Proposal for Standards – Lighting: LED

Appliance Efficiency Standards and Measures

for California Energy Commission's Invitation to Submit Proposals

Lighting: fluorescent dimming ballasts, light-emitting diodes, and multifaceted reflector lamps.

Docket #12-AAER-2B.

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1 Executive summary

In the area of Light Emitting Diode (LED) lamps it is proposed that California Standards be harmonized with existing standards of the US EPA ENERGY STAR program.(1,2) The ENERGY STAR program provides a framework of standards and testing which could be applied to the needs of California. A key element of the proposal is that the California standard require no additional testing beyond that required by ENERGY STAR. Another element of the proposal is that California standard allow product performance and feature choices so as to meet the needs of a range of applications.

Together these proposal elements would enable, eventually, 80% energy savings while addressing many of the existing barriers to widespread LED adoption.

2 Product Description and Proposal Scope

2.1 Technical Description

Lamp types intended to replace incandescent lamps.

2.2 Technologies and Best Practices for Energy/Water Efficiency

Integral, self-ballasted LED lamps which meet the ENERGY STAR program requirements are suitable replacements for incandescent lamps and consume at least 75% less energy than the equivalent incandescent lamps they are rated to replace.

2.3 Design Life

Self-ballasted LED lamps are typically rated to last for 25,000 hours, although shorter and longer ratings are possible. At 3 hours of burning per day, a 25,000 hour life rating corresponds to about 24 years.

2.4 Manufacturing Cycle

Due to the rapid pace of LED technology development, self-ballasted LED lamps are replaced with newer, higher performing models with a cycle time of order 1 year.

2.5 Product Classes

The ENERGY STAR program has a detailed product structure for LED lamps.

3 Unit Energy/Water Usage

The electrical energy used at the site by a lamp is calculated by multiplying the rate of energy consumption (watts) by the length time the lamp is on (hours).

3.1 Duty Cycle

A lamp is typically controlled by a switch, possibly in combination with a dimmer. There may also be an automatic control such as a timer, a motion sensor or a daylight sensor. Ideally a lamp in a frequently vacant room, such as a closet, is only switched on when a person is accessing the room. An exterior security light, on the other hand, may be left on from dusk to dawn. Unlike Compact Fluorescent Lamps (CFLs), LEDs turn on instantly and are not degraded by frequent on-off switching. LEDs are thus much more compatible with motion sensors.

3.2 Efficiency Levels

Self-ballasted LED lamps operated with dimmers are typically even more efficient in the dimmed state. This is a significant advantage when compared to incandescent lamps, which are less efficient when dimmed. A caveat, however, is that LED lamp dimming has proven problematic due to lamp-dimmer compatibility issues.(3)

3.3 Energy and/or Water Consumption

The following table is a 2012 estimate for the total US economy based on a 2013 US DOE study.(4) The energy use values are for TWh of electricity consumed at the site. The potential annual LED energy savings are 130.7 TWh, which is 80% of the 162.7 TWh energy usage in 2012. The DOE report covers many types of LED lighting; the values shown here are only for the subset of types which include self-ballasted LED lamps. “To determine the potential energy savings for each application it is assumed that the entire lighting stock is converted instantaneously to the most efficacious [currently available] LED product that meets the replacement criteria.”

Indoor lamp type	Unit LED 2012 US Installations (millions)	LED 2012 Penetration (%)	Total US Application Energy Use (Site-TWh)	2012 LED US Energy Savings (Site-TWh)	Potential LED US Energy Savings (Site-TWh)
A-Type	19.9	<1%	101.8	2.1	79.1
Directional	11.4	4.6%	18.7	2.3	16.7
MR16	4.8	10%	6.7	0.4	6.2
Decorative	4.7	<1%	35.4	0.1	28.7
Total	40.8	<1%	162.7	4.9	130.7

Various sources indicate that California electricity usage is 6-7% of total US usage, so the California Potential LED Energy Savings would be ~8 TWh.

4 Market Saturation and Sales

4.1 California Stock and Sales

It is estimated, from the above-mentioned 2013 US DOE study that less than 1% of the existing lamps in California are presently based on LED technology. The study also estimates that in the common omnidirectional "A" format, CFLs, which offer similar energy savings, have already achieved 43% penetration.

4.2 Efficiency Options: Current Market and Future Market Adoption

ENERGY STAR rated LEDs (and CFLs) are available now to fit most applications and offer energy savings of 75% or more in those applications when compared with incandescent lamps. (The 80% savings in the DOE analysis is based on the best available product today.) A visit to any big box home center or website will show the variety of available products. There have been, however, several barriers to large LED penetration. These observations are somewhat anecdotal, based on discussions within the industry and by experiences of real consumers.

