

In the next step of the process, the wholesalers sell to retailers. Wholesalers make money in two ways: in the mark-up they charge to retail customers, and through bids on government and large institution contracts. In other industries, wholesalers typically do not bid on end-use contracts, but an odd manufacturer's rebate system permits wholesalers to undercut retail bidders on government contracts.

Whatever the benefits of this distribution system, it does not favor rapid diffusion of innovation. The tight grip the manufacturer has over its wholesalers ensures that all of the manufacturer's product line will be supported, but limits the potential for an innovative product to challenge traditional buying patterns. That is, CFLs are going to be distributed in the context of a system designed for smaller bulbs that burn out frequently and are more than an order of magnitude cheaper. This approach is hardly sensitive to Ohmae's challenge to structure an industry around products, and not the opposite.

A contrasting distribution relationship would involve dozens or hundreds of smaller-scale distributors pushing innovative products and providing feedback on consumer preferences and buying patterns to the manufacturer. In fact, two lesser CFL manufacturers have chosen a flatter distribution structure which is more amenable to the rapid diffusion of innovation. A third CFL manufacturer, until its recent merger with one of the Big Three, also had over one hundred distributors in the San Francisco bay area alone. After the merger, it cut off nearly all of its distributors, choosing instead to go with the portfolio approach to lighting sales, involving just a handful of major wholesalers.

As a way of highlighting the importance of industrial organization to the rapid adoption of innovation, consider the case of the radial tire market during the early 1970s. Invented in France, they were an innovation that increased tire mileage from 17,000 miles with cross-ply tires to 40,000 with radials. They provided additional benefits in terms of road handling and tread retention, but required that automakers modify auto suspensions to permit their use. They cost 80% to 100% more than cross-ply tires. In 1972 radial tires held roughly 6% of both the original equipment market and the replacement market *(Forbes* 1976:48).

At the time, there were five major tire manufacturers, and numerous smaller ones. There were thousands of retailers in the form of repair shops and gasoline stations. Competition was fierce. One publication pointed out in 1973: "Prophets of doom for the tire makers insist that radials will virtually crunch the replacement tire market-the one where profit margins are highest and the growth is excellent" *(Financial World* 1973:7). Just the same, predictions for radial market share growth were rosy, with one of the leading firms predicting an 80% market share for radials by 1976, and another leader predicting a 65% share. All of the majors were embarking on capital-intensive factory upgrades in anticipation of the switch to radials.

In fact, Detroit did adjust the suspension on new models. By 1975, the consumer preference for radials was becoming clear in spite of their higher price *(Business Week* 1975:24), and by 1976, radials had a two-thirds market share. Radial tires were being hailed as "a marketing success but a profit disappointment" *(Forbes* 1976:48). By 1978, the *Economist* (1978:86) reported on the profound adjustment the tire industry was experiencing:

> This year, motorists would normally be replacing the tyres on new cars bought two or three years ago. Many are not replacing them, because their tyres still have plenty of tread. Good news for motorists, but not for those who sell tyres.

Sales were up, but profits were down across the industry. Today, radial tires remain standard equipment in the new vehicle and replacement market sectors.

Radial tires and CFLs share many common elements, including that they were superior but more expensive technologies introduced to the U.S. from Europe. Why did radials experience such rapid growth compared to the sluggish CFL market? Key reasons, I believe, concern the structure of industrial competition. The five majors and numerous important minor tire manufacturers were locked in an extremely competitive market and had to exploit any technological improvement that came along. As discussed above, the Big Three lighting manufacturers, as an oligopoly, experience less competitive pressure. Further, tire distribution primarily involved manufacturers selling to retailers. There was no internal layer of a wholesaler whose goal was to move a wide variety of the manufacturer's products. Retailers were trained in radial technology, and were in a position to move the new product.

In closing, it should be noted that the tire industry become more concentrated with the advent of radial technology. Many firms went out of business, and a mix of old and new leaders emerged. With CFL adoption as slow as it has been, the Big Three lighting manufacturers appear to be holding their ground.

Manufacturers Are Losers

The Big Three are full-line lighting manufacturers. CFLs are undoubtedly a "cannibalistic" innovation. For each CFL sold, the Big Three lose sales of 10 incandescent. It is highly likely that many incandescent manufacturing plants are fully depreciated, so that sales on incandescent bulbs are big cash generators. In contrast, part of the revenues from CFL sales is no doubt going to capital expenses, including investment in plant, equipment, and retraining. Further, internal measures of production often include unit sales. The adoption of CFLs could drastically shrink unit production levels in the lighting industry, make incandescent manufacturing plants obsolete, and displace workers. A fictional parallel situation in the garment industry, which well described the alignment of interest groups against radical innovation, was presented in the 1951 Alec Guiness movie, "The Man in the White Suit."

