Building a Better Bulb: Technologies, Policies, and Programs Behind the Battle to Increase the Efficiency of General Service Incandescent Light Bulbs

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ABSTRACT

After 15 years of promotional efforts by utilities, retailers, and lamp manufacturers, screw-based compact fluorescent lamp (CFL) sales have risen to a few percent of the general service bulbs sold in the U.S. While there is room to improve that market share, it is also clear that there are upper limits due to a variety of aesthetic, form factor, performance, and perception concerns by buyers. CFLs have caused at least 5% of the bulbs sold to consume 75% less energy. Wouldn't it also be worthwhile to supplement those savings by improving the efficiency of at least 75% of the remaining bulbs by 5%?

California and other states are considering the energy savings obtainable from shifting the marketplace from the present mix of general service incandescent bulbs to more efficient designs employing krypton or halogen fill gas. This paper discusses the process pursued in California to encourage such technology changes through mandatory efficiency standards and voluntary programs. It highlights anticipated energy savings, incremental costs, marketing approaches, and possible utility program designs. It also offers a glimpse into the negotiation process itself – the means by which consultants, utilities, advocates, and manufacturers narrowed the range of their disagreements. It describes the advantages and disadvantages of the final California Energy Commission decision, and discusses opportunities to secure additional incandescent lamp energy savings in other markets.

Introduction

Since 1998, Pacific Gas and Electric Company (PG&E) has been conducting a novel type of efficiency program: Codes and Standards Enhancement (CASE). The program employs systems benefit charge funding to screen candidate technologies for appliance standards consideration, propose efficiency levels and standards language, and participate in technical and policy discussions with industry stakeholders before the California Energy Commission. To date, the CASE process has led to the successful adoption of more than a dozen new appliance efficiency standards in California, including the world's first minimum efficiency standard for general service incandescent light bulbs. This paper distills the lessons learned from that effort and suggests directions others might follow to capture similar energy savings in their state or country.

Electric utilities have been promoting compact fluorescent lamps (CFLs) to their commercial and residential customers in the U.S. for nearly 20 years. And though their initial success was modest, the tide began to turn in the late 1990s. CFL market share reached 5 to 13% of all retail light bulb unit sales in 2001-2003 in California, the Pacific Northwest, the Northeast, Wisconsin, and other parts of the country with extensive utility promotion programs (Calwell et al 2002). National market share reached about 2%, and has likely grown thereafter, though precise market data are no longer available (McNary 2005). Sales have continued to grow steadily in regions with continued regional program support like the Pacific Northwest, reaching 7.4 million units in 2005 for an area with about 4% of the U.S. population (Northwest Energy Efficiency Alliance 2006).

But while attention was turned to the success of utility programs in those regions, CFLs were also diffusing into the rest of the country as a low-cost, mass market, commodity lighting product. Once Home Depot, Lowe's, and Costco were able to offer CFL multi-packs at prices of less than $3 per bulb without utility incentives, the retail shelf space dedicated to the products increased, national television and print advertising campaigns began, and utility incentives became even less important than marketing to overall national sales of the products. Utility commissions may greet future CFL incentive proposals from utilities with increasing concerns about free-ridership, given the sales volumes now occurring in parts of the country where no utility incentives are offered.

A point may be reached during the next five years where national CFL market share plateaus at something like 6% to 8% of light bulb unit sales. Three factors are responsible for that upper bound:

First, a long term market share of 6% to 8% implies a significantly higher socket share, because of the substantial difference in average lamp lifetime between CFLs and general service incandescents. Even if CFLs tend to be installed in the sockets that are used most often, a long term national market share of 7% would tend to be consistent with CFLs occupying perhaps 3 to 4 times that percentage share of all residential sockets.[1]

Second, the factors that drove significant reductions in CFL pricing have largely played themselves out in the marketplace. Further economies of scale in manufacturing and distribution may lead to some additional price reductions, but they will be less dramatic than the reductions that occurred in the competitive free-for-all between 2000 and 2004. Manufacturing has already shifted very heavily to China, where labor and materials costs are among the lowest in the world. Patents on the key components have already expired, limiting royalty payments for tri-phosphors. Manufacturing, distribution, and retailing markets are already highly competitive, and sales volumes are large enough to achieve great economies of scale in mechanized production. If anything, recent efforts to impose take-back and mercury recycling costs on CFL manufacturers may push future CFL prices higher, rather than lower.

