AND IN THIS CORNER, THE REIGNING CHAMPION COMING IN AT 800 LUMENS…

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ABSTRACT

For the past decade, CFLs have been the champion of energy efficient lighting. CFLs have bested other lighting technology contenders and, as the reigning champion of efficient lighting, they still account for the largest amount of sales volume and reported savings for the suite of energy efficiency programs. However, in recent years, LEDs have shown great promise as the next efficient lighting champion. Multiple factors are influencing the rapid rise of LEDs as a contender for the champion's title. The Energy Independence and Security Act of 2007 (EISA)—which mandates new energy efficiency standards for light bulbs—has certainly been one of the main drivers pushing LEDs since 2012, when the requirements took effect. In addition, decreasing cost and increasing LED product selection, as well as consumer preference, are also threatening the CFLs leading position.

With LEDs looking more and more promising, one question looms large: *Can LEDs take the energy efficiency title belt of lighting away from the CFL?* If the answer is yes, should utilities continue to promote CFLs, or should they move toward promotions that feature LEDs and ramp down support for the CFL?

In the battle for residential lighting supremacy, the CFL and the LED are headed into the ring to duke it out. Who will be the winner?

Title Fight Predictions

Each technology competitor comes to the ring with some notable strengths and a few weaknesses (Table 1).

Table 1. Pound for Pound Comparison

	Reigning Champion: The CFL	Contender: The LED
Strengths	Familiarity Initial lower cost compared to alternatives with equivalent savings	Higher satisfaction ratings More applications Retailers/manufacturers show great interest in partnering with program administrators
Weaknesses	Mercury Poor specialty performance	Cost-effectiveness challenges Higher upfront cost

Although the CFL has been the reigning energy efficiency champion for many years now, it is starting to show some signs of fatigue. Familiarity and overall satisfaction for the CFL continues to be relatively high, but there are technical issues that have and continue to disappoint users. The CFL has worked hard to overcome its dubious reputation, however, it continues to fall short in key performance

areas such as dimming and coming to full brightness quickly. Furthermore, its use of mercury, though miniscule, presents a dark side that many environmentally minded consumers are unwilling to overlook.

Although the LED has been on the scene for decades, it was not until about 2012 it showed promise in taking on the CFL. Users have been very impressed with versatility of the LED, saying it works in more applications. Some users are fans of the "instant on" of the LED, while others tout its dimming capabilities and light quality—a known weakness of the CFL.

In terms of energy consumption, the LED enters the ring a bit underweight—consuming on average a few less watts than the CFL. Clearly the biggest advantage the LED has in today's fight is its longevity. It can simply outlast the CFL. Although it is uncertain how long standard application LEDs will last, some predict it will double, if not triple, the lifespan of a CFL. To gain a competitive edge, the LED hit the weight room to work on its greatest weakness—price. It was able to shed some pounds and is now retailing as low as $8 without incentives, and there is talk that it will retail for less than $5 in the next few years.

Even with the LED's recent training, it is still too close to call. Round 1 is starting. Ding.

Round 1: The Fight for Socket Share

The CFL comes out strong and clearly dominates the share of socket space. In fact, the CFL has over 30 times more socket share than the LED. This is not unexpected since the vast majority of lighting budgets, approximately $450 million nationwide, have been spent to promote and install CFLs in homes and businesses. While these efforts were largely successful, saturation levels of CFLs plateaued at approximately 35% to 40% for medium-screw based bulbs, which tend to be the bulbs that work in most applications with light bulb replacements (Table 2).

Table 2. Medium-Screw Based CFL Saturation

State or Region	Date of data collection	Saturation
Southern State	2013	33%
Midwest State 1	2013	29%
Midwest State 2	2013	40%
Midwest State 3	2013	36%
Midwest State 4	2013	35%
New England County	2012	25%
Georgia	2013	23%

In other words, only one in three medium-screw based sockets contain a CFL even after a large and steady influx of money, marketing, and program support. And CFL saturation across all socket types is even lower (Table 3).

Table 3. Saturation of all socket types

State or Region	Saturation
Southern State	26%

Midwest State 1	22%
Midwest State 2	31%
Midwest State 3	28%
Midwest State 4	31%
Northwest Region	25%
Massachusetts	28%
California	30%
Georgia	20%
Connecticut	32%

Newer programs, those that started to promote CFLs five years ago have seen significant increases in CFL saturation levels. For instance, two Midwest utilities saw CFL saturation levels nearly double from the mid-teens to nearly 30% from 2009 to 2013. It is anticipated that the CFL saturation levels begin to taper off and have much smaller incremental shifts similar to states with more well established residential lighting programs.

