# Small Diameter Directional Lamps

Codes and Standards Enhancement (CASE) Initiative
For PY 2015: Title 20 Standards Development

UPDATE ON SDDL MARKET TRENDS, PERFORMANCE PROPOSAL, AND HAZARDOUS/TOXIC CONTENTS



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# Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SoCal Gas), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Program seeks to address energy efficiency improvement opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC), and other stakeholders in the development of these new and updated standards. The objective of this Program is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards.

This document is an update on small diameter directional lamps in three areas:

- Market share and price trends
- Performance proposal of color rendering index (CRI)/efficacy requirements
- Hazardous material contents

The CASE team investigated market performance through review of recent DOE publications, used web crawling software to collect price trends, and collected data on recent photometric performance metrics from online retailers. This document outlines the observed growth in market share, and decrease in price related to improvements in performance.

The CASE team recommends a performance requirement wherein the sum of the CRI value and the lumens per Watt value must be greater than or equal to 165, with a minimum efficacy of 70 lumens per Watt and a minimum CRI of 80.

Finally, the CASE team reviewed a DOE publication, *Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products* (2013), and researched current products that demonstrate that LED lamps have far less potential for hazardous waste impacts than incandescent lamps.

# 1 Market Performance and Price Trends

## 1.1 Market Share of LED Small Diameter Directional Lamps

A 2014 DOE report entitled *Energy Saving Forecast of Solid-State Lighting in General Illumination Applications* estimates that 9% of lumen-hour sales are LED MR16s.[1] We recommend using this value as Market Share of LED Small Diameter Directional Lamps (SDDLs).

## 1.2 Current LED SDDL Pricing

Using software that searches nine major online LED retailers once every month, we have collected price and performance data on LED lamps available since December 2013. Table 1.2 shows online price data collected from January 2015 to June 2015, and includes a) the average price found of all SDDL products, b) the average price of SDDL products with prices below the median price, and c) the average price of SDDL products with prices below the 10th percentile price. While sales-weighted averages are not available, in 2014 Lawrence Berkeley National Laboratory published a report on price data for A-shape LED lamps that found that products in the lowest 10th percentile of pricing represented 50% of all sales, and products in the lower 50th percentile (i.e. below the median) represented 90% of sales.[2] As such, we are reporting a typical unit price of $10 - $15 for the majority of *current* LED SDDL sales.

**TABLE 1.2 – 2015 ONLINE SDDL PRICE RANGES**

| 2015 Average Online Price | 2015 Average Online Price below Median Price | 2015 Average Online Price below 10th Percentile Price |
|---|---|---|
| $20.39 | $14.50 | $9.31 |

## 1.3 Price Trends and Future Projections

Figure 1.3.1 shows unit price trends by efficacy bins: less than 50 lumens per watt, 50 – 60 lumens per Watt, and greater than 60 lumens per Watt. Solid lines show average price of all products below the median price, and dotted lines show average price of all products below the 10th percentile price. Figure 1.3.2 shows unit price trends by lumen bins: 150 – 300 lumens, 300 – 500 lumens, and greater than 500 lumens. Solid lines show average price of all products below the median price, and dotted lines show average price of all products below the 10th percentile price.

Price trends in both categories, efficacy and lumen output, show decreasing trends with pricing below the 10th percentile already under $10.

[1] *Energy Saving Forecast of Solid-State Lighting in General Illumination Applications*. DOE, 2014.
[2] *The evolving price of household LED lamps: Recent trends and historical comparisons for the US market*. Gerke, B., Ngo, A., Alstone, A., and Fisseha, K. LBNL, 2014.