Finally, there are functional limitations to CFL sales. A core fraction of residential customers have long been opposed to CFLs for aesthetic or perceived health reasons, and are unlikely to change their mind regardless of product price or level of promotion (Calwell, Granda & Gordon 1999). Accent lighting applications and fixture designs intended to showcase the filaments of exposed, clear lamps are generally poorly suited to CFLs. Many customers prefer dimming or three way switching capabilities, which remain elusive in CFLs at affordable price

[1] If average residential CFL lifetimes are 6,000 to 8,000 hours and average incandescent lifetimes are 1,000 hours, we can assume that 1 CFL displaces the purchase of about 7 incandescent lamps. However the rising popularity of CFL multi-packs and the prevalence of utility incentives covering more than half of the products' cost likely lead to some stockpiling of the products during promotional periods. Not all purchased CFLs are immediately placed in service. CFLs may also tend to be used in sockets with longer than average hours of operation, which means their share of total lumen-hours in a home would tend to be higher than their share of sockets occupied. So socket share appears to be lagging market share * lifetime multiplier. For example, the 2005 California Statewide Residential Lighting and Appliance Efficiency Saturation Study (RLW Analytics, Inc. 2005) found that CFLs occupied about 8.6% of California residential sockets in the November 2004 to May 2005 timeframe, compared to less than 1% in 2000. The 2005 figure is lower than many CFL advocates would expect, given CFL market share of 4% to 7% in California in 2001-2002 and expected CFL operating lifetimes of 3 to 5 years.

points. Even at very low prices, CFLs may not make sense in sockets that are very frequently switched or rarely used, or where light must be available instantly at full brightness for safety.

Capturing New Lighting Savings

All of this suggests that the efficiency community should not assume its residential lighting market transformation strategy for the next ten years should resemble its game plan so far. We should be asking ourselves a basic question: What can be done to improve the efficiency of the other 90+% of light bulb unit sales?

Many believe that LED (light emitting diode) technology represents, literally, the great white hope. And indeed, LEDs are a very promising option for saving energy in many lighting applications. They are well suited to highly directional lighting situations, or any applications where rapid cycling and dimming are essential. Efficacies are improving very rapidly, but they are not likely to become cost-effective substitutes for the general service incandescent lamp in the next few years (Ton et al 2003). The immediate challenge is to match the warmth of incandescent light color, which is likely achievable. The much greater challenge is to achieve the same uniform distribution of light as a general service incandescent lamp. Some imaginatively designed products have attempted to approximate the effect, but they are very expensive because individual LEDs have to be soldered facing multiple directions in order to distribute the light roughly evenly (see Figure 1). At $40 to $100 apiece, they face a long development path to matching incandescents that provide far more total lumens in a more diffuse way for a dramatically lower purchase price.[2]

Figure 1. Sample LED products Intended to Replace Conventional Light Bulbs

While CFLs may head toward an eventual plateau in sales and the LED technology continues to evolve, general service incandescent lamps are still selling more than 1 billion units

[2] A variety a Web sites offer LED products. See the following Web site for a complete product list: https://www.surplusled.com/Merchant2/merchant.mvc?Screen=CTGY&Store_Code=S&Category_Code=_MED and http://www.theledlight.com/120-VAC-LEDbulbs.html.

per year nationwide (Horner 2006 and RER 2002).[3] Every watt that can be shaved from their average power consumption saves roughly 1 billion kWh per year. What can be done to improve their efficiency?

The Basics of Incandescent Technology

Incandescent filaments need to glow white hot in order to produce visible light. The hotter they get, the brighter they shine and the more efficiently they operate (not on an absolute power consumption basis, but on a lumens per watt basis). The challenge is to sustain the high temperature without burning up the filament rapidly. Incandescent lamps are a study in compromise – hot enough to emit enough visible light, but cool enough to last for 750 to 2000 hours of operation or more.

Virtually all strategies for improving incandescent efficiency boil down to one or both of these approaches: consuming less power to achieve a given filament temperature or reducing the tendency of the filament particles at a given temperature to evaporate until the filament is thin enough to break.

One of the basic ways to accomplish the first outcome is to coil the filament tightly to give it a large surface area and still reflect much of its heat back on itself. Many technologies are used to accomplish the second outcome:

- Selecting tungsten for the filament, so it can operate at extremely high temperature with minimal evaporation,
- Replacing oxygen in the bulb with low-pressure nitrogen and argon to largely eliminate oxidization,
- Using halogen fill gas under high pressure to discourage filament evaporation and encourage evaporated tungsten to redeposit on the hot filament

But perhaps the most intriguing and cost-effective approach is to replace the argon fill gas with krypton. Both are non-reactive noble gases, but the krypton is heavier and functions as a more effective insulator. By discouraging heat flow away from the filament, it allows the filament to maintain its desired temperature of incandescence while consuming less power (not unlike the role an insulating blanket serves with a water heater). Krypton is much more rare than argon in the atmosphere and more expensive, but highly prized in the lighting and window industries for its insulating properties.[4]

A number of krypton-filled incandescent lamps are already available in the U.S. market from Duro-Test, Osram Sylvania, and other manufacturers. Many are optimized for very long lamp life or higher brightness instead of for efficiency, and find application in incandescent traffic signals and premium lamp models.

