

RELIGHTING AMERICAN HOMES WITH LEDS:

Are we destined to repeat past mistakes or move forward with a rational plan that addresses consumer preferences?

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The lighting industry is already well on its way to repeating many of the same mistakes made in past years with compact fluorescent lamp (CFL) market transformation programs, and unless public opinion is quickly transformed with LEDs, it's only going to get worse.

How did we get into this situation?

As a collective, the energy-efficiency community, which includes federal and state agencies, regulatory bodies, utility organizations, and efficiency-advocacy groups, has been reluctant to make the difficult, long-term, collaborative decisions that are desperately needed to realize long-term market transformation in residential lighting. Without forward thinking, solid commitment to real change, and better understanding of consumer lighting preferences, we are headed toward another expensive train wreck with Edison-base LED lighting.

With an almost explosive array of technologies and products about to enter into this marketplace, fueled by unbridled and uninformed enthusiasm from federal agencies, consumers will be overwhelmed, confused, and ultimately could be disappointed by unmet performance expectations. We are currently at the very beginning of one of the largest market transformation events in the lighting marketplace. American homes, illuminated with the ubiquitous filament lamp, eventually will recognize LEDs as the light source of choice. The question today is not whether it will happen; it's when and how painful and expensive this process will be for American consumers. If we act now, we can accelerate this process and save a lot of energy, and do it without wasting public money.

Our effort to convert American homes to CFL lighting proved to be very limited, despite glowing reviews by energy advocates and agencies on market penetration, of whom are still clinging desperately to the tantalizing promise of deep energy savings that are not happening. The dollars spent per kilowatt (kW) actually saved in this country with CFLs seem to eclipse any other lighting energy-efficiency program in our history. The sad reality, however, is that most of this kW will suffer snapback because of consumer dissatisfaction, stemming from poorly considered (or not considered at all) performance aspects, such as color, longevity, or both. No good studies exist to indicate or demonstrate the numbers of sockets that experience a second or even third relamping with CFL, demonstrating positive consumer experience and justifying further public investment.

Unquestionably, the national 10–15% (20% in California) adoption rate for CFLs in American residences is embarrassing compared to vast amounts of time, energy, and public investment. This statistic raises the question of why it happened, and what we can do to prevent it from happening again.

Why did this happen?

In their early days, CFLs had all the potential to evolve into light sources people would embrace for illuminating their homes. Phosphors could be blended to produce spectra that rendered color well, and lamps could be dimmed and fabricated to last for years. Key attributes, including color, dimming, and longevity, were topics of research, investment, and product development. Clearly it was an upward trajectory in terms of addressing consumer preferences.

Energy agencies and efficiency advocates locked on to CFL technology as a singular path to energy savings in the home, and the CFL became our poster child for the greening of America. It was certainly a great vision and a good goal, considering that our homes were almost exclusively illuminated with

15 lumens per watt (lpw) incandescent lamps—heaters that haven’t substantially changed since the time of Edison. Fifty lpw CFLs would, and should, have given us impressive national savings, if only consumers had bought them.

But they didn’t. Arguably as an oversimplification, energy agencies, environmental groups, and their advisers set eyes on cost, above all other issues, as a paramount barrier to widespread market penetration. Cost was deemed the reason people were not rushing to the store to relamp their homes with first-generation CFLs. Aggressive utility programs and energy agency efforts eventually brought millions of low-cost CFLs to American homes, where the technology was mostly rejected, and by and large the purchase behavior for lamps for the home hasn’t changed significantly.

Responding to cost-driven programs, industry focused on low cost and in this process often compromised longevity and product quality and did the minimum acceptable for color quality performance. High color rendering and enhanced phosphors for color brilliance are expensive and reduce efficacy, which unfortunately wasn’t subject to compromise. A 40-lpw CFL lamp with great color could ultimately have been better than a 50lpw CFL lamp if consumers liked it. This is a very important issue that was poorly considered in the national dialog.

