LED LIGHT DISTRIBUTION COMPARISON STUDY

U.S. ENVIRONMENTAL PROTECTION AGENCY

Washington, DC

LED Light Distribution Comparison Study

Background:

The ENERGY STAR label identifies products that offer superior energy efficiency without compromise in performance. ENERGY STAR specifications for lighting products have historically included performance criteria such as color, start time, life and the distribution of light to make sure products earning the mark meet consumer expectations for performance.

Unlike traditional incandescent light bulbs which distribute light in all directions, LEDs are inherently directional light sources. Thus, ENERGY STAR requirements address light distribution to ensure that LED lamps earning the label are designed to distribute light more evenly so as to mimic the technology consumers are used to. As part of a revision to the ENERGY STAR lamp specification in 2015, the Environmental Protection Agency (EPA) is exploring opportunities to increase flexibility without adverse impact on performance or consumer experience. If more affordable LED bulbs can earn the ENERGY STAR mark then increasing the rate of adoption will bring increased national energy savings.

One potential adjustment that EPA is exploring is a slight modification of the light distribution requirements that could allow cost reductions by simplifying the secondary optics and reducing the number of LEDs needed. EPA selected the photometric performance under consideration based on an evaluation of five general purpose LED bulbs available at a price point that stakeholders identified as desirable for increased consumer adoption but that do not meet current ENERGY STAR distribution requirements.

To help assess whether this change would adversely impact consumer experience, EPA conducted a blind experiment asking consumers to compare the acceptability and readability of two general purpose light bulbs. Each bulb had a rated light output of roughly 800 lumens which is equivalent to a 60 watt incandescent bulb. One bulb was ENERGY STAR certified, meeting the current ENERGY STAR requirements for omnidirectional light distribution (version 1.1). The other was a lower-cost, non-certified LED bulb that did not meet the current requirements but that would meet the slightly modified requirements. Participants evaluated each bulb in two different table lamps. Following is a detailed description of the experimental design and the results.

Experimental Design:

Location: EPA offices, Washington, D.C.
Windowless conference room - approximately 10 ft x 15 ft.

Equipment:

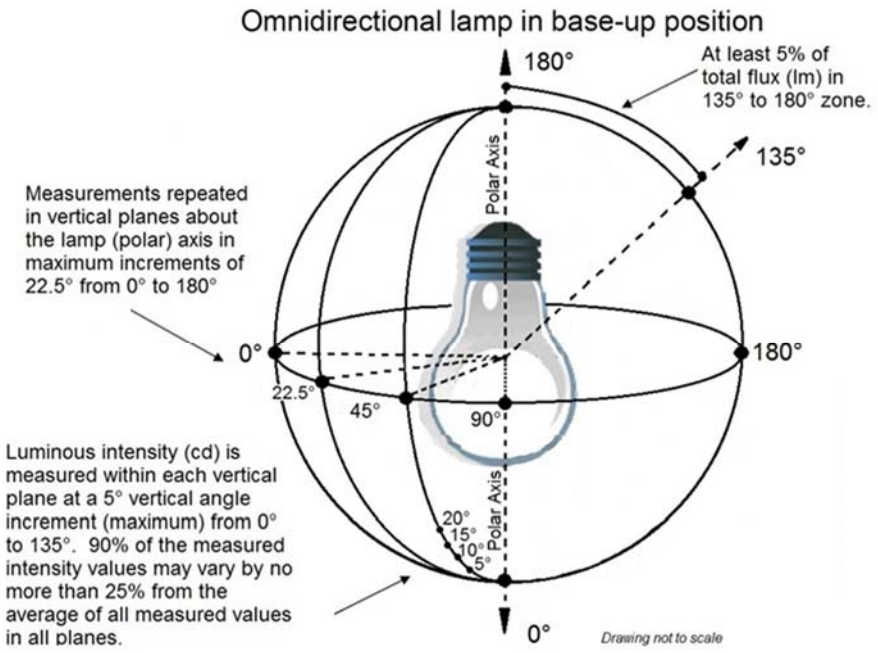
Two residential table lamps with different fixture bases and lamp shades.
(See Photos below).