[3] Total medium-base incandescent bulb sales in the U.S. in 2003 were about 2.5 billion units (Horner 2006). RER/Itron estimated national incandescent sales of 1.5 billion units (RER 2002, 51). Both estimates include large numbers of specialized, decorative, and three-way products that are not general service lamps, but the dominance of conventional lamps in the totals leads us to believe the estimate of 1 billion units sold per year is conservative.

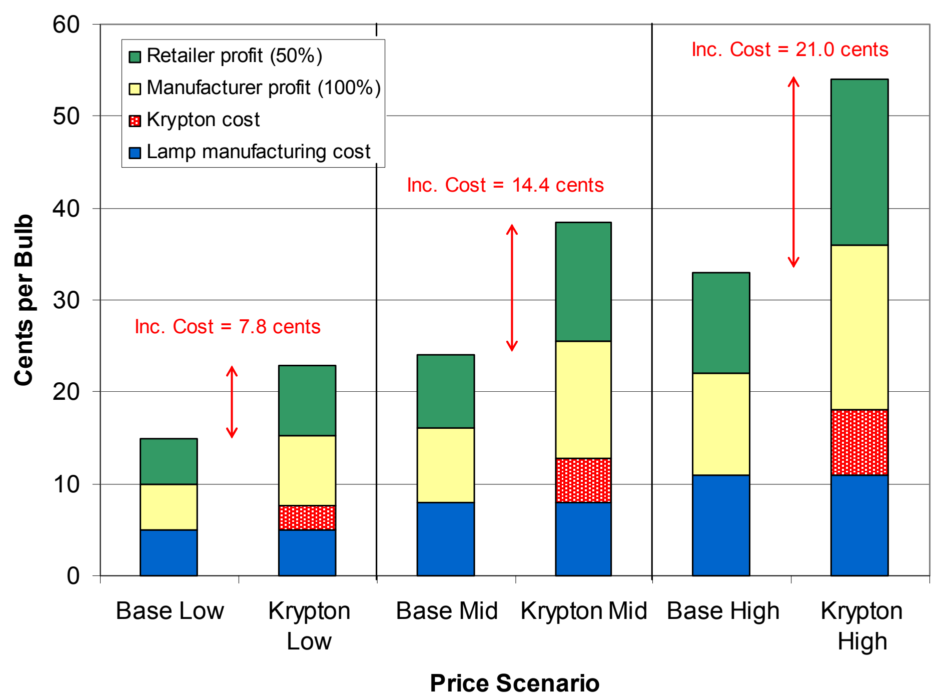
[4] Xenon carries this trend even further, but its even greater scarcity and radically higher cost limit its use primarily to automotive, under-cabinet, and flashlight applications with relatively small physical lamp volumes.

Economics of Better Incandescent Technology

At current market prices for krypton and argon, the incremental cost to a bulb manufacturer of filling a typical A-19 incandescent bulb with krypton instead of argon is approximately 2.6 to 7.0 cents (Calwell 2005). To forecast the impact this would have on the final retail price of a light bulb, we first needed to build a model to explain current incandescent lamp prices. Manufacturers carefully guard information about their own costs of producing a standard incandescent lamp, so we modeled a range of base case price assumptions from 5 to 8 to 11 cents per unit. Allowing for 100% markup from manufacturer to retailer and another 50% retailer markup of that wholesale price to the final purchaser, this predicts low, medium, and high final retail prices of 15, 24, and 33 cents respectively.

These amounts are consistent with what is seen in retail stores today. The least expensive incandescent lamps are private label products sold by Wal-Mart and others for about 17 to 19 cents each. The lowest cost models from General Electric, Philips, and Osram Sylvania routinely sell in 4-packs for $1 at the nation's largest retailers, corresponding to the middle of our forecasted price range. The upper end corresponds to prices often paid in grocery stores or when smaller quantities are purchased. From this modeling, it is then possible to forecast a range of retail incremental costs for krypton lamps of roughly 8 to 21 cents (Figure 2).