- Confusion created by the proliferation of choices
    - The consuming public is on a learning curve, one which started with the widespread introduction of CFLs. The consuming public has proven capable, over time, of learning to purchase other products with far more complexity and choices than light bulbs. Large commercial customers climb the learning curve more quickly because they have the resources and incentive to reduce business costs. Residential customers, in general, are slower to learn. Early adopters play a key role in growing acceptance of new technologies.
    - The Lighting Facts labels, now required on all US lighting products, are a great help as consumers learn. They show, for instance, the difference between "watts" and "lumens", and provided estimates of energy costs. These labels enable consumers to evaluate and compare all products (incandescent, halogen, CFL and LED) in a self-consistent way.
    - By staying within the framework of the existing Energy Star program and Lighting Facts labeling this California proposal will help send a consistent message within California and nationally, and help consumers climb the learning curve.
- Low quality LED (and CFL) products create initial bad experiences
    - The proposed California standard will address the LED quality issue directly.
- Compatibility issues with LED (and CFL) products on dimmers

  - Dimming is a double-edged sword. On the one hand, dimming of LEDs can reduce energy consumption, and lots of installations already have installed dimmers. On the other hand, a new LED product rated as "dimmable" will not necessarily work properly on an existing dimmer. When it does not work properly, the customer will live unhappily with an improperly performing LED, try replacing the dimmer, or both. The issue is greatly exacerbated by legacy dimmers and the wide variety of both dimmer and ballast circuits. Also, phase-cut dimming is technologically simple for incandescent lamps, and consumers have come to expect deep, reliable dimming. Self-ballasted LED lamps are technologically more challenging to dim deeply and reliably.
  - The dimmer compatibility issue for LEDs is being addressed through industry standards, such as NEMA SSL 7-A, and through the ENERGY STAR testing protocols. This California proposal will take advantage of the considerable industry-wide effort that has gone into these standards. It will, however, take years to resolve this legacy issue satisfactorily in all applications and installations.
  - For many applications it might make more sense to promote non-dimmable products selected with the desired lumen level and placed on circuits without dimmers.
- Aesthetic issues with LED (and CFL) products in legacy luminaires and decorative applications that traditionally held incandescent lamps
  - Large heat sinks are often viewed as unattractive in an open luminaire where an exposed incandescent lamp with a clear outer jacket was part of the initial aesthetic design. Over time, new luminaires will emerge which exploit the many advantages of LEDs in aesthetically pleasing ways. For LEDs, aesthetics have the potential of becoming a great strength.
  - Discomfort glare is an issue with some LED products which seek to maximize luminous efficacy by placing LED emitters near the lamp surface facing outward. This is often an issue with directional products. Gradually, modivated by market forces, LED manufacturers are adopting diffuser optics schemes which eliminate the glare issue.
- Certain applications, at present, are better suited to available CFLs than available LEDs
  - Available LEDs in the 100W incandescent equivalent range are primarily in the bulky A21 format whereas CFLs are available in the A19 format. Above 100W equivalent, required for a reading lamp or other high lumen application, only CFLs are available. It is not surprising that CFL penetration is estimated to be 43% in the "A" applications whereas LED penetration is <1%.

  - LED penetration of existing CFL space is not an issue from the viewpoint of energy saving since CFLs are good energy savers also.
  - Especially at higher lumen levels, penetration presents a compelling challenge for the LED industry to develop attractive and omnidirectional "A" products,
- Prior consumer experiences with CFLs have made some suspicious of the newer LEDs
  - In spite of comments maligning CFLs, it is important to keep in mind that they have reached 43% penetration in 2012, up from 34% in 2010 for the "A" lamp profile. These are number from the previously cited US DOE report. Many people are quite happy with CFLs.
  - LED lamps do offer key long term advantages over CFLs. LEDs provide instant light, and are not degraded by frequent off-on-off switching. LEDs do not have the cathode failure mode inherent to CFLs. LEDs do not contain Hg, which is troubling to some customers. LEDs are inherently easier to dim. LEDs may pull ahead of CFLs in energy efficiency. Available LEDs have a clear performance advantage over CFLs in directional formats – PAR, R, BR, MR, etc. The DOE report estimates that LED penetration is already 10% in MR16 applications and 4.6% in the other directional formats. As mentioned above, LEDs enable new aesthetic possibilities.
- The high initial purchase cost of LED products.
  - Market forces and technological advances are bringing these costs down gradually. In fact, for many existing ENERGY STAR rated LED products the performance is already so good that future penetration is arguably better served by cost reduction than by performance enhancement. There is a tradeoff between cost and performance.
  - Harmonized standards, such as those proposed here, can only help. Failure to harmonize standards across the US would drive costs up through added design cycles, added testing, and reduced economies of scale for state-specific models.
  - It will also help to allow a range of products. An LED lamp intended for a utility or exterior security application, for instance, need not be dimmable, and need not have the same color quality as one intended for a sensitive interior task lighting application. This utility/exterior LED could well have lower cost and provide more energy saving than one designed to meet indoor color and dimming expectations. It could also be more reliable if dimming were removed as an expectation.