<u>Bulb 1</u>

- ENERGY STAR certified A19 omnidirectional, “60 watt” equivalent, rated at 815 lumens, with a 2700K correlated color temperature. Brand and model: *Cree 4flow*

- Meets light distribution requirement of ENERGY STAR Specification for Lamps Version 1.1; lamp luminous intensity distribution shall emulate that of the referenced incandescent lamp as follows:
  - 90% of the luminous intensity measured values (candelas) shall vary by no more than 25% from the average of all measured values.
  - All measured values (candelas) shall vary by no more than 50% from the average of all measured values. No less than 5% of total flux (zonal lumens) shall be emitted in the 135° to 180° zone (see Figure 1).

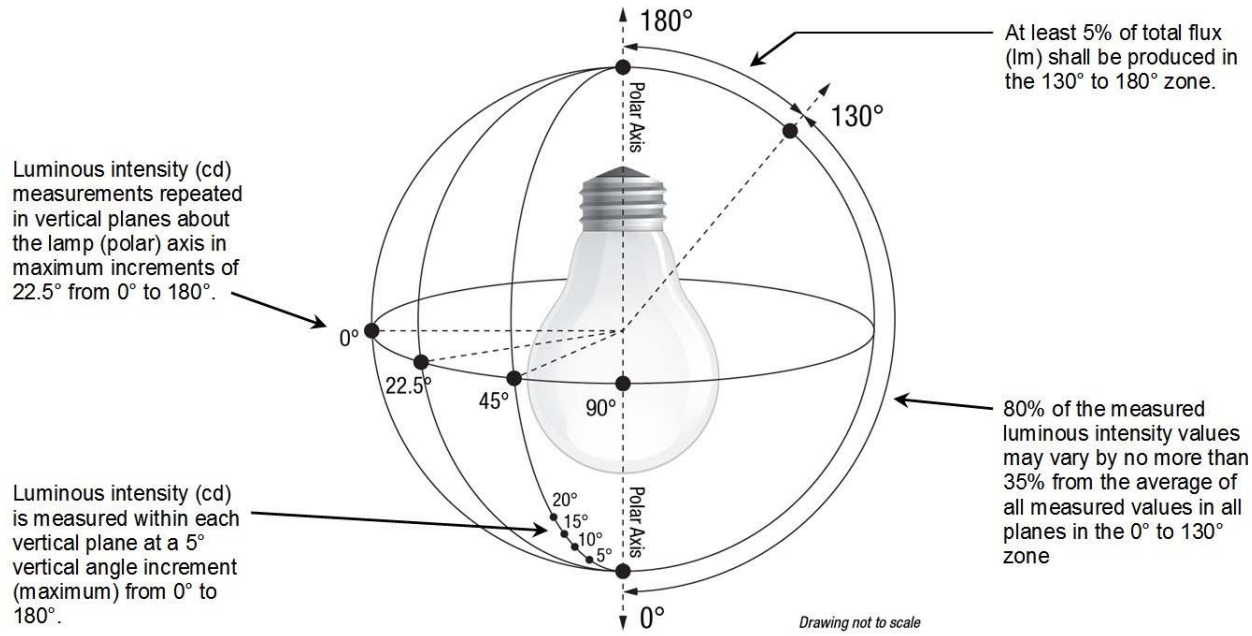
Figure 1



Bulb 2

- Non-certified general purpose A19 bulb. “60 watt” equivalent, rated at 800 lumens, with a 2700K correlated color temperature. Brand and model: *Great Value 60, Soft White*
- Meets modified light distribution proposal; lamp luminous intensity distribution shall emulate that of the referenced incandescent lamp as follows:
  - 80% of the luminous intensity measured values (candelas) shall vary by no more than 35% from the average of all measured values in the 0° to 130° zone.
  - No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° zone (see Figure 2).

Figure 2



Survey goal:

Determine whether participant can discern a difference in performance due to light distribution differences between an ENERGY STAR certified general purpose bulb and one that meets slightly less stringent requirements for omnidirectional distribution.

Null Hypothesis:

Respondents will rate the ENERGY STAR certified bulb higher than the non-certified bulb.

Survey subjects:

51 employees from EPA, approximately 25 – 60 years of age, men and women, of varying backgrounds, educational and professional levels. Subjects were volunteers.