Color performance wasn’t being demanded or encouraged and was therefore abandoned in favor of lower cost. Innovation and new investment in color was hard to justify and largely not pursued by mainstream manufacturers. Unfortunately, high color rendering lamps became the rarity and an expensive option. Industry also didn’t invest in research that would have brought us better products (dimming and long life). Instead, the focus was on reducing costs. Competing for large program purchases essentially forced the industry into this race to the bottom. A large manufacturer recently stated that “we can make anything the government wants, but there’s no room for great products at \$2 a lamp.” The main mistake is pushing industry to build lamps for agencies and programs, not consumers, and this is why we failed. The mantra became “make a \$2 lamp and they will buy them.” Clearly they did not, and the CFL now is relegated to being a cheap giveaway at grocery stores, sometimes free, as in a recent California effort, part of energy-efficiency programs to encourage public awareness.

In this environment, the American consumer has grown suspicious and wary of claims, and doubtful of life, color, quality, and amenity — the very attributes we need to transform a demanding marketplace. Recent attempts to educate the consumer on what’s inside the package don’t really change the fact that the product may or may not have the color quality performance attributes that consumers want.

Sadly, a \$2 CFL that has terrible color, a reputation for short life, and that flickers when it’s dimmed, simply isn’t going to engender long-term confidence or sustained market penetration. When the consumer goes into the grocery store, they aren’t purchasing energy savings; they are buying service and amenity, with an expected high light quality from many years of experience. It seems like a relatively simple construct, but this was largely overlooked in our CFL market transformation efforts and related programs.

From a consumer’s point of view, CFLs represent a departure from a set of expected performance attributes, principally color quality, appearance, life, and dimming. How good does my skin look in the mirror under this light? How about the art on the wall, the rug, the apples? There is now significant evidence that many of the primary purchasers (women) may have tetrachromatic vision, meaning that they have broader (enhanced) color sensitivity than men and trichromatic women. Giving them a lamp with less than stellar color rendering performance doesn’t bode well for changing their long-term lamp purchase behavior. How many women-specific focus groups on color preference were conducted for the development of Energy Star specifications?

What should we do now?

There are some relatively simple things that need to be done, but they require leadership and immediate action.

We need to move forward without repeating the expensive and unproductive processes of past residential lamp programs, which involves a lessons-learned effort. To address the main causes of failure in the CFL market transformation, there are really three performance attributes that we need to focus on: color quality, dimmability, and longevity. Incidentally, cost and efficacy also should be considered, along with the ability to dim, which offers both amenity and energy savings. If we persist in placing cost as the foremost priority, we again will create a climate of least cost and, by default, lowest quality. By their very nature, incentive rebates and buy-down programs are finite and involve unit savings calculation, pushing manufacturers to cater to the lowest common denominator. If we keep lowest cost as the driving force with LEDs, we will undoubtedly go down the same path as CFLs, risking continuing embarrassment from ineffective use of public funds.

While it's a very important performance attribute, efficacy already is a huge leap forward, compared to 15 lpw incandescent lamps. Market saturation of 30 lpw lamps that people loved and embraced would give us 50% national savings. In the current lackluster energy-efficiency environment, this would be a novel standout achievement. Tungsten halogen (enhanced performance incandescent) could get us there, but our national perspective has been focused on CFLs with bigger "anticipated" savings based on 50–60 lpw. Now the focus is on LEDs with same efficiency-efficacy bias.

With significantly higher lpw performance than CFLs, there is even more room to balance efficiency and color quality for products that the market will value and embrace. Buying lighting to make money—the true meaning of pay-back periods and life-cycle cost—is indeed the main selling point of energy efficiency. A very small fraction of American consumers prefers to save a few dollars per year experiencing poor light performance. The longevity of CFLs that would provide the monetary benefit is in serious doubt, as many fail much sooner than the incandescent they replaced.

Environmental groups and energy agencies have hoped that Americans would "get used to the CFL" as it is "almost as good." However, consumers did not get used to CFLs, inferior products to incandescent lamps in terms of quality. Learning from the CFL market failure, we need to better understand what consumers prefer rather than assume what they will just accept what we give them. The energy part of this equation is done, and the LED at 50–100 lpw would be a colossal homerun if consumers like it. Let's start addressing consumer interests. Replacing our national stock of incandescent lamps with LEDs is one of the best ways to help realize our goals for energy savings, greenhouse gas reduction, and national energy independence.

The most effective way to succeed in realizing lighting market transformation in the residential sector is to develop a national lamp specification that focuses more on color quality and longevity and a lot less on energy efficiency. The spec then will serve as the basis for lamp programs with well-specified and measurable goals.

