Screw-Based CFLs or Pin-Based Fluorescent Fixtures: Which Path to Greatest Lighting Energy Savings in Homes?

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ABSTRACT

Programmatic approaches for promoting energy-efficient residential lighting have typically followed one of two paths; 1) screw-based compact fluorescent lamps (CFLs) and 2) hard-wired fluorescent fixtures. The two technologies have separate ENERGY STAR® programs, screw-based CFLs under the Department of Energy (DOE) and fluorescent fixtures under the Environmental Protection Agency (EPA). The quantity and quality of available screw-based CFLs and fluorescent fixtures have been increasing steadily and the market share of these energy-efficient alternatives to incandescent lighting is growing. However, the historic and administrative divisions between these two ENERGY STAR technologies, at both the local and national levels, now pose barriers to innovation and flexibility in residential lighting energy efficiency programs. To continue the transformation of the residential lighting market toward ENERGY STAR, we must step back, take a fresh look at the full range of our current choices, and re-tool our program approaches.

For some time now, the dominant assumption has been that dedicated fluorescent fixtures offer superior persistence of savings, compared to screw-based CFLs. This assumption is based on intuitive commonsense: screw-based CFLs are made to replace incandescent light bulbs ("lamps"), but incandescent lamps can just as easily replace screw-based CFLs. Most people hire an electrician to install fixtures and pin-based fixtures will not accept incandescent lamps. However, recent empirical information from active residential lighting programs suggests that this assumption may be false. In any case, the persistence of an energy efficient light is only relevant once it is installed. Over the past five years builder and consumer resistance, limited availability, and complex lamp/ballast combination requirements have resulted in slow sales for ENERGY STAR fixtures. During this same time, screw-based CFLs have gotten brighter, much cheaper, more reliable, and widely available and sales have exploded.

Our work with programs in the field has lead us to believe, at least in the new homes market, that residential lighting programs which allow builders and their customers to choose from the complete array of ENERGY STAR residential lighting options are more likely to result in satisfied participants, and more likely to maximize energy savings.

The Evolving Focus of Lighting Programs

Compact fluorescent lighting has been the primary technology promoted by most residential lighting efficiency programs. Screw-based compact fluorescent lamps (CFLs) have been program mainstays, but over the last five to seven years, efficiency advocates and program managers have embraced dedicated, pin-based fluorescent fixtures. A main reason for this shift is that it is not possible to replace the fluorescent tube in a fluorescent fixture with a regular

incandescent lamp. Theoretically, the consumer will have no choice but to replace expired lamps with new fluorescent lamps (either compact or long-tube style, depending on the fixture), and will not be able to revert to incandescent lighting in the future. This idea of "locking in" residential lighting energy savings is appealing in the energy efficiency community, and particularly in residential new construction programs. As a result, many residential new construction programs tend to see the roles of screw-based CFLs and fluorescent fixtures quite differently and often attempt to promote or impose fluorescent fixtures in preference to screw-based CFLs.

This common, local programmatic separation between screw-based CFLs and fluorescent fixtures also reflects an administrative division within the ENERGY STAR residential lighting program area between the DOE (screw-based CFLs), and the EPA (fluorescent fixtures). Each agency tends to champion the technology it is responsible for and there are few examples of technology-blind, integrated residential lighting approaches at the federal level. For example, the EPA's Advanced Lighting Package (ALP), a relatively new ENERGY STAR program designed to recognize builders who install high concentrations[1] of ENERGY STAR fluorescent fixtures in new homes, does not allow the inclusion of screw-based CFLs to count towards the program standards.

Over the last few years, however, some residential lighting energy efficiency program managers have begun to question the rationale for blanket preference for fluorescent fixtures, and have come to view screw-based CFL applications in standard residential screw-based fixtures as a complementary option. Several developments have contributed to this recent repositioning:

- The market penetration and consumer acceptance of screw-based CFLs has increased dramatically. Sales of ENERGY STAR labeled screw-based CFLs have increased nationally by 400% over the last several years[2]. This was due to several factors including: lower prices, smaller models appropriate for more applications, improved product quality, rising electricity rates, and increased support by utilities, manufacturers and retailers.
- At the same time, market penetration and consumer acceptance of ENERGY STAR fluorescent fixtures has lagged. The overall market share of ENERGY STAR fixtures has not grown significantly during the past few years, despite intensive programmatic interest and financial support from many utilities[3]. While the number of ENERGY STAR qualified fluorescent fixtures has increased greatly, the selection of products available to most buyers is quite modest. ENERGY STAR fixtures continue to face many market barriers, especially where there are no active programs supporting them.
- The quality and reliability of compact fluorescent lighting products, both screw-based CFLs and CFL fixtures, has become a pressing concern. However, quality problems with CFL fixtures are more difficult to address, and to compensate for. Results from the Program for the Evaluation and Assessment of Residential Lighting (PEARL) testing have raised a red flag about screw-based CFL quality. However, the ENERGY STAR for residential light fixtures technical specification is far less stringent with regard to

[1] 50% of high-use lighting applications, 25% of low-use applications, and all ceiling fans must also be ENERGY STAR.
[2] In 1999 and 2000, CFL market share rose from 0.36 percent to 0.54 percent. During 2001, that number quadrupled, putting the national CFL average market share at just over 2 percent (Itron 2003).
[3] EPA estimates ENERGY STAR fixture sales at only about 2% of the residential lighting market (EPA 2004).

reliability and performance than the ENERGY STAR for screw-based CFLs technical specification. In contrast to the screw-based CFL specification, the fixture specification contains no lumen maintenance requirement and no rapid cycle stress test. PEARL tests ENERGY STAR qualified lighting products for their compliance with the ENERGY STAR specification. PEARL did not test fixtures in the last two rounds, but if it had, the results would not necessarily have said much about the reliability of the fixtures. Reliability and performance are more difficult and expensive to test in fixtures than in CFLs. However, based on costs alone, one would assume that consumer expectations for fixtures are higher than for screw-based CFLs. Screw-based CFLs are now so inexpensive and easy to obtain that the occasional failed product may not cause consumers to return exclusively to incandescent lamps. However, consumers may be less willing to forgive and forget the considerable expense and inconvenience of replacing a bad fluorescent fixture. The limited data available on product returns indicate that fixtures are much more likely to be returned by consumers than screw-based CFLs (ACEEE 2002). While some fixtures may be returned for esthetic reasons, most returns are likely due to some kind of failure. Program experiences in Vermont and Massachusetts also appear to support elevated concern about fixture quality (see below for more detail).

- The diversity and complexity of CFL tube and base combinations, and concerns about the long-term availability of replacement lamps are increasingly viewed as significant customer service issues. The ENERGY STAR for residential light fixtures specification requires that lamps included with fixtures be rated for a minimum of 10,000 hours. This means that a replacement lamp will be needed after roughly nine years of normal usage. Given the speed of technological and market change in the lighting industry, will the right replacement lamp for the fixture be available when needed? If sales volumes of ENERGY STAR fixtures remain relatively small, and if the lamps used last as long as they are rated, the turn-over for each of the many lamp types may remain so low that it may not make economic sense for retailers to carry a wide selection of them. This means that consumers may be forced to go to electrical suppliers or specialty lighting houses to get replacements. The problem with lamp availability is compounded by a lack of uniformity in the configuration of lamp pin bases. Some progress is being made in this area, but absent regulation it is not clear that manufacturers will give up proprietary designs to help resolve this problem.
- Program strategies increasingly rely on cooperative promotions and relationships with manufacturers, and the screw-based CFL market has proven to be amenable to these strategic market intervention methods. The screw-based CFL market is relatively concentrated around a dozen or so key manufacturers of unitary products. The screw-based CFL market is also dominated by ENERGY STAR qualified products. The fixture market is inherently more decentralized with hundreds of important manufacturers, many of whom use OEM lamps and ballasts in their fluorescent products. Fixtures tend to go through more complex distribution channels (i.e. lighting showrooms, wholesale electrical contractors, etc.) and (as of this writing) the large residential fixture manufacturers such as Juno and Lightolier have yet to make a full-scale commitment to the ENERGY STAR program.

Questioning the Current State of Residential Lighting Affairs

For these and other reasons, several energy efficient residential lighting programs, particularly residential new construction programs, are increasingly embracing complementing fixture and CFL strategies. One program in Massachusetts has more than five years experience attempting to convince builders to install ENERGY STAR fixtures, but has recently changed focus to allow ENERGY STAR screw-based CFLs as well.