Figure 2. Impact of Krypton Fill on Estimated Lamp Prices and Profits



Source: Ecos Consulting 2006

According to industry research funded by Duro-Test, the typical power savings that can be achieved with a krypton lamp while holding light output and lamp life constant is about 8 to 11% (Rea 2000; Thouret, Anderson & Kaufman 1970; Thouret, Kaufman, & Orlando 1975).

The savings percentage tends to be highest with lamps that operate at lower temperatures (lower wattages), as shown in Table 1. Absolute wattage reductions are still higher with 100 watt lamps than with 40 watt lamps, however.

Table 1

	Existing Lamp Wattages			
	40 watts	**60 watts**	**75 watts**	**100 watts**
Krypton lamp equivalence	36 watts	54 watts	69 watts	91 watts
Wattage savings	4 watts	6 watts	6 watts	9 watts
% savings	11%	9.5%	9%	8.5%

The actual savings achieved by market-ready products are likely to be substantially lower, because the standards levels adopted by the California Energy Commission are only about half as stringent as what the research shows is possible and focus primarily on power savings rather than efficiency gains. The Energy Commission's final standards (see more in-depth discussion below) are intended to save an average of 2 to 5 watts per bulb.

The cost effectiveness of the krypton technology is attractive at national average electric rates, but especially compelling in California. PG&E's current residential rates are 11.43 cents per kWh for baseline consumption, and progressively higher tiered amounts ranging from 12.99 to 33.04 cents per kWh for consumption above baseline. PG&E estimates the average rate for all of its residential energy sales is now about 15.44 cents per kWh. At these electricity prices, a more efficient incandescent lamp that cuts power use by 3 to 5 watts can save 46 to 77 cents worth of electricity. That is more than the expected retail price of the entire bulb, and about 3 to 6 times the incremental retail cost, implying a payback period of a few months.

The Process of Securing a California Standard

PG&E and Ecos Consulting first met with the lighting industry to discuss conceptual approaches to general service incandescent standards at a National Electrical Manufacturers Association (NEMA) meeting in October 2003. Based on the input we received from industry and product data gathered from manufacturer catalogs, we proposed a two-tiered efficiency standard shortly thereafter. The first tier aimed to trim off roughly the bottom third of the marketplace by drawing a standards line on a plot of lumens vs. watts of incandescent lamps available at the time (see Figure 3). Qualifying models fell below and to the right of the proposed specification line, meaning they consumed less power than the standard proposed for their particular light output level. Separate lines were eventually proposed for the three major categories of lamps – soft white, clear/frost, and modified spectrum[5], since the coated lamp categories were inherently and unavoidably less efficient than their clear/frost counterparts. In all three cases, the enclosure of a standard lamp "chassis" (filament and fill gas) receives different coatings to achieve different visual effects. These coatings diffuse and absorb various fractions of total light output, cutting light output and efficacy by up to 30% in products of otherwise identical wattage. Various specialized incandescent lamps using different filaments or