- See 8.2 for an example application where, in spite of perceived high cost, available LED products make good economic sense for a residential customer today.

5 Statewide Energy Usage

It is estimated that 17% of both residential and commercial electricity is used in lighting.(5) This estimate comes from the US Energy Information Administration. The percentage for California must be similar. This energy usage could be reduced to 20% of its present value based on the US DOE report.

6 Proposal

6.1 Summary of proposal

It is proposed that California Standards be harmonized with existing standards of the US EPA ENERGY STAR program. The version and implementation timing should be the Product Specification for Lamps released in July 2013.(2) The ENERGY STAR program provides a framework of standards and testing which could be applied to the needs of California. A key element of the proposal is that the California standard require no additional testing beyond that required by ENERGY STAR. Another element of the proposal is that California standard allow product performance and feature choices so as to meet the needs of a range of applications. Basing the California Standard on the ENERGY STAR framework would accelerate product availability without driving up costs. Without sacrificing energy saving, a range of available products suitable to different applications would help drive competition and innovation.

6.2 Implementation Plan

Phase 1 would be to simply require ENERGY STAR for LED lamps in California. Phase 1 could have sub-phases based on specific product formats. Phase 2, requiring more planning, could drive specific California specifications within the ENERGY STAR framework. A specific requirement could be made more stringent than ENERGY STAR. If more stringent, the product would meet the ENERGY STAR requirement, have the ENERGY STAR loge, and have test data already in place to meet the more stringent California requirement. If less stringent, which is not advocated here, the product would not meet the ENERGY STAR requirement, not have the ENERGY STAR logo, and would likely require testing to the ENERGY STAR protocol to meet the hypothetical less stringent California requirement.

6.3 Proposed Test Procedure(s)

All test procedures and reporting formats should be taken directly from ENERGY STAR.

6.4 Proposed Regulatory Language

The existing California Voluntary LED spec, Docket #12-BSTD-03, is a good starting point.(6) The California Energy Commission should, however, consider tradeoffs inherent in this specification. The requirement that all products be dimmable with CRI 90 will necessarily increase product costs, reduce energy savings, and slow LED penetration to varying degrees, depending on the specific application. These more restrictive requirements could be phased in over time as indicated above in section 6.2.

7 Technological Feasibility

The proposed specification based on ENERGY STAR is feasible right now. Within that framework, the spec may or may not be tightened over time based on continued market and technological development.

8 Economic Analysis

For many residential applications, those where the lamp is on more than 3 hours a day, LEDs available today commercially offer dramatic energy savings over incandescent with an attractive payback. For downlights in a residential kitchen where high usage keeps the lights on for more than 3 hours a day the payback may be less than 2 years as shown below in 8.2.

8.1 Incremental First Costs

No incremental costs are required to improve the product's efficiency for Phase 1. The existing products and market momentum will do the job. Over time existing barriers to LED adoption will erode due to free market activity discussed above in section 4.2.

8.2 Incremental Operating Costs and Savings

Consider the following specific example involving directional products in recessed can downlights. The specific values shown are based upon the ratings of actual products in the catalog of a major home center retailer in July, 2013. In each case the product chosen is a premium lighting brand. The number of light bulbs is assumed to be 10, which is representative of a modern up-scale kitchen or family room. Choosing different products for comparison gives slightly different payback results, but all in the same payback range. While the payback time does not depend on the number of bulbs, the total economic saving does.