Massachusetts Energy Star Homes

The Massachusetts ENERGY STAR Homes Lighting Program began in 1999. In 2000 the program created a full-color catalog to make it easier for builders and homeowners to find ENERGY STAR qualified lighting and offered a rebate of up to $500 per participating home for eligible fixtures. The program installed approximately 4,200 fixtures that year (average seven fixtures per home or apartment). There were many problems at the beginning including long lead times for obtaining products, fixture failure, incompatible replacement lamps, changes to the ENERGY STAR qualified products list, high prices, lack of availability of attractive models and conflicts with showrooms and manufacturers. Some builders had problems with delivery and quality while others became discouraged with callbacks and the complexity of the program and refused to take advantage of the rebate. Costs to the builder for electrical contractors to remove and replace failed fixtures were a major issue (Steele 2004).

The program then transitioned to a more direct market approach. The program no longer distributed a catalog, but identified qualified fixtures and assisted customers in finding eligible products on their own. This system simplified the process substantially and, along with improvements in availability and performance, allowed the program to expand. The Massachusetts program installed approximately 7,700 ENERGY STAR fixtures (8.0 fixtures per unit) in 2001 and approximately 8,200 ENERGY STAR fixtures (5.7 fixtures per home) in 2002.

In 2002, the decision was made to eliminate the lighting rebate for single-family homes. By the beginning of 2003, the program rebated only low income/affordable housing projects up to a total of $300 for up to six fixtures per unit. In 2003, the Program installed approximately the same number of ENERGY STAR fixtures as the previous year, but because more ENERGY STAR homes were completed under the program, the number of fixtures per home decreased (5.0 per home). The same rebate structure exists for 2004. In January, the average number of ENERGY STAR fixtures installed per home was 3.37.

Lamp Pilot

Early in 2001, discussions began about a pilot to also use screw-based CFLs in the Massachusetts ENERGY STAR Homes Program. Program management saw that screw-based CFL technology had advanced rapidly and thought that with screw-based CFLs it would be possible to save energy in lighting applications where ENERGY STAR fixtures, for one reason or another, had not been installed. The pilot design allowed the Home Energy Rater to install screw-based CFLs during final inspection, and receive an incentive of $1 per lamp. The program purchased the screw-based CFLs wholesale, and the sponsoring utilities negotiated a per-lamp installation fee (taking into account staff time, breakage, data-tracking and ordering) with the program delivery contractor (Conservation Services Group or “CSG”).

To date, the pilot has been quite successful. Raters began installing screw-based CFLs in 2002 with a total of 1,619 for the year. In 2003 they installed 12,207 CFLs, or an average of 7.5 per house. In the month of January 2004 alone, over 1,200 screw-based CFLs were installed, an average of 14.6 CFLs per home. Recent data indicates an average of 10 screw-based CFLs per house since that time. This increase reflects screw-based CFL price reductions and size reductions, and increasing rater familiarity with what works and what does not. Builders have been very receptive to the screw-based CFLs. One builder, who had not been interested in using fluorescent fixtures due to a fear of callbacks and obtaining replacement lamps, recently welcomed the installation of 72 screw-based CFLs in one of his completed homes.

Lamp Pilot Evaluation

An evaluation of the Massachusetts ENERGY STAR Homes Program was completed in February 2004 and examined the removal rates of screw-based CFLs and ENERGY STAR fluorescent fixtures (Nexus Market Research 2004). Evaluators conducted telephone surveys with 51 Massachusetts ENERGY STAR Homes program participants whose new homes had received direct-install screw-based CFLs at the completion of construction, roughly 12 months prior to the survey. Participants were asked whether they were aware that they had screw-based CFLs and/or ENERGY STAR fixtures, if they were in any way dissatisfied with the performance of these products, and if any had been removed. As the Table 1 shows, only small (and not statistically different) percentages of both screw-based CFLs and fluorescent fixtures had been removed.

Table 1. Fluorescent Light Fixtures and Lamps Removed Since Moving in to Home

	Total Number Estimated in Homes	Number Removed	Percent Removed
Fluorescent Fixtures (n=28)	232	11	5%
Screw-Based CFLs (n=17)	174	6	3%

These results bring into direct question the assumption that fixtures offer poorer persistence of savings than CFLs. Another surprising finding from this study was that customers were only able to identify 20% of the fixtures that had had screw-based CFLs installed. The evaluators concluded that this response showed, at least in this program, that both customer acceptance of screw-based CFLs and likely screw-based CFL retention rates appear to be quite high.