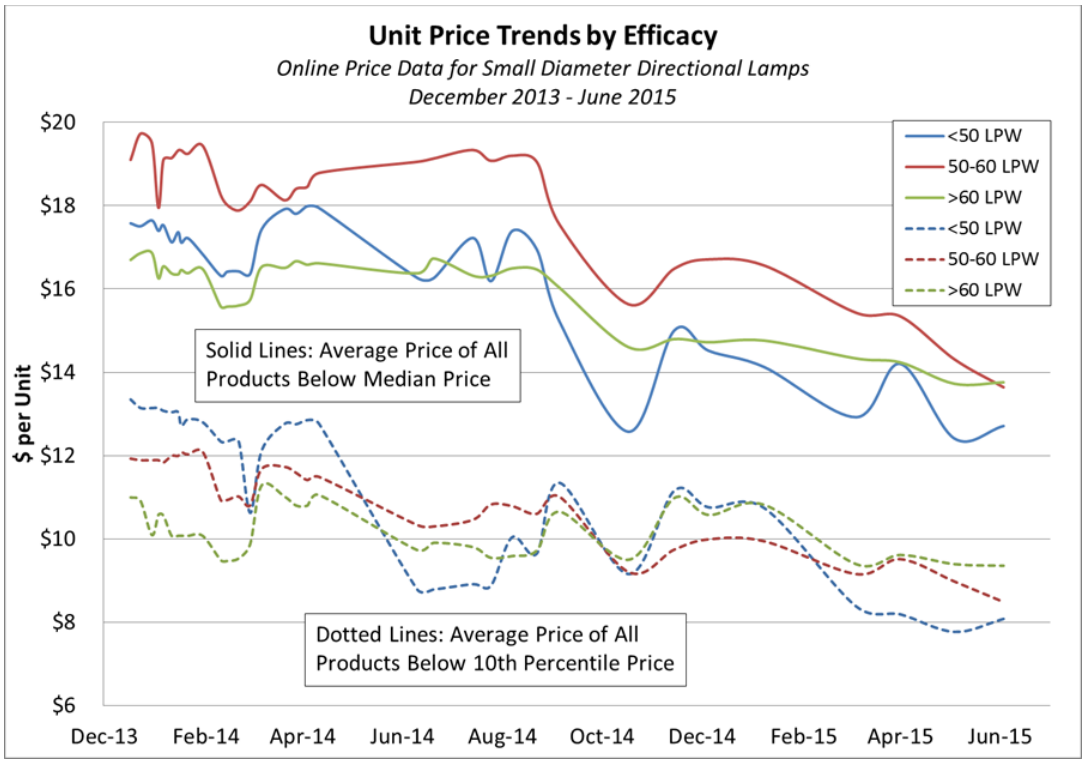


**FIGURE 1.3.1 – UNIT PRICE TRENDS BY EFFICACY BINS, BELOW MEDIAN AND 10TH PERCENTILE PRICE**

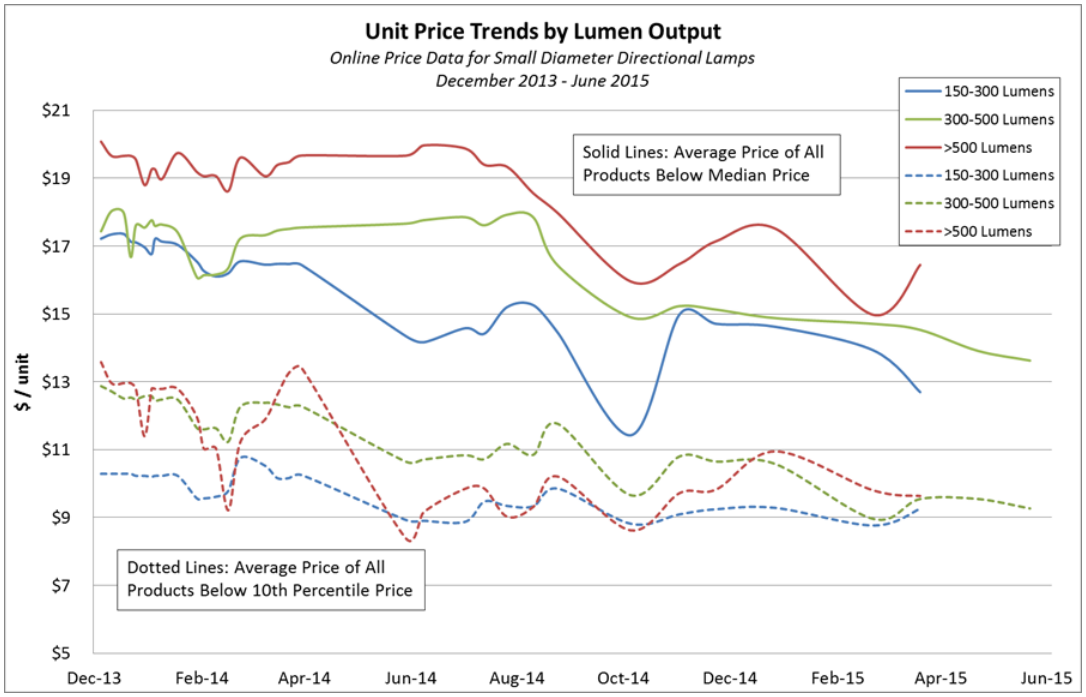


**FIGURE 1.3.2 – UNIT PRICE TRENDS BY LUMEN BINS, BELOW MEDIAN AND 10TH PERCENTILE PRICE**

Figure 1.3.3 shows trends of average online prices of products below median price projected through 2018. As mentioned above, we assume that these products represent 90% of sales, as concluded in the referenced 2014 LBNL study. From December 2013 to June 2015, prices dropped an average of 23%.