CFLs may not merely cannibalize sales of equivalent-lumen incandescent; they may influence sales of other bulb types. If consumers are trained to think of lighting costs in terms of both capital and energy expenses, as suggested above, they may come to demand similar energy savings from more and more of their lighting needs, which would render obsolete large parts of the Big Three's product lines which are sold on other qualities, such as bulb shape.

Similarly, for some of the Big Three, the cannibalizing can extend to other divisions. One firm in the oligopoly, for example, has a Power Systems division which posted 1992 revenues of $6.7 billion. The potential influence of CFLs on power generating equipment can be realized by comparing the consumers' cost of energy with their cost of conserved energy. Both can be expressed in $/kWh. The cost of energy is, of course, what consumers pay their utilities, and varies from roughly $0.04/kWh to $0.15/kWh. Taking a middle figure of about $0.10/kWh, it can be broken down into fuel costs, operating expenses, capital expenses, and profits. While capital expenses can vary tremendously depending on the age and type of facility, an estimate of 20% of the cost of energy going toward capital expenses is not unreasonable. This means that Power System suppliers are receiving in the neighborhood of $0.02/kWh from energy use.

Cost of Conserved Energy (CCE) measures the additional cost the consumer pays for devices which will save energy while providing equivalent amenity. The assumption which underlies CCE calculations, and which fits for CFLs, is that a higher-tech, energy-efficient device will cost a little more than the device it is replacing, and the additional cost for the new technology should be compared to the cost of energy that is being saved.

Let us assume a continuous operation of a CFL for 1.2 years, a capital recovery factor of 0.93 (corresponding to a 10% interest rate for consumer loans), an additional expense for a CFL of $10 (corresponding to an $18 retail price of a CFL minus $8 for ten incandescent bulbs), and 45 W saved electricity (corresponding to the replacement of a 60 W incandescent with a 15 W CFL). The CCE calculation is:

CCE = ($10 x 0.93) / (8760 hrs/yr x 45 W) = $0.024/kWh.

(Note: capital recovery factor, 0.93, has units of "per year".)

The CCE can be interpreted as the incremental revenue accrued to the lighting industry when a CFL substitutes for power generation equipment. Roughly half of the CCE goes to wholesale and retail lighting distributors, which means that CFL manufacturers receive roughly $0.01/kWh as a substitute for $0.02 lost to power equipment manufacturers. If the same firm manufactures both lighting and power generation equipment, as is the case here, there is a clear incentive on the part of the manufacturer NOT to promote the energy-efficient equipment.

So, while consumers win by comparing the CFL CCE of $0.024 with a utility cost of energy of $0.10, and the environment wins due to reduced power generation, multi-division lighting manufacturers lose. This might account in part for the silence of manufacturers in terms of television, radio, and print advertising of CFL products.

On a macro level, this same idea was spelled out by Rosenfeld and Mills in a *Washington Post* editorial (1992). They estimated that the adoption of CFL technologies in the former Soviet Union could replace five to ten Chernobyl-type nuclear reactors. Of course, they didn't discuss the implementation difficulties that would arise if the same "firm" built both CFLs and nuclear reactors, and made more money off of reactor sales, as appears to be the case here in the U.S.

CFL Longevity, Price, and Package Dimensions Lower Retail Profits

An important CFL brand (though not from the Big Three) with electronic ballast and initial output of 810 lumens has packaging dimensions of 3" x 3" x 7.5". By contrast, the equivalent lumen incandescent package has dimensions of 6.5" x 5" x 2.5" and holds two bulbs, A typical supermarket shelf devoted to lighting in a market has dimensions of 4' (length) x 18.5" (depth) x 8" (height). Even though the two products' cubic inch dimensions are roughly equivalent, this shelf configuration can hold either 96 CFLs or 162 incandescent bulbs.