Other Programs

The Vermont ENERGY STAR Homes service has seven years of history promoting efficient light fixtures in new homes. Implementation contractor Jeff Gephart reported that one model of compact fluorescent recessed down lights experienced a 30%-40% failure rate, requiring the retrofitting of an entire development and threatening the continued support of several prominent builders, several of whom had taken years to coax into the program. In another 62 unit development 11 to 15 ENERGY STAR fixtures from a prominent national manufacturer were to be installed per home. After completing the first home, ballast noise from four fixtures

prompted the builder to replace them, and threaten to install incandescents in the remaining homes. After significant additional support from program personnel requiring creating a whole new fixture schedule utilizing a different product line, the builder did install ENERGY STAR fixtures (Gephart 2004).

Vermont ENERGY STAR Homes is committed to using fixtures and has a simple and flexible minimum requirement of four fixtures per home in high to medium-use locations. However, non-ENERGY STAR qualified fixtures are eligible for the program due to ENERGY STAR availability problems, and a belief that the best available technology is not always ENERGY STAR qualified (Gephart 2004). As in Massachusetts, HERS raters now directly install screw-based CFLs in Vermont ENERGY STAR homes during final inspections as an unadvertised portion of the service.

In the Northwest, the Northwest Energy Efficiency Alliance ("Alliance") made a significant lighting element part of the compliance requirement for the ENERGY STAR Homes Northwest program. Fifty percent of all sockets must contain fluorescent lamps. The Alliance specifically allows either ENERGY STAR fixtures or screw-based CFLs to satisfy this requirement, although they expect screw-based CFLs to dominate the installations.

The Residential Energy Services Network "(RESNET") recently proposed updates to the Home Energy Rating System (HERS) Standards that incorporate lighting in the HERS score. Score credits are specifically allowed for both fluorescent fixtures and screw-based fixtures with CFLs installed, recognizing that screw-based CFL persistence is probably about the same as fixtures.

An Integrated Approach

What we see in the field are a growing number of ENERGY STAR Homes programs getting creative about ways to integrate the installation of screw-based CFLs and fluorescent fixtures in new homes. We believe that the result will be greater savings, better customer satisfaction, and better builder acceptance.

Rather than basing program eligibility for energy efficient residential lighting products on broad technology types, we think a more reasonable approach would be for programs to offer the broadest possible range of options that can have the following characteristics:

- Energy efficient;
- Reliable;
- Reasonable lifecycle cost;
- Reasonable retail price;
- Best combination of features for the application (including dimmable where desired);
- Adaptability to changing lighting needs such as future lumen level adjustments;
- Instant start and quiet, flicker-free operation; and
- Easily located and inexpensive replacements.

Example: The New Approach and Recessed Cans

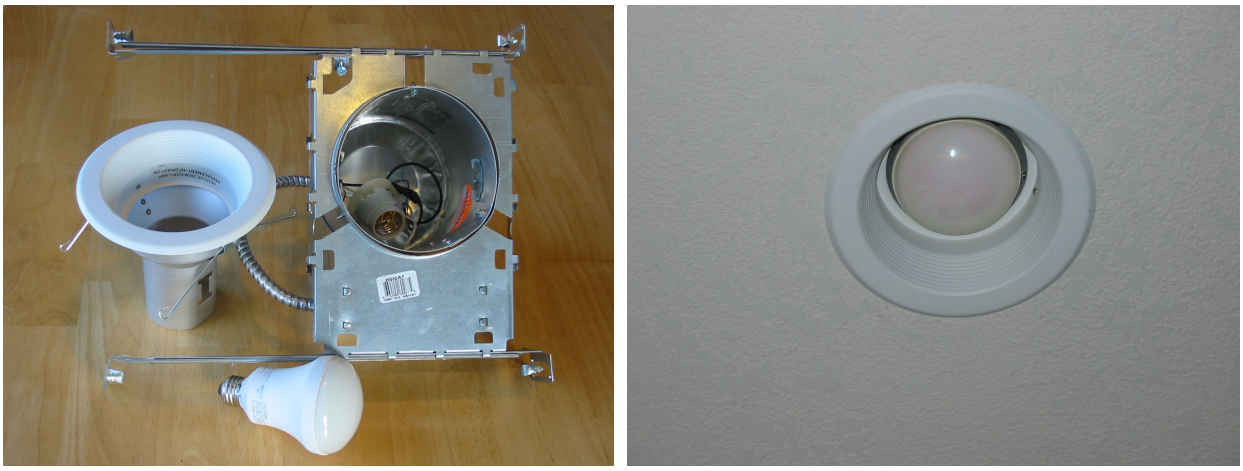
Incandescent recessed ceiling cans are cheap and extremely popular. Recessed cans represent almost one third of all new fixture sales yet pose a daunting technical challenge for energy efficient residential lighting (Economic Industry Reports, Inc. 1998). They tend to subject