LED penetration (defined as homes with at least one LED installed) and saturation (defined as the percentage of LEDs out of all bulb types) are also increasing at a rapid pace. Dayton Power and Light, a utility in Ohio, saw their LED saturation levels nearly double from 2009 to 2013. Similar increases have been noted in other states as well. While LEDs still represent a small percentage of the typical homeowner's lighting (approximately 1% to 2%) homeowners are buying more and more of them. In 2014, a lighting inventory for a northeastern utility showed nearly 25% of all households have at least one LED installed. This is four to five times what was found just a couple of years ago for other utilities. In fact, that same utility saw lower CFL saturations than expected, and penetration of CFLs was at 80% (meaning 20% of homes did not have a single CFL installed). Most studies find CFL penetration at 90% or higher. Even more compelling evidence that consumer behavior is changing, is that this study found zero incandescent bulbs in the 75 to100 watt range installed in homes (likely due to EISA regulation).

CFLs clearly dominate socket share, but things are rapidly changing. According to the North American Electrical Manufacturers Association, fourth quarter 2013 national sales figures provide conclusive evidence that sales of LED bulbs and halogen A-lamps continue to increase and take market share from CFLs and incandescent bulbs. LEDs and halogen A-lamps grew at a rate of 42.3% and 41.8%, respectively, when compared to previous quarter's sales. This data supports the two following assumptions made by industry experts before the EISA provisions took effect:

1. The baseline lighting technology is shifting from incandescent to halogen A-lamps.
2. LEDs are beginning to replace CFLs as the energy-efficient option.

Based on the data, the CFL took the first round. However, the LED looks more and more promising and are likely to have a bright future (pun intended) that could possibly outshine (and, again, pun intended) CFLs in socket saturation.

Round 2: Pricing

As expected, the CFL packs a punch with its lower price point, and puts the LED on shaky ground with consumers. A recent study of Midwest utilities, using sales weighted average prices, found that LEDs are seven times more expensive, even after markdown (Table 4).

Table 4 Mean Price by Midwest Program Retail Channel and Bulb Type

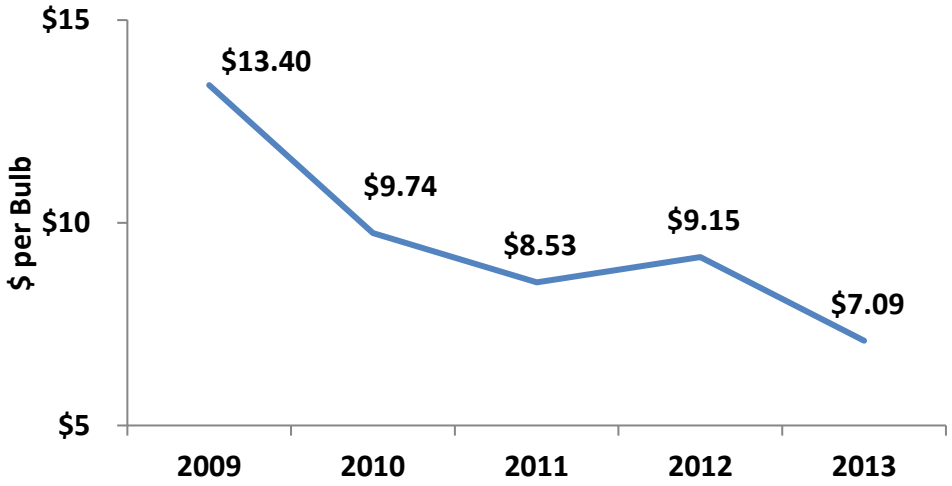
Store Type	Bulb Type	Mean Regular Price/Bulb
DIY and Non-DIY	LED	$15.33 - $21.15
DIY and Non-DIY	CFL Specialty	$3.71 - $4.98
DIY and Non-DIY	CFL Standard	$1.70 - $2.08

Note: DIY stands for Do-it-Yourself

CFL prices have not dramatically changed over the past few years, and in some instances increased in tandem with other fluorescent lighting products due to lack of available low-cost rare earth metals coming out of China. It is unlikely CFLs will experience a significant downward shift in price in the near future, particularly since interviewed manufacturers indicated they were not putting any additional research and development funds into CFLs.