Assume the incandescent packages sell for $2 each, which includes a 100% mark-up (or $0.50 mark-up per bulb). The revenues to the retail establishment from that shelf are 162 x $0.50 = $81. If the shelf were to clear six times (for product lifetime equivalent to a shelf of 96 CFLs), the revenues would be $486. To earn equivalent revenues in terms of allotted shelf space, the shelf's 96 CFLs would have to carry a mark-up of $5.06. This is well below the markup CFL sellers currently apply. This brief calculation demonstrates that relative mark-ups of incandescent versus CFLs are not a disincentive to offer CFLs. There must, then, be other reasons for supermarket reticence to sell CFLs.

Three possible reasons for retailer reticence to sell CFLs can be ventured. First, in supermarkets the use cycle of the vast majority of products sold at a supermarket lasts less than six months. CFLs can last six years in residential settings, and thus are out of place in a supermarket. Further, short-lived incandescent provide consumers with nine additional incentives per CFL to return to the store. Second, the average price of goods sold in supermarkets is in the range of $3 to $5 per unit. Very few products carry a price tag of $20, as do many CFLs. Supermarkets may fear the perception among shoppers that the presence of a few CFLs in one's basket will turn an inexpensive shopping trip into an expensive one. Finally, depending on the store configuration, CFLs may be too big for the eye-level shelves, and therefore relegated to way-up-high or way-down-low locations which will limit their sales.

Social Convention of Leaving Bulbs Behind Reduces Buying Incentive

The previous discussion has centered around supply-side issues. Based on repeated comments from potential CFL buyers, one additional demand side constraint should be considered. Much has been said about the supposedly irrational short payback period individual consumers use to assess the costs and benefits of CFL purchases. In one set of instances, however, a long-standing social convention may justify the short pay-back period calculation.

Many lighting customers are not simply purchasing lighting, but are purchasing lighting for a particular space and/or fixture. If the fixture is a permanent one, most likely there was an incandescent bulb there when the person/family moved in to the residence, and most likely, when they move out they will again leave a working bulb behind in the socket. This social convention arises because of how convenient it is to have working lights when one moves into a new residence, how difficult it is to transport fragile incandescent bulbs, and how little money is at stake in purchasing new bulbs, rather than porting used incandescent of undetermined age to a new residence. In short, leaving bulbs behind has attractive convenience characteristics, and is practiced by nearly everybody.

Light bulbs are the only property commonly left behind when people change residences. This behavior, in conjunction with a perception that one may not remain at a particular residence for another six years, means that in fact, the correct consumer pay-back period is often less than the lifetime of the CFL. This reduces the incentive to pay the initial premium for a CFL from which one won't get full use. Adherence to this social convention and the perception that light bulbs are fragile may be limiting the potential market for CFLs.

Observations and Recommendations

Based on the above discussion, a number of observations and recommendations emerge. Recommendations are in the form of government initiatives to influence industrial organization (1-3), interest group action (4), and private firm initiative (5).

1. In order to reduce the oligopoly-related constraints on diffusion of CFL innovation, second-tier manufacturers of CFLs must be encouraged. These groups are in a position to market CFLs aggressively and to invoke unique distribution channels for the product. Current holders of CFL technology rights can be encouraged to offer licenses to relatively smaller manufacturers, and tax, zoning, or other incentives can be provided to non-integrated CFL manufacturers.

2. The restrictive lighting distribution policies of the Big Three should be reviewed in terms of their impacts on CFL proliferation by experts in industrial organization and technology management. One potential reform includes allowing far more wholesalers to contract directly with manufacturers without current high-volume, full-product-line requirements. This would increase opportunities for selling CFLs as well as for customer feedback, both critical to the proliferation of new consumer technologies.

3. CFL innovation should be encouraged in a manufacturing context where internal decision makers are not torn between watching CFL sales grow at the expense of even greater offsetting losses in other divisions. This context can be encouraged both by creating incentives for appropriate firms to acquire CFL manufacturing rights (see (1) above), as well as by requiring current full-line manufacturers to provide evidence of how they are handling their mixed motivations in their internal accounting and sales incentive programs.

4. Until CFLs are regularly on the shelves of supermarkets and other stores, they will not be widely disseminated. This can be accomplished in part by applying interest group pressure to large supermarket chains to accept and sell these products.

5. Consumers should be exhorted to “Take them with you!” Consumers could learn to set aside the incandescent they removed when switching to CFLs (assuming the incandescent are still functioning), or simply purchase cheap incandescent as transition bulbs for the next occupant. The break-resistant nature of CFLs as compared to incandescent should also be touted in the context of their surviving a move to a new residence. CFL packaging, which in most cases is quite shock resistant, should indicate that it should be saved in anticipation of a future move.

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