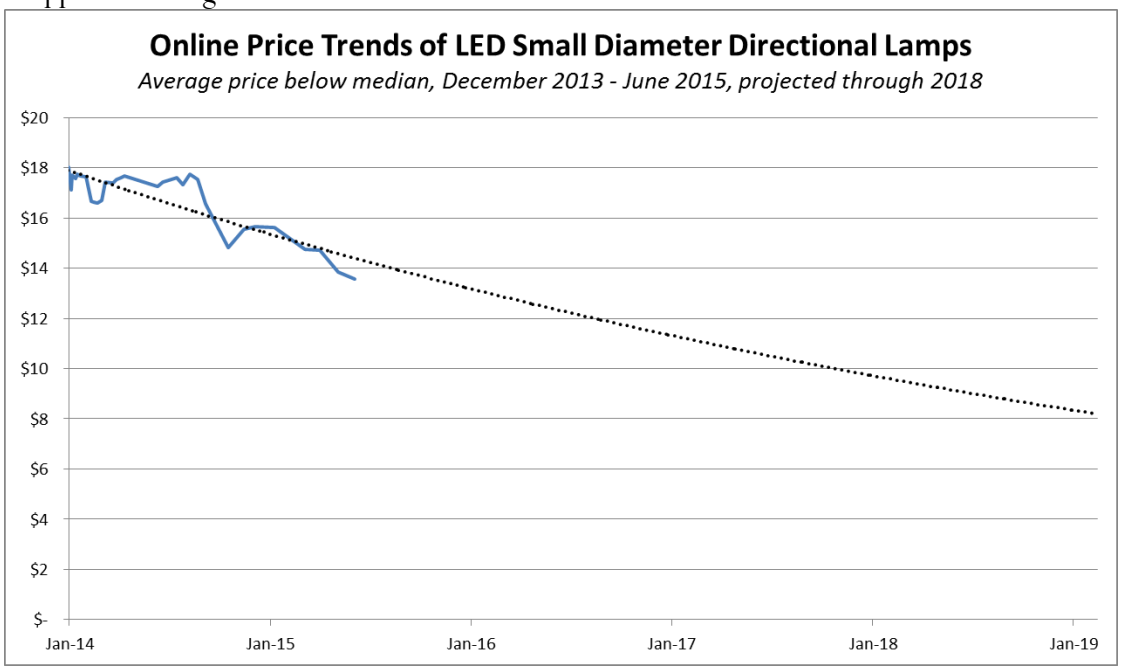


**FIGURE 1.3.3 – UNIT PRICE TRENDS PROJECTED THROUGH 2018**

Based on the above analysis suggesting that half of LED SDDL sales are already under $10, and this trend analysis suggesting that average of all products below the mean online price will be $10 by 2018, we recommend that the CEC use $10 as its assumed LED SDDL price in 2018.

# 2 Performance Proposal

The CASE team recommends a trade-off approach wherein the sum of the color rendering index value and lumens per Watt value must be greater than or equal to 165, while meeting a minimum efficacy of 70 lumens per Watt and a minimum CRI of 80. That is to say, first and foremost, the sum of CRI and LPW must equal at least 165. Once that condition is met, qualifying lamps can have any combination of efficacy and CRI, as long as efficacy is greater than or equal to 70 lumens per Watt, and CRI is greater than or equal to 80. Please consider the hypothetical examples in Table 2.1 and the graphical representation in Figure 2.1.

**TABLE 2.1 – HYPOTHETICAL EXAMPLES OF LAMPS AND THEIR QUALIFICATION STATUS**

| Example | CRI | LPW | CRI+LPW | Qualify? | Notes |
|---|---|---|---|---|---|
| 1 | 80 | 70 | 150 | No | CRI + LPW is below 165 |
| 2 | 75 | 90 | 165 | No | CRI is below 80 |
| 3 | 100 | 65 | 165 | No | LPW is below 70 |
| 4 | 95 | 70 | 165 | Yes | Minimum LPW is met and the sum of both is 165 |
| 5 | 80 | 85 | 165 | Yes | Minimum CRI is met and the sum of both is 165 |
| 6 | 85 | 95 | 180 | Yes | Both minimum requirements are met and the sum is ≥ 165 |

If a manufacturer wants to make a lamp with the minimum efficacy of 70 LWP, then the lamp must have a CRI of 95 to qualify. Similarly, if a manufacturer wants to make a lamp with the minimum CRI of 80, then the lamp must have an efficacy of 85 LPW.