whatever light source is in them to high operating temperatures, particularly if the fixture is IC, or "insulation contact" rated and air-tight. In sixty-seven percent of the states, building energy codes now require airtight fixtures in all insulated ceilings. High temperatures do not bother incandescent lamps, but can dramatically reduce the life-spans of compact fluorescent ballasts and tubes.

Very few ENERGY STAR/IC/airtight models of recessed ceiling cans are currently available (four as of the April 27, 2004 update to the ENERGY STAR qualified product list) and even these ENERGY STAR products have not been subjected to a rapid cycle stress test or other reliability tests. The Pacific Northwest National Laboratory (PNNL) has successfully completed testing on six models by three manufacturers of energy efficient down lights (out of an undisclosed number of products that did not survive testing). These successful products endured 12 months of long-term cyclic laboratory testing, in a simulated insulated ceiling environment. The fixtures also passed a short-term thermal test. For more information visit www.pnl.gov/cfldownlights. Two of the PNNL down lights are also ENERGY STAR qualified.

Another energy-efficient down light solution is to combine a standard screw-based IC/airtight recessed can with a screw-based CFL designed for recessed can/down-light applications. This approach has been successfully implemented by one of the authors in his new home, and has earned favor with the greatest lighting critic of all, his wife.

Figure 1. Genura Screw-Based CFL and Incandescent IC/Airtight Recessed Fixture



The purchase cost of this particular screw-based CFL and conventional recessed fixture combination was comparable to that of the less expensive down lights tested by PNNL. Of course, the costs to the consumer of replacing a failed screw-based CFL are much lower than the cost of replacing a failed fluorescent fixture. However, PEARL testing has raised concerns about the reliability of many reflectorized screw-based CFLs. Given the number of issues at stake, it may be useful to think about the relative costs, benefits and risks of the two options using a matrix as shown below in Table 2.

Table 2. Cost, Benefit and Risk Comparison for Energy Efficient Recessed Fixture Options

Efficient Lighting Solution	Price	Reliability Assurance	Availability	Implications of Failure
Technical Consumer Products (model 13726/13426)	Around $50 (per PNNL)	ENERGY STAR qualified, has passed stringent tests at PNNL	Available through TCP, PNNL, and some distributors	Costs and time associated with fixture removal and replacement
GE Genura Screw-Based Lamp and Conventional IC/Air-Tight Can	Around $50 (est. combined cost of CFL, fixture, and trim kit)	Genura is ENERGY STAR CFL qualified, well-established product	Fixture widely available. CFL available through GE distributors	Costs and time associated with CFL replacement

Both energy efficient down light solutions offer different packages of costs, benefits and risk. The point is that program managers should be able to access all options to meet the needs of program partners and participants.

Integrated Approach Strategy for Residential New Construction

Our conversations with builders have made it clear that screw-based CFLs are often an easier sell, at least initially, than fixtures. Mack Caldwell is a partner with Ideal Energy Homes, the largest builder in Oklahoma (600 homes in 2003) and winner of numerous awards for energy performance. He has made it very clear that because of the incremental costs, and the desire to ensure consumer choice, Ideal is unwilling to install ENERGY STAR fixtures but is eager to install screw-based CFLs. Mr. Caldwell says that his company has no interest in becoming the "energy police" that limits their customers' options (Caldwell 2004). Ideal's philosophy is that consumers will make the right choice given good information, and they will choose screw-based CFLs and keep them in place when they realize the savings they provide (average of $35/month in model homes, according to Ideal).

Two of the authors have worked under sub-contract to EPA promoting the Advanced Lighting Package (ALP) to builders around the country for the last two years. It has become clear to us that there would be a greater opportunity to get more ENERGY STAR lighting into homes if the ALP also allowed screw-based CFLs. Time and again, builders have shied away from making the large commitment to fixtures required by the ALP. Builders want the additional recognition the ALP ENERGY STAR designation offers them, but many cannot justify the perceived risk of callbacks, or the higher product costs. With screw-based CFLs, they know that if a customer is dissatisfied, it will not take an electrician and a replacement fixture (at a total cost of $100 or more per fixture for labor and materials) to resolve the complaint. In fact, most of the time, the customer can probably make the switch themselves without any builder involvement. By allowing screw-based CFLs as part of the ALP, we suggest that many more builders would be willing to participate, resulting in much greater energy savings and far out-weighing any situations in which screw-based CFLs get replaced with incandescent lamps.