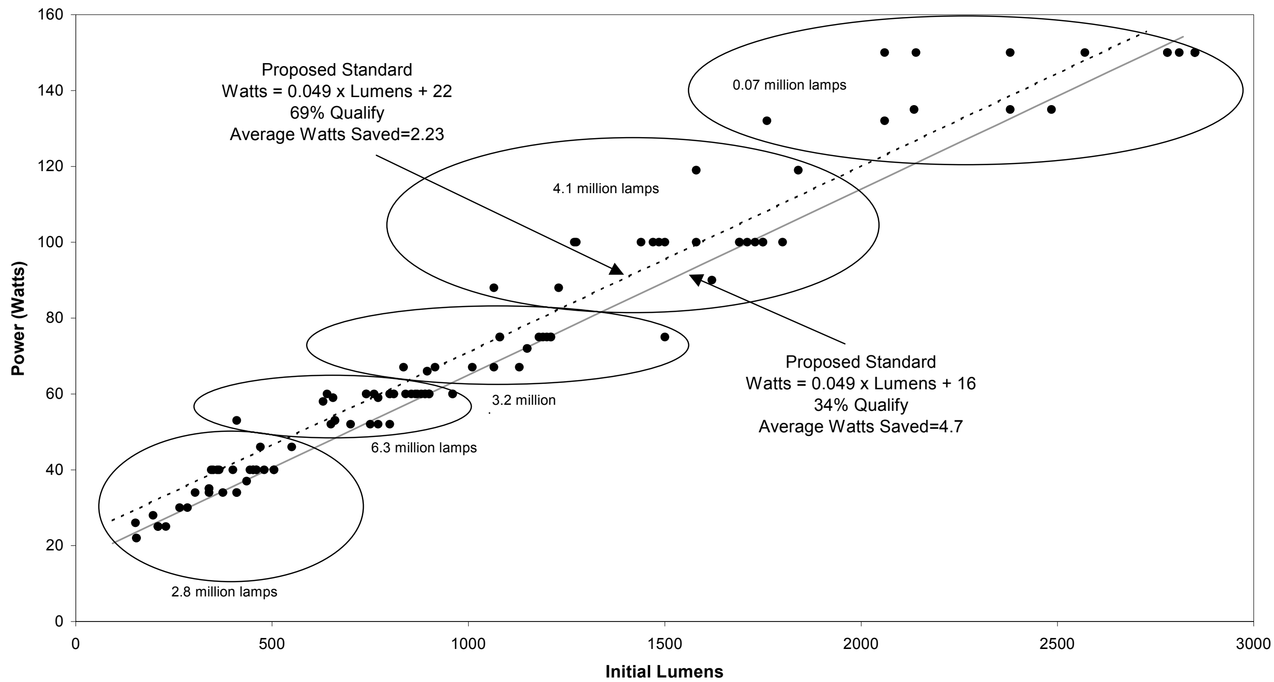
[5] "Modified spectrum" or "enhanced spectrum" are terms that apply to the products often advertised as "full spectrum" bulbs or otherwise enhanced with a neodymium or similar coating to reduce emission of the green/yellow portions of the spectrum. GE brands these products as "Reveal," Philips as "Natural," and Osram Sylvania as "Daylight" or "Daylight Plus."

lamp chassis were ultimately exempted entirely, such as 3-way, decorative, candelabra, and vibration-resistant products.

The second tier standards proposal represented a more stringent specification line, parallel to the first, but shifted downward about 6 watts. In general, this corresponded to roughly the top third of the products available at the time, so would have prevented two-thirds of existing models from being sold unless they improved their efficiency. The standards proposal came in the form of a CASE report and accompanying standards language, research findings, and savings estimates (Ecos Consulting 2005).

Industry's initial response was that California was preempted from regulating general service incandescent lamps. The three major lamp manufacturers and their trade association, NEMA, focused largely on trying to defeat the standards outright rather than modify the stringency or methodology behind them. In December 2004, the California Energy Commission voted to adopt the Tier 1 standards, but deferred its vote on Tier 2 to await more dialogue among the stakeholders.