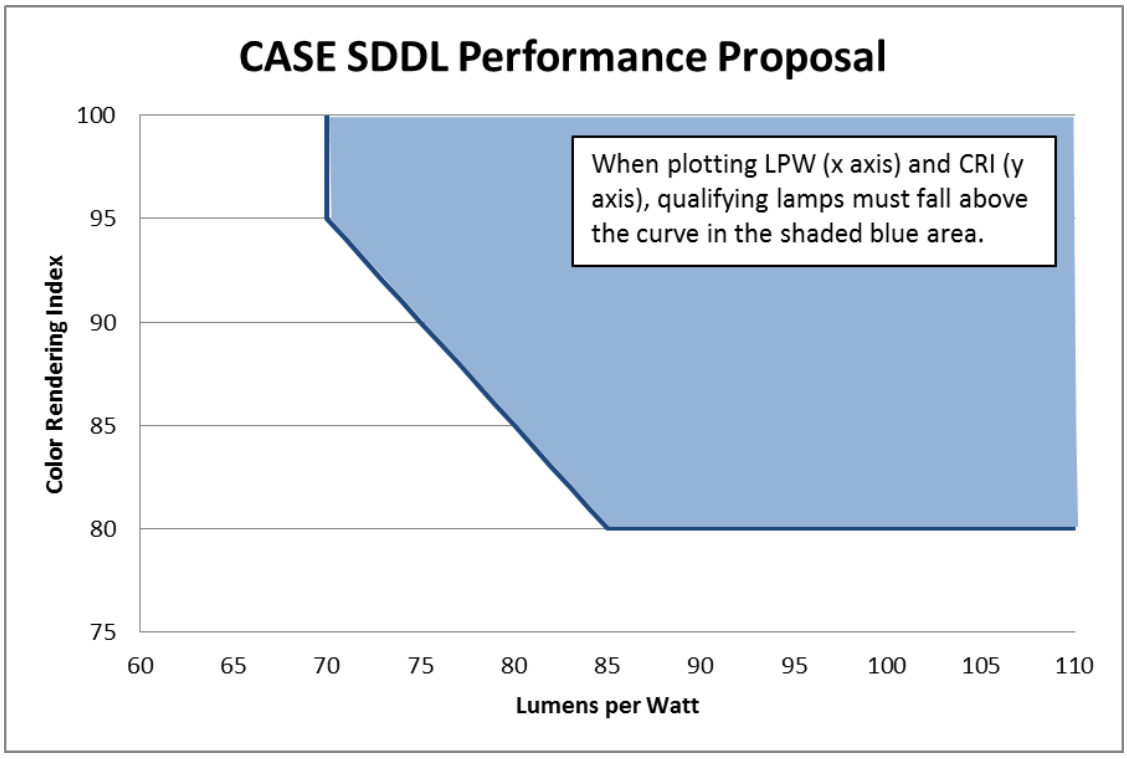


**FIGURE 2.1 – CASE TEAM SDDL PERFORMANCE PROPOSAL GRAPHICAL REPRESENTATION**

This proposal provides minimum requirements for efficacy and color rendering, but also allows for flexibility in allowing manufacturers to focus on either more efficient products or higher CRI products beyond a defined minimum performance threshold. This proposal recognizes that rendering colors accurately is part of the role of a light source, and that those light sources with very high color rendering capabilities provide an important level of functionality and user amenity. Though high CRI sources generally are slightly less efficient, they can often provide a better user experience or perceived brightness, and thus could be operated at lower Wattage, as was explained in Leukos, the quarterly journal of the Illuminating Engineering Society of North America, in the article *High Color Rendering Means Better Vision without More Power*.[3]

# 3 Hazardous and Toxic Material Content of LEDs

DOE's publication, *Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products* (2013), demonstrates that LED lamps have far less potential for hazardous waste impacts than incandescents.[4] The study is a chemical analysis of a variety of LED, CFL, and incandescent lamps using standard testing procedures. 22 samples of 11 lamp models (four of which were LED) were tested to determine whether any of 17 elements identified as potentially harmful were present at levels exceeding CA or Federal regulatory thresholds for hazardous waste. Figure 3.1 (Figure 2.2 from the DOE report) shows lifecycle environmental impacts of LEDs from 2012 (represented by the green ring) far below incandescents (represented by the outer blue ring) in every single category considered, including "hazardous waste landfill." Furthermore, performance and material improvements projected for LEDs by 2017 suggest even greater lifecycle benefits from LEDs, and further reduced hazardous waste impacts (as shown by the purple ring in the figure). For example, significant forecasted improvements in efficiency will result in less waste heat and thus reduce the need for large heat sinks, resulting in less overall product material and weight.