Integrating screw-based CFLs and fluorescent fixtures should also allow residential new construction programs to achieve higher overall penetrations of energy efficient lighting, and higher energy savings. In the Massachusetts ENERGY STAR Homes program through January 2004, builders averaged just over three ENERGY STAR fixtures per house. If we conservatively assume that the 14.6 screw-based CFLs installed in the average home there went into seven fixtures (at two per fixture), that is still double the installation rate of fixtures and twice the energy savings. Rated at a minimum of 6,000 hours of life, screw-based CFLs should last at least

five years. Five years from now it is likely that screw-based CFLs will be even cheaper, smaller, of higher quality, and give better light. It seems likely that when it comes time to replace a screw-based CFL installed today that there will be a good selection of products at competitive prices from which to choose a replacement. Most homeowners tend to replace a broken or worn-out item with a similar product, especially if they are available at their local food and drug stores, which is where most screw-base CFLs are sold nationally (Itron 2003). Contrast this situation with what may happen when it comes time to replace the expired pin-based lamp from a dedicated CFL fixture. These pin-based CFLs are not available where consumers typically purchase their lamps, so they would need to be specially ordered or found at a lighting or electrical supplier, which will be an inconvenience. Because of the dozens of non-compatible pin-based configurations, it will be a confusing challenge to then match the replacement lamp. Consumers will become quite frustrated with the whole situation. Why do we need to put them through it?

Conclusions and Recommendations

Residential energy efficient lighting technology has made significant advances in the last five years. It is time for the way we think about applying it to catch up. It is important that all parties appreciate that neither dedicated compact fluorescent fixtures nor screw-based CFLs can conclusively claim superiority in terms of efficiency, reliability, consumer satisfaction or energy saved. Rather than worrying about which is better overall, we should gather all the empirical data on the performance of specific products that we possibly can and use that information to try to offer consumers efficient lighting choices that will meet their expectations. This means establishing the primary goal as saving lighting energy, rather than promotion of a particular technology. EPA and DOE should develop a combined, cooperative approach to ENERGY STAR residential lighting that will allow both screw-based CFLs and fluorescent fixtures to find their best niches. Additional recommendations include:

- Continue to improve the quality and reliability components of the ENERGY STAR specifications for both fluorescent fixtures and screw-based CFLs to encourage product improvements;
- In cooperation with EPA, DOE, manufacturers, distributors and the efficiency community, develop a new ENERGY STAR light fixture designation that includes a screw-based fixture that is designed specifically to accommodate (and is sold with) screw-based CFLs as an alternative to pin-based fixtures;
- Consider changing the ENERGY STAR Advanced Lighting Package to include conventional fixtures with screw-based CFLs;
- Study builder and consumer acceptance of compact fluorescent options (i.e., screw-based versus fixture options) and the implications of their preferences on lighting energy savings; and
- Study more fully the question of persistence of ENERGY STAR fixtures and screw-based CFLs placed in fixtures.

References

American Council for an Energy-Efficient Economy. 2002. Brad Steele. *An Examination of the Performance and Acceptance of Compact Fluorescent Bulbs and Fixtures in the Residential Market*. ACEEE Summer Study on Energy Efficiency in Buildings.

Caldwell, Mack. 2004. Personal communication. Ideal Energy Homes. Okalahoma City, Okalahoma. May 3, 2004.

Consortium for Energy Efficiency. 2004. *CEE Summary of ALA Think Tank Meeting on Lamp Bases*. Norfolk, VA. January 28, 2004.

Gephart, Jeff. 2004. Personal communication. Vermont ENERGY STAR Homes Service. Rochester, Vermont. April 2004.

Itron, Inc. 2003. *Massachusetts Lamp Trends.* San Diego, California.

Nexus Market Research, Inc.. February 2004. *Estimates of Fixtures and CFLs Installed by the Massachusetts ENERGY STAR Homes Program and Removed by Home Buyers.*

Steele, Brad. 2004. E-mail and personal correspondence. Energy Federation Inc. April 2004.