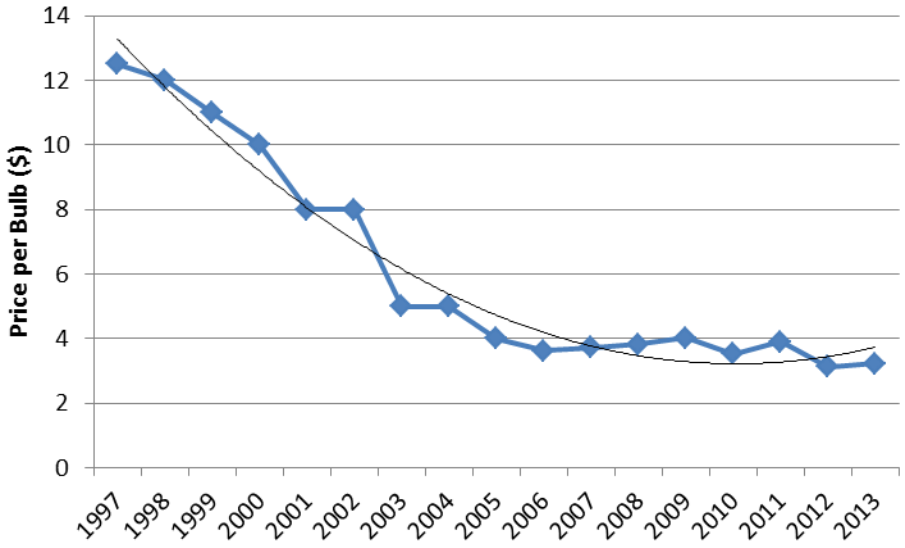
LEDs, on the other hand, have shown a steep decline in pricing. For example, analysis of sales data from the grocery, discount, dollar, club, and mass merchandiser channels show a decrease from $13.40 per bulb to $7.09 per bulb in 2013 (LightTracker, Inc). This is a 53% price drop.

Figure 1. Average LED Prices U.S. Market 2009 - 2013



Comparatively, in the first four years of CFL commercialization, CFL prices fell by only 37.5% (Holland, 2014; Figure 2).

Figure 2. Average CFL Price and Trend



In a simulated market test that offered participants multiple random combinations of bulb attributes such as type, price, brightness, efficiency, LEDs showed real promise with a price point less than $12 per bulb (participants selected LEDs as their preferred bulb more often than when they were priced above $12). Now that LEDs retail for less than $10 per bulb (and in some cases as low as $5 per bulb after mark downs), the LED is becoming a more viable option for the typical light bulb purchaser.

Both bulbs bring avoided replacement costs to the ring. CFLs and LEDs outlast other bulb types such as the halogen. In fact, longevity should not be underestimated and is a key consideration in the cost-effectiveness analysis. When the lifespan of the CFL and LED is compared to that of the incandescent bulb and halogen as a baseline, consumers can save roughly $4.00 (for CFLs) to $7.00 (for LEDs) over the lifetime of the bulbs in reduced costs for replacement bulbs. Multiply this by the number of CFLs and LEDs incentivized in a given year by a program administrator and that adds up to millions of future dollars saved. Due to its longer life, the LED delivers more than the CFL on higher avoided replacement costs.

When it comes to which technology has a lower initial price point, CFLs are the clear winner. In a couple of years the LED may be able to match up better in this category. LEDs, however, are delivering higher overall benefit associated with longer life and, thus, fewer replacement costs. Although it is close, the winner of this round is the CFL. Initial price point is still too big of a factor for the average customer.

Round 3: Annual and Lifetime Savings

Both bulbs appear to be swapping blows regarding energy savings. When categorized by lumens, CFLs consume just a few more watts than the LED. When comparing wattages from the ENERGY STAR® database, the percentage of improvement from CFL to LED is approximately 6% to 11%, depending on if it is a general purpose bulb or a reflector. LED general purpose bulbs consume two watts less, and reflectors consume slightly less than four watts. Just enough, to edge out the CFL and declare the LED the winner of annual savings.

The LED looks strong with regard to lifetime savings and packs a wallop with longevity. LEDs are predicted to outlast CFLs by 10 to 15 years. Assuming the average CFL and LED save 44 kWh per year, at $0.11 per kWh, this could result in lifetime savings upward of $47 per bulb for the LED and approximately $23 for the CFL. From the program administrator perspective, that is 264 kWh versus 660 lifetime kWh in savings.

Furthermore, the assertion that CFLs last 10 times longer than the traditional incandescent light bulb has not necessarily lived up to the manufacturer and industry claims.[1] CFL life may be compromised by an increased "switch factor," or more frequent on and off switching. In addition, there is substantial anecdotal evidence that CFLs dye after a few months of use—the CFL loses points here.

Annual savings for LEDs are just slightly better than for CFLs; however, the longevity of LEDs is so much better than CFLs that the overall lifetime electric and cost savings outweigh the similar annual savings. The LED wins the third round.