Figure 3. Original Tier 1 and 2 Proposals for Clear/Frost Lamps



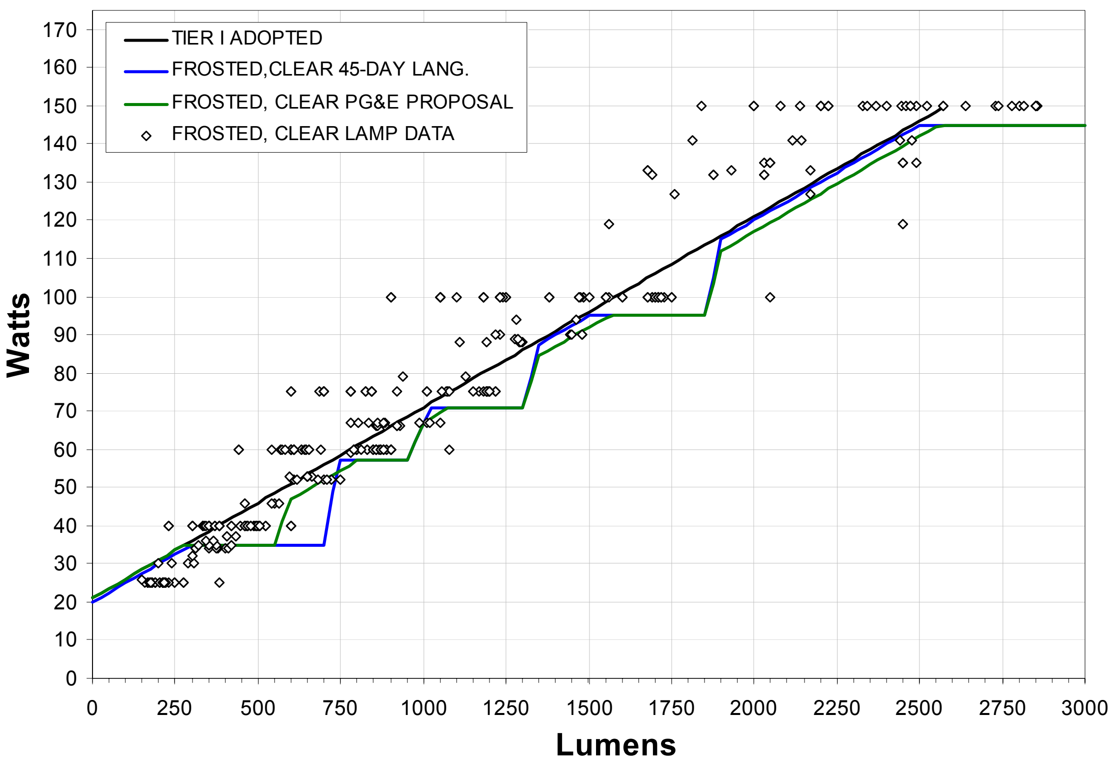
Source: Ecos Consulting, 2005

This dialogue occurred through a series of workshops and hearings throughout 2005 and early 2006. The key breakthrough occurred when Commissioner advisor Tim Tutt proposed a different conceptual approach to the standard involving "plateaus" of constant wattage requirements for particular lumen ranges of bulbs. He observed that most of the bulbs being sold were clustered around the familiar wattages of 40, 60, 75, and 100 watts, so proposed plateaus a few watts beneath each of those ranges, with those plateaus joined together by diagonal lines similar to the original Tier 2 proposal.

A great deal of debate occurred over the next nine months regarding the exact width and height of the plateaus, as well as the slope of the connecting lines between them. PG&E and Ecos Consulting proposed more stringent variants of the standards than industry did. The levels the California Energy Commission ultimately preferred (Figure 4) yield power savings of about 5%: 2 watts for 40 watt bulbs, 3 watts for 60 watt bulbs, 4 watts for 75 watt bulbs, and 5 watts for 100 watt bulbs. The Commission adopted these final standards levels on April 26, 2006, with an effectiveness date of January 2008.[6]

In its final negotiations with industry, the Commission exempted modified spectrum lamps (the least efficient general service models sold today) from standards coverage entirely, with a promise to revisit standards for the category in the future if sales increase sharply. This exemption will amplify the effectiveness of manufacturers' current marketing strategies for modified spectrum bulbs by allowing them, and them alone, to continue being sold at familiar wattages, in premium packaging, at declining prices. The products covered by standards will tend to have higher prices than their predecessors, and will now be offered in unfamiliar wattages, so may have a competitive disadvantage relative to modified spectrum bulbs.

Figure 4. Comparison of Frost/Clear Standard Proposals



Source: Ecos Consulting 2006

The Commission also extended each of the plateaus far enough to the left to allow most of the popular lamp models sold today to qualify by dimming alone, which could actually reduce efficacy from the levels of incandescent lamps sold today.[7] Figure 5 illustrates this effect with typical 60 watt bulbs.

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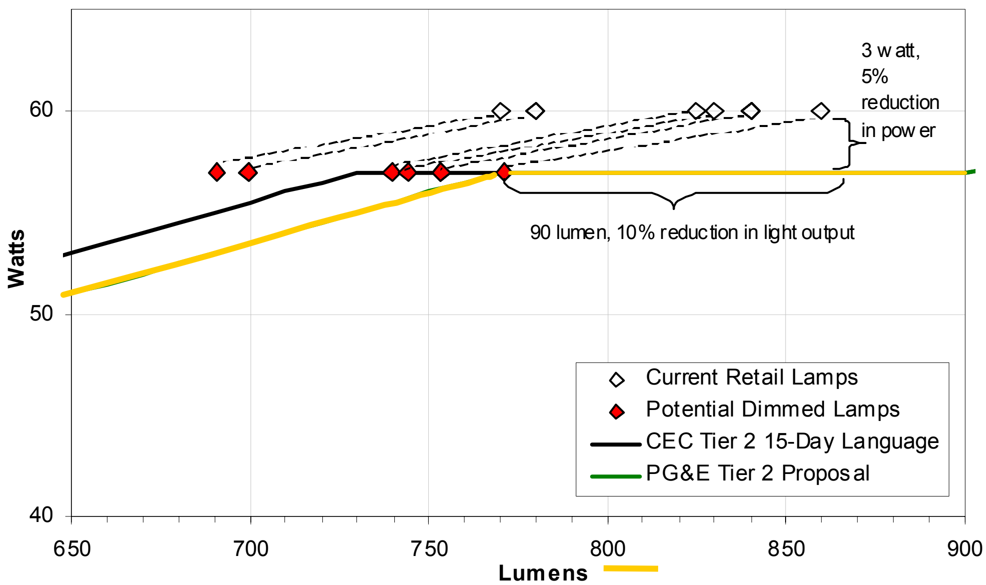
[6] See http://www.energy.ca.gov/appliances/2006rulemaking1/notices/index.html.