[3] Whitehead, L. et. al; High Color Rendering Means Better Vision without More Power; 2014. http://cltc.ucdavis.edu/sites/default/files/files/publication/leukos-feb2015-high-color-rendering-enable-better-vision.pdf

[4] *Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products*. DOE, 2013.

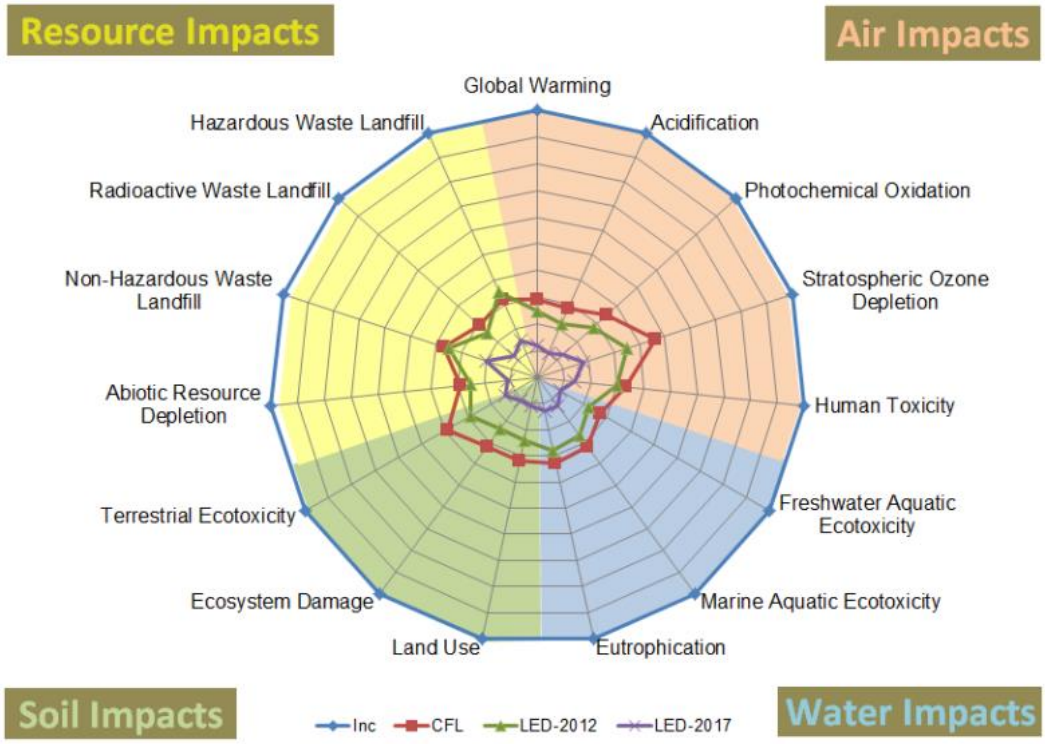


**Figure 2-2. Life-cycle impacts relative to incandescent lamps (DOE 2012c)**

**FIGURE 3.1 – LIFECYCLE IMPACTS RELATIVE TO INCANDESCENT LAMPS. SOURCE: DOE**

Previous studies from 2011 suggesting that LEDs had significant levels of toxic waste did not appear to consider the impacts of the much improved lifetime and efficacy of LED lamps over incandescents. With an estimated lifetime that is 5 to 10 times longer than incandescent, far fewer LED lamps will be disposed of each year.

The European Union's RoHS (Restriction of Hazardous Substances) Directive restricts the use of certain hazardous substances in electrical and electronic equipment, including LED Lamps. Several other major economies have adopted the RoHS requirements, including China and Japan. As a result, most major manufacturers of LED lamps in the U.S. market are already designing their products to be RoHS compliant, such as GE,[5] Cree,[6] Feit,[7] and others.[8,9] Similarly, ENERGY STAR Version 2.0 DRAFT 3 restricts a number of the same materials and concentrations by weight as the RoHS Directive.[10] Collectively, these initiatives help to ensure that LED lamp products, including SDDLs, do not contain unsafe amounts of hazardous substances.

[5] http://www.gelighting.com/LightingWeb/na/solutions/led-lamps-and-modules/
[6] http://www.cree.com/~/media/Files/Cree/Legal/RoHS%20Compliance.pdf
[7] http://www.feit.com/led-lamps/performance/Performance_LED/Performance_LED
[8] http://www.ledtronics.com/RoHS/RoHS.aspx
[9] http://www.lumileds.com/company/environment
[10] http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.0%20Draft%203%20Specification.pdf