Survey methods:

This was a single blind study, participants did not know the intent of the study. Each subject entered the room with the overhead lights on, and was read the following script:

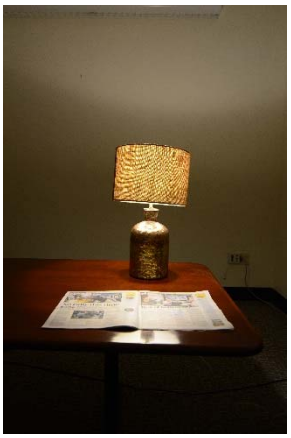
"Hello, thank you for participating in our lighting experiment. We're going to show you a few light sources in various lamp shades and we want your opinion on what you see. There are no wrong answers; just tell us what you think."

Overhead lights were turned off before beginning the experiment. Only one table lamp fixture was turned on at a time for observation. There was no additional information given to the respondents about the intent of the study, or any other details. Clarification questions were not answered except to direct the respondents to answer the questions as best they could with the information that they had.

Four different treatments were presented.

1. Bulb 1 with fixture 1
2. Bulb 1 with fixture 2
3. Bulb 2 with fixture 1
4. Bulb 2 with fixture 2

Treatment 1



Example: Bulb 1 with fixture 1

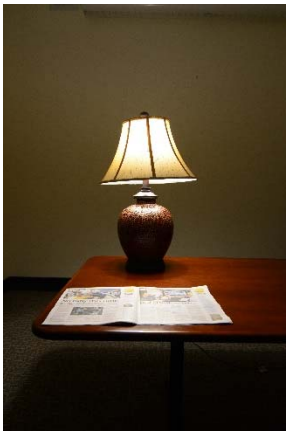
Photographic settings: Nikon D7000, 1/60 second, F-4, ISO 1250. Tokina 11-16 F 2.8 DX @16.

Treatment 3

Example: Bulb 2 with fixture 1

Photographic settings: Nikon D7000, 1/60 second, F-4, ISO 1250. Tokina 11-16 F 2.8 DX @16.

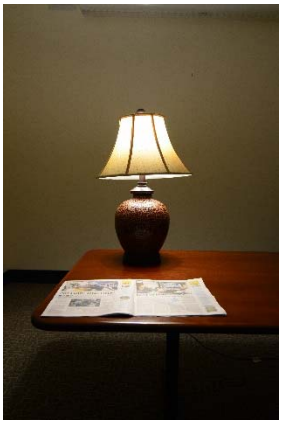
Treatment 2



Example: Bulb 1 with fixture 2

Photographic settings: Nikon D7000, 1/60 second, F-4, ISO 1250. Tokina 11-16 F 2.8 DX @16.

Treatment 4



Example: Bulb 2 with fixture 2

Photographic settings: Nikon D7000, 1/60 second, F-4, ISO 1250. Tokina 11-16 F 2.8 DX @16.

Participants viewed each of the 2 bulbs in each of the 2 fixtures and were asked the same questions. The order of treatment presentation was varied, using a random number generator, to eliminate bias that could result from the order of the presentation.

Questions:

1. On a scale of 0-10, where 0 is completely unacceptable and 10 is completely acceptable how would you rate the acceptability of the light?
2. On a scale of 0 to 10, where 0 is impossible to read, and 10 is perfect for reading, how would you rank this light bulb?
3. Would you buy this light bulb for your home?

Results:

The null hypothesis is rejected. There was no statistical difference between the combinations when using 95% confidence intervals for each average score for acceptability and readability. A Chi Square test of likelihood to purchase was not significant when comparing the combinations. (See Appendix 1)

This survey showed that under these conditions, where variations in light could have been visible, using fixed conditions and two different experimental treatments, respondents were not able to distinguish between the certified and the non-certified bulbs.

Survey limitations:

Given that the participants were all EPA employees, and volunteers, this was a self-selecting group and therefore not fully representative of all demographics. This limitation may be mitigated by the fact that the group spanned a wide range of ages, approximately 25 – 60, and included men and women. It is not known whether other demographic groups would have made different distinctions between the treatments; it is equally plausible that other groups would have been less observant, resulting in the same experimental outcome.

Appendix 1: Results and Statistical Analysis

Chart 1, Acceptability:

On a scale of 0-10, where 0 is completely unacceptable and 10 is completely acceptable how would you rate the acceptability of the light?