How do we do this?

First and foremost we need a specification that addresses the following core issues:

- 1) **Color brilliance:** This is essentially how all colors are rendered, not just discrete samples. Both CRI and CQS are based on a limited number of color samples. We should focus more on proposed color rendering metrics that use extensive color sampling across the complete color gamut to ensure effective characterization for color rendering performance. We need the same or better performance than incandescent technologies; almost the same with wide variations across brands isn't good enough.

- 2) **Light color appearance:** The color of the light itself is very important in residential applications, with preference toward lower color temperatures, i.e., light with reduced blue content. Strong evidence shows that absence of blue light during the evening and night is essential for support of our circadian rhythms, which are important for health and well being. The blue content of traditional incandescent lamps is very small, making them appropriate for evening and nighttime illumination. In contrast, CFLs produce the appearance of white light by mixing blue, green, and red light. The blue light is perceived by the ganglion cells on the retina and affects circadian rhythms. Most white LEDs produce white light by exciting phosphors with blue light and having the same effect on circadian rhythms. It is not difficult to filter out the blue part of the spectrum, if it is required to do so. The issue here is that we just don't know.

LEDs offer a unique potential for development of light sources with dynamic color composition, manually or automatically adjustable to best support circadian rhythms for better health and wellbeing. This may be the true value that will move consumers toward LEDs, assuming they will do well in color rendering and longevity. Mom and Dad would be willing to pay for lighting technologies that will not only allow them to enjoy the visual aspects of their homes, but also help their children sleep better during the night and study more effectively during the day. They will not be considering payback periods, just like they do not put a price on granite counter kitchen tops.

- 3) **Light color uniformity:** Light needs to appear consistent from the same lamps in a space, especially when used in groups, such as downlights, sconces, and table lamps. The human eye is very good at discriminating small light color variations between lamps. This may be tolerable in lighting garages, but certainly not when lighting dining and living rooms. The specification should include consideration of perceptible variations in color appearance between samples of same LED lamp types.
- 4) **Dimmability:** People like to dim lamps, and, based on their experiences with incandescent lamps, they expect smooth dimming without flicker and drop in blue content. Dimming also is a very promising way to save energy. Dimming is common in most new homes, and it's a typical upgrade in renovations. Consumers have had bad experiences with CFL dimming, and we must ensure we do it right with LEDs.
- 5) **Longevity:** This is perhaps the most important underlying issue in why America has become disillusioned with CFLs. We have catch-up work to do here as we have created enormous suspicion within the consumer marketplace by promoting/suggesting long life and then falling short. Complicated testing and labeling programs won't easily overcome a marketplace flooded with short-life products. Consumers were promised long life, and we failed to deliver in a unified manner. Many CFLs failed to deliver longevity because of heat-related failure of the electronics that drive them, such as in downlights with vertical sockets that trapped the heat in the area of the CFL base that houses the heat-sensitive electronics. LEDs also are sensitive to heat, and their life is reduced significantly when they operate in hot environments. We need to ensure we address heat issues for all possible residential applications.

Many of these issues were spelled out in the draft "super spec" that was developed in California for next-generation lighting utility programs. Other issues, including power quality, efficiency, cost, packing, etc., are secondary concerns that can be fine-tuned. (*"Research Matters."* LD+A. Mar. 2010: 22–25.)

What else needs to be done?

We can't do this with an enhanced specification alone; it needs to be part of a much broader, well-thought-out plan. Clearly the CFL market transformation plan went poorly, in part because of a lack of consumer orientation but also due to poor integration with other "public interest" activities that could have been helpful, such as education, unified incentives and programs, measurement and verification, consumer testing, research and development. Clearly we need to think this out better this time.

So what does a potential plan look like?

- 1) **Develop a national lamp specification:** We need to immediately develop clear, unambiguous lamp specifications that are based first and foremost on color quality and long life, reflecting and underscoring consumer preferences. The specifications process needs to start with a comprehensive study of consumer preferences, focusing on two important priorities:
 1. Establishment of a “quality space” with better-thought-out educational programs that will allow it to dominate.
 2. Elimination of the window and corresponding demand for poor-quality products that will allow less-than-best products to flourish.