[7] A 5% reduction in lamp power (W_2) through dimming in 60 watt bulbs yields a 10% reduction in light output (L_2), as predicted by the following equation: $W_2 = W_1\left(\frac{L_2}{L_1}\right)^{\frac{1.6}{3.4}}$

These two changes greatly undercut the effectiveness of the standards, making it difficult to assess how much of the originally forecasted 200 to 300 million kWh per year of savings will actually be achieved by the standards alone. Qualifying incandescent lamps will be using less power than the ones they replace, but many will also deliver an even greater reduction in level of service (light output). Many customers may choose to purchase the next brighter lamp model to have the same or more light, thus eliminating the desired energy savings.

Figure 5. Impacts of Dimming in Commonly Available Soft White Lamps



Where Do We Go from Here?

Follow-on standards efforts in California, in other states, or at the federal level could address these drawbacks with more stringent or differently shaped specifications. The Energy Policy Act of 1992 required the Secretary of Energy to initiate a rulemaking to consider federal general service incandescent lamp efficiency standards no earlier than October 24, 2000 and publish it no later than April 24, 2002, with standards taking effect 3 years thereafter.[8] The Department of Energy took no action on general service incandescent lamps between 1992 and 2005, but is now showing signs of acknowledging its long-overlooked obligation (DeLaski 2006). DOE appears ready to begin the initial phases of rulemaking determination in 2006, with a goal of adopting standards by June 2009 (U.S Department of Energy 2006).

Manufacturers have already begun the design of new technologies to comply with California's standards. Many of the products will not need krypton fill gas to comply, and we expect a vigorous competition among the various technologies, including conventional and halogen-based designs. Some will maintain light output levels and reduce power levels by improving efficiency. Others will be dimmer than the products they replace.

Although PG&E believes that incentive programs for other technologies are likely to be more promising over the long term, there is a near term efficiency opportunity with general service incandescents that some utilities may wish to consider. Utilities can employ financial

[8] See USC Sec. 6295(i4).

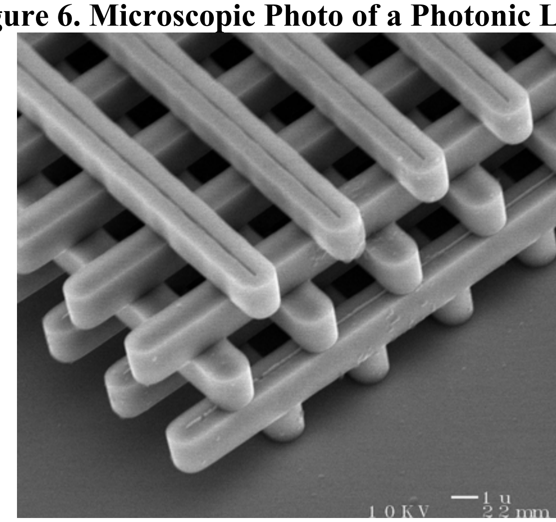
incentives, marketing programs, retailer training efforts, and other tools at their disposal to confer a market advantage to the most efficient technologies. If they do not act, there is a significant risk that less efficient products will prevail in the marketplace (and be allowed by future standards). So the 2006-2007 timeframe represents a very narrow window of opportunity to transform the market for this product category.

Ecos Consulting intends to work with utilities to position the most efficient redesigned incandescent lamps as "better" in a good/better/best framework, with conventional incandescents characterized as "good" and ENERGY STAR compliant CFLs characterized as "best." The customer education message is fairly simple: "buy CFLs wherever possible, and use improved incandescents in any remaining sockets where you might otherwise use conventional incandescents." Such programs could run until the end of 2007 in California and for a longer period of time in other states that do not yet have mandatory standards in place for general service incandescent lamps. Such programs, if successful, could usefully influence the direction manufacturers take with future product introductions.

Meanwhile, a number of experimental technologies are under development that could radically improve incandescent lamp efficiency in future product generations. Some focus on ways to reflect infrared radiation back onto the filament with dichroic coatings that still allow visible light to shine through. Many infrared reflecting PAR lamps and MR16s already employ this technology, but are more expensive.