ENERGY STAR and Non-ENERGY STAR bulb in Fixture 1

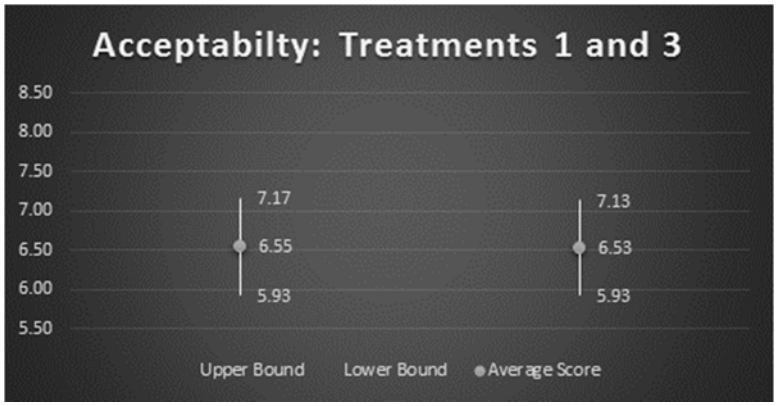


Chart 2, Acceptability:

ENERGY STAR and Non-ENERGY STAR bulb in Fixture 2

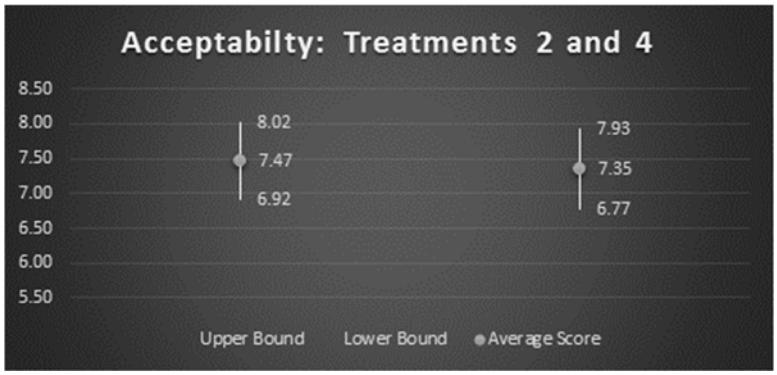


Chart 3, Readability:

On a scale of 0 to 10, where 0 is impossible to read, and 10 is perfect for reading, how would you rank this light bulb?

ENERGY STAR and Non-ENERGY STAR bulb in Fixture 1

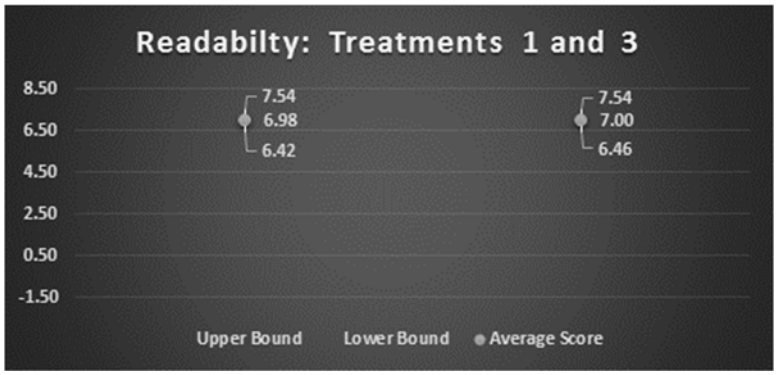


Chart 4, Readability:

ENERGY STAR and Non-ENERGY STAR bulb in Fixture 2

Table 1, Purchase Preference:

Purchase		Combination				
		1	2	3	4	Total
No	Count	14	8	11	7	40
	% within Combination	27.5%	15.7%	21.6%	13.7%	19.6%
Not Sure	Count	10	11	19	13	53
	% within Combination	19.6%	21.6%	37.3%	25.5%	26.0%
Yes	Count	27	32	21	31	111
	% within Combination	52.9%	62.7%	41.2%	60.8%	54.4%
Total	Count	51	51	51	51	204
	% within Combination	100.0%	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.373a	6	0.154
Likelihood Ratio	9.234	6	0.161
Linear-by-Linear Association	0.569	1	0.451
N of Valid Cases	204		

a 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.00.