Round 4: Product Innovation and Trends

CFLs appear to have maxed out in terms of efficiency, and CFL innovation seems to be obsolete. Manufacturers have yet to fix some important flaws with CFLs, namely that the quality of light is not well liked, flickering occurs, and they do not dim the way one would expect a light bulb to dim.

The LED, on the other hand, dances around the CFL when it comes to staying current with changing times. LEDs are changing and adapting to how consumers interact with other technologies, such as our tablets and smart phones. Innovative products, such as the Philips Hue, are on the market and allowing customers to interact with their lighting in ways not feasible even just a few years ago.[2] Even newer products, such as the alba by Stack, are reporting upwards of 70% savings compared to the other efficient light bulbs. Although alba is an LED, it incorporates occupancy sensors and behavior learning algorithms to help save additional energy over the conventional LED.[3]

It appears that the tide has shifted and manufacturers are investing more money and resources into LEDs and letting the CFL run its course without additional investments. If the LED lifespan is even half of what is reported, then it certainly makes sense for a manufacturer to be the first to have its LED product in consumer homes.

With manufacturer investments and innovation, the winner of round 4 is clearly the LED. The CFL really let its guard down on innovation.

Round 5: Opportunity

CFLs and LEDs have both scored well over the last few rounds. This round compares the competitors with regard to versatility and compatibility with not-so-common sockets (dimmers, small based sockets, etc.)

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[1] More information available online at: http://energy.gov/energysaver/articles/frequently-asked-questions-lighting-choices-save-you-money#longer

[2] Available online at: http://www2.meethue.com/en-us/

[3] Available online at: http://stacklighting.com/

Table 5 summarizes different saturation levels and the remaining technical potential of efficient lighting for six utilities across the country.

Table 5. Efficient Lighting Remaining Opportunity

Utility	CFL Saturation	LED Saturation	Technical Potential	% Specialty	% Standard
Utility 1	23.9%	1.1%	89%	20%	80%
Utility 2	22.3%	0.9%	87%	20%	80%
Utility 3 (SF)	31.2%	1.5%	91%	20%	80%
Utility 3 (MF)	34.0%	1.4%	90%	18%	82%
Utility 4	32.7%	1.4%	91%	19%	81%
Utility 5	27.8%	2.2%	87%	25%	75%
Utility 6	28.5%	1.5%	89%	15%	85%
Average			89%	20%	80%

Again, CFLs clearly dominate the sockets when compared to LEDs. The technical potential, defined here as all sockets minus linear fluorescents and pin based halogens, is quite high; approximately 90% of sockets will take a CFL or an LED. Out of this technical potential, 80% of the opportunity remains in standard sockets (medium-screw based) connected to a standard switch (on/off). Twenty percent of this opportunity is with specialty type sockets (small or pin based) and specialty switches (dimmer and three-way).

In addition, the achievable potential for LEDs will likely be significantly higher than for CFLs. For example, in a recent study in New York, survey respondents who were using LEDs and CFLs, ranked LEDs as superior to CFLs in all aspects except price.

There is an LED bulb for every socket type in the home. While the same can be said about CFLs, LED performance surpasses CFLs when considering outdoor applications (LEDs are perfect cold weather products), and indoor tracked, recessed, and spot lighting applications often require dimming capability. CFLs can still compete with LEDs in a few applications due to price (and with no trade-off in quality), such as globes in a bath bar, but it is only a matter of time before LEDs win that fight as well. Table 6 shows one strategy for what bulb type should marketed based on application.

Table 6. Marketing CFL and LED by Application

Application	CFLs	LEDs	Both
Omnidirectional: general			X
Omnidirectional: three-way	X		
Omnidirectional: dimmable		X	
Bulged Reflector		X	
Candelabra		X	
Globe	X		
Multifaceted Reflector		X	
Parabolic Aluminized Reflector: Indoor		X	
Parabolic Aluminized Reflector: Outdoor	X		
Reflector		X	

Based on its future opportunity for energy savings, the LED wins last round.

And the Winner Is?

Although CFLs maintain a strong lead on current saturation, and remain the less expensive option, LEDs are the clear winner when it comes to lifetime savings, product innovation and trends, and future opportunities. The momentum is clearly turning —if it has not already—to LEDs. The champion's belt may have been worn by the CFL for over a decade, but it is clear that a new winner—the LED—belongs on the podium.

Not all is lost for the CFL. The CFL will still play a role in lighting our homes for several more years; however it may not be the consumer's first choice when it comes to energy efficient lighting.

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