With finite program dollars there is a financial incentive in the industry to reduce product price allowing more lamps to be purchased if the calculated savings per socket is the same. This process essentially allows low-cost products to dominate. We've been unable/unwilling to ask for better products, fearful of price increases, accepting less and now paying the price in a cost-driven race to the bottom. This needs to change, and our future specifications need to be directed toward obtaining the best, not toward defining the worst or what's simply acceptable. Our current standards and specs have been based on establishing minimum performance criteria, and in the absence of strict compliance have resulted in a plethora of poor products. We should make sure we do not repeat the same mistake again.

- 2) **Refocus national efforts on establishing and achieving goals:** At a national level, agencies should focus on defining real and measurable goals and developing coherent strategies that will realize them. “Measurable” is the operative term here, as we need to evaluate the success of these strategies, particularly with large public investments. These goals should be tied to timelines with highly aggressive incentives that let the industry and marketplace do their magic. Establishing and achieving real energy reduction goals and deliverables should be “mission one” of our national energy plan. The climate of vaguely defined goals and shifting priorities at a national level, coupled with the lack of any real oversight, has insulated efficiency programs from achieving any long-term market transformation, as no real incentives exist to push toward real change. In fact, the absolute amount of energy being used per household for lighting during the last 30 years has increased rather than decreased. Perhaps it's time to re-evaluate our investment portfolio and our strategic energy-efficiency plan at a national level and develop one that delivers.

The development of the national spec should be based on partnerships with industry and consumer groups that could help to better understand how to appeal to American consumers. There are many business schools and innovation centers that can help the regulatory/efficiency community develop a process to better identify and then articulate consumer needs and desires. At a national level, once good specs and products are available, we should aggressively incentivize the transformation. Clearly, it's in our national interest to move the American marketplace to the next generation in residential lighting rather than continue with increased demands for power generation and associated greenhouse gas issues.

- 3) **Obtain market and consumer intelligence:** We need to better understand consumer needs and preferences for lighting. First we must establish well-thought-out protocols and studies that reveal needs and preferences addressing broad issues of color spectra, intensity, and light distribution. This will involve detailed consumer and human subject research that engages relevant human factors/science institutions and organizations. Additionally, subtle issues associated with shape, packaging, and distribution need to be better understood in terms of what people want in their homes. Again, this is an issue of understanding what people want, not what they could live with. Clearly, understanding this distinction will allow our federal agencies and environmental groups to move forward in a more positive and effective manner. Lastly, we need to better understand the issues associated with spectrum and health impacts. It could very well be that the strong blue components in LED light sources may be quite distributive in terms of circadian rhythm effects.

This unintended consequence could have a significant impact on long-term market transformation. Addressing it now can open significant value-added promise through light sources that enhance circadian rhythms through adjustable spectra that best match changing human needs through the day-night cycle.

- 4) **Make compliance with lamp specifications a national requirement for any type of public investment, rebate, or buy-down:** We need to link, with an absolute commitment, any future public investment in market transformation (including buy-downs, rebates, or other incentives) to well-defined, quality-based lamp specifications. A specification based on quality that is strictly adhered to on the program side will level the playing field for the industry. This will send a clear signal to the public that we are interested in them, and it will communicate clear objectives to the industry that is trying to design and build products in an often confused and erratic regulatory marketplace.
- 5) **Invest heavily in consumer education:** We have a lot of damage control to do in convincing American consumers that the next generation of residential lighting technologies is going to be better. Even when we have better technology, most consumers will be highly suspicious of both government and industry claims. Once we have a good product stream, we should incentivize it with public dollars to seriously transform the market once and for all. Ultimately, the product should be as good as or better than incumbent technology; but the reality is that it will be more expensive, and this difference needs to be addressed directly. The potential of dynamic light color LED sources to offer most important health and well-being benefits could provide significant added real value, justifying higher costs.
- 6) **Engage in a positive codes and standards effort:** Well-planned codes and standards efforts would seek to provide leverage and encouragement to a well-crafted, consumer-oriented lamp product specification. A national lamp standard based on quality would help create, unify, and maintain the quality space.

The residential marketplace is poised for the next step in this unprecedented opportunity for market transformation on our path to national energy independence. It will be difficult to address the apprehensiveness and cautiousness that characterizes this market and move forward. Let's start by developing specifications for products that people will prefer and develop programs that connect strategies to measurable goals.