Other technologies attempt to modify the filament itself to be a more selective emitter of visible instead of infrared radiation. Researchers at Sandia National Laboratories have created a "photonic lattice" of tungsten atoms at the microscopic level, shown in Figure 6.[9] The individual openings in the lattice are large enough to allow visible wavelengths of light to emerge, but too small to allow infrared wavelengths to escape (giving new meaning to the colorful cinematic phrase "caged heat"). This could lead to a design of much greater inherent efficiency than a conventional incandescent lamp, which only emits about 10% of its energy in the visible spectrum.

Figure 6. Microscopic Photo of a Photonic Lattice



[9] See http://www.sandia.gov/media/NewsRel/NR2002/tungsten.htm.

In the final analysis, the most important thing is to create the kind of market conditions under which a more efficient incandescent lamp can succeed in the marketplace. CFLs, LEDs and other advanced technologies are creating market pull toward efficiency at the top end of the market. Properly designed minimum efficiency standards can augment that effort very decisively by pushing up on the bottom end of the market and preventing the sale of the least efficient bulbs. If CFLs have been deemed a runaway market success for making 5% of the light bulbs 75% more efficient, wouldn't it also be a great efficiency success to make 75% of the light bulbs at least 5% more efficient?

References

Calwell, C., C. Granda, and L. Gordon. 1999. "Lighting the Way to Energy Savings: How Can We Transform Residential Lighting Markets?" Volume I: 15-16. San Francisco, Calif.: The Natural Resources Defense Council.

Calwell, C., J. Zugel, P. Banwell, and W. Reed. 2002. "A CFL Odyssey – What Went Right?" *In Proceedings of the ACEEE 2004 Summer Study on Energy Efficiency in Buildings*, 6:15-28. Washington D.C.: American Council for an Energy-Efficient Economy.

Calwell, C. 2005. "Background on Proposed Tier 2 Efficiency Standards for General Service Incandescent Lamps" Sacramento, Calif.: Presentation to the California Energy Commission by Ecos Consulting on behalf of Pacific Gas and Electric Company, Sacramento, Calif., July 18.

DeLaski, A. (Appliance Standards Awareness Project). 2006. Personal communication, February.

Ecos Consulting. 2005. "Proposed Energy Efficiency Specifications for General Service Incandescent Lamps." Pacific Gas and Electric Company's Codes and Standards Enhancement Initiative for PY2005: Title 20 Standards Development. Available online: http://www.energy.ca.gov/appliances/lamps/documents/2005-07-13_REVISED_PG+E_PROPOSED_INCANDESCENT.PDF.

Ecos Consulting. 2006. "Comments on the California Energy Commission 45-day Language for General Service Incandescent Lamps and NEMA Counter-Proposals." Presentation to the California Energy Commission on behalf of Pacific Gas and Electric Company, Sacramento, Calif., February 14.

Horner, P. (Osram-Sylvania). 2006. Personal communication. April.

Rea, M. ed. 2000. *IESNA Lighting Handbook: Reference & Application*. New York: Illuminating Engineering Society of North America. 9th ed: 6-9.

McNary, B. 2005. "In Search of ENERGY STAR Qualified CFL Market Share: National Retailer Data on the National Lighting Tracking Feasibility Study." Presentation at the ENERGY STAR Lighting Partners Meeting, Las Vegas, Nevada, April 5.

Northwest Energy Efficiency Alliance. 2006. "Residential Sector Initiative Update." Available online: http://www.nwalliance.org/news/meetingdocs/RSI%20Newsletter_January_2006%20.pdf

Regional Economic Research, Inc. (RER). 2002. *California Lamp Report 2001 Volume 2*. Prepared for Southern California Edison. April 30.

RLW Analytics, Inc. 2005. *2005 California Statewide Residential Lighting and Appliance Efficiency Saturation Study*. Prepared for California's Investor Owned Utilities. August 23.

Thouret, W.E., H.A. Anderson, and R. Kaufman. 1970. "Krypton Filled Large Incandescent Lamps." *Illuminating Engineering* (April): 231-240.

Thouret, W.E., R. Kaufman, and J.W. Orlando. 1975. "Energy and Cost Saving Krypton Filled Incandescent Lamps." *Journal of IES* (April): 188-197.

Ton, M., S. Foster, C. Calwell, and K. Conway. 2003. "LED Lighting Technologies and Potential for Near-Term Applications." Market Research Report #E03-114. Portland, Oregon: Northwest Energy Efficiency Alliance.

U.S. Department of Energy. 2006. "Schedule Setting for the 2006 Appliance Standards Rulemaking Process." Available online: http://www.eere.energy.gov/buildings/appliance_standards/2006_schedule_setting.html.