	Halogen PAR30LN	LED PAR30LN
Initial cost of 10 light bulbs	$80	$330
Wattage (1 light bulb)	53	13 (75% saving)
Light output (1 light bulb, lumens)	920	750
Rated life (hours)	1,000	25,000

Dimmable	yes	yes
ENERGY STAR™	Not applicable	yes
Warranty	no	6 year
Energy cost per year assuming 10 bulbs and $0.15/kW-hour		
On 8 hours per day	$232	$57
On 3 hours per day	$87	$21
Financial payback time considering energy plus relamping costs		
On 8 hours per day		<1 year
On 3 hours per day		<2 years

8.3 Infrastructure Costs and Savings

There are no infrastructure costs initially. Over time, homeowners and commercial owners may gradually migrate to new luminaires which are better suited to LED technology than those designed for screw-in incandescent lamps, etc.

8.4 State or Local Government Costs and Savings

A reporting and surveillance scheme would be required which is no different than what is already in place for things such as the incandescent phase-out and the lighting RoHS requirement in California.(7) By some means suppliers would be required to certify that products offered for sale in California meet the specification. Upon request, suppliers would be required within 28 days to provide test results to the California Energy Commission showing that a specific product or products meet the specification. Ideally these California requirements would be harmonized so as to reduce paperwork both for suppliers and for California agencies.

California government agencies generally would benefit from the commercial availability of high quality, energy saving LED light bulbs.

8.5 Business Impacts

Business impact would overall be minor. Some California firms involved in LED lighting would benefit from the elimination of competition from low quality and low cost LED light bulbs. The overall California economy would benefit from reduced energy consumption.

8.6 Lifecycle Cost and Net Benefit

Lifecycle analyses have shown significant energy benefit to LED (and CFL) light bulbs when compared with Incandescent.(8) The LEDs (and CFLs) consume more energy in manufacturing. Energy consumed in manufacturing, however, is dwarfed by the far greater energy usage in operation over life. LED (and CFL) light bulbs consume far less energy overall than incandescent.

9 Savings Potential

See 8.2 above.

10 Acceptance Issues

See 4.2 above. Almost all issues are being addressed now through existing market forces and standardization. Some of the issues (quality, dimming, and cost) are addressed directly by this proposal. Other issues will take longer to be resolved.

11 Environmental and Societal Impacts

The lifecycle energy savings are a huge benefit. Consumers will also benefit from needing to change light bulbs much less frequently.

12 Federal Preemption or Other Regulatory or Legislative Considerations

There is in harmony, not conflict, with the Federal regulations.

13 Methodology for Calculating Cost and Savings

The methodology draws on the 2013 US DOE study for the potential savings, and on the US EPA ENERGY STAR program for the specification details.

14 Bibliography and Other Research

(1) ENERGY STAR® Program Requirements for Integral LED Lamps

Eligibility Criteria - Version 1.4

May 13, 2011

http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf?86b4-6ebb

(2) ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs)

Eligibility Criteria Version 1.0, FINAL DRAFT

specification shall take effect September 1, 2014

https://www.energystar.gov/products/specs/sites/products/files/ENERGY STAR Lamps V1.0 Final Draft Specification.pdf

(3) Dimming Behaviors of LED Replacement Lamps

Lighting Research Center, Solid-State Lighting, ASSIST program

http://www.lrc.rpi.edu/programs/solidstate/assist/dimming.asp

(4) Adoption of Light-Emitting Diodes in Common Lighting Applications,

US DOE, April 2013 revised May 2013

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf

(5) US Energy Information Administration

Frequently Asked Questions

How much electricity is used for lighting in the United States?

http://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3

(6) VOLUNTARY CALIFORNIA QUALITY LIGHT-EMITTING DIODE (LED) LAMP SPECIFICATION

California Energy Commission

December, 2012

http://www.energy.ca.gov/2012publications/CEC-400-2012-016/CEC-400-2012-016-SF.pdf

(7) HEALTH AND SAFETY CODE SECTION 25210.9-25210.12

http://www.leginfo.ca.gov/cgi-bin/displaycode?section=hsc&group=25001-26000&file=25210.9-25210.12

(8) Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products

Part I: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps

US DOE, February 2012 Updated August 2012

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_LED_Lifecycle_Report.pdf

APPENDIX: Cost Analysis Assumptions

[The Energy Commission used the following rates to evaluate initial proposals received in response to the August 31, 2011 scoping workshop.

The cost of electricity: $0.15 per kWh

The cost of natural gas: $1 per therm

The cost of water: $0.0052 per gallon

Discount rate: 3%

The Energy Commission is investigating whether to update these figures over the course of the rulemaking. Stakeholders are welcome to suggest appliance-specific rates, or alternates to these flat rates to support cost-effectiveness of their proposals. If stakeholders choose a different rate, they should describe the analysis and rationale for the different rate.]