December 18, 2015

Ms. Taylor Jantz-Sell
ENERGY STAR Lighting Program Manager
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Subject: ENERGY STAR Version 2.0 Lamps Specification Proposed Revisions

Dear Ms. Jantz-Sell:

This letter comprises the comments of the Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SCGC), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE) in response to the Environmental Protection Agency's (EPA) release of proposed revisions to the Draft Final Version 2.0 ENERGY STAR Lamps Specification, intended to replace the Lamps Specification Version 1.1. We support EPA's stated goal of revising this specification to keep pace with the rapidly evolving light emitting diode (LED) lamp market.

The signatories of this letter, collectively referred to herein as the California Investor Owned Utilities (CA IOUs), represent some of the largest utility companies in the Western United States, serving over 35 million customers. As energy companies, we understand the potential of national appliance efficiency programs to cut costs and reduce consumption while maintaining or increasing consumer utility of the products. We have a responsibility to our customers to advocate for voluntary program requirements that accurately reflect the climate and conditions of our respective service areas, so as to maximize these positive effects.

The replacement lamp product category has been a focal point of the CA IOU's energy efficiency program strategies for over two decades, and we are currently running multiple incentive programs in support of ENERGY STAR compact fluorescent lamps (CFLs) and high efficiency, high quality LED lamps. Since December 2013, our residential upstream rebate program efforts have been referencing the Voluntary California Quality LED Lamp Specification (CEC Spec),[1] published by the California Energy Commission (CEC), to establish eligibility for LED rebates. The CEC Spec was designed to leverage the framework established by ENERGY STAR. It uses most of the same test procedures and metrics, and in many cases the requirements directly align with ENERGY STAR Lamps Version 1.1. Similar to ENERGY STAR, the CEC Spec aims to increase market acceptance of LEDs by promoting a level of user amenity that is comparable to or higher than the lamps they replace. In a number of metrics the CEC Spec requirements are more stringent than those in the ENERGY STAR Lamps Version 1.1 Specification, including Color Rendering Index, R9 (red rendering), Power Factor, Duv (color consistency and light source whiteness), dimmability, and flicker.

When first adopted, the CEC Spec was considered to be quite ambitious, as few compliant products were available, and those that were available were quite expensive. However, within two years of using the CEC Spec for our upstream rebate program eligibility, average prices of compliant products dropped by

[1] http://www.energy.ca.gov/2015publications/CEC-400-2015-001/CEC-400-2015-001.pdf

about 75% (see Figure 2, below), and there was an order of magnitude increase in the availability of compliant products. In the first year alone, the IOU incentive programs provided incentives for sales of over 2 million lamps that met or exceeded the minimum requirements in CEC Spec.

The State of California is also now considering adoption of mandatory requirements, effective in 2017 that would require compliance with many of the aspects of the CEC Spec both in residential new construction (Title 24)[2] and in retail sales of lamps (Title 20).[3] These specifications and standards are gaining momentum, and the market is responding – the performance levels in the CEC Spec are no longer as lofty as they once seemed. Still these initiatives focusing on higher quality lighting would be further strengthened by increased utilization at the national level. National adoption of similar specifications to the CEC Spec would result in even more product availability, more competition among manufacturers, increased economies of scale and industry learning, and eventually a wider array of lower cost, higher performing products. We therefore encourage EPA to consider strengthening some of its proposed requirements for LED lamps as specified below. We also recommend that EPA maintain separate specification performance levels for CFLs so that these lamps will continue to be supported by the ENERGY STAR program. These recommendations are outlined in more detail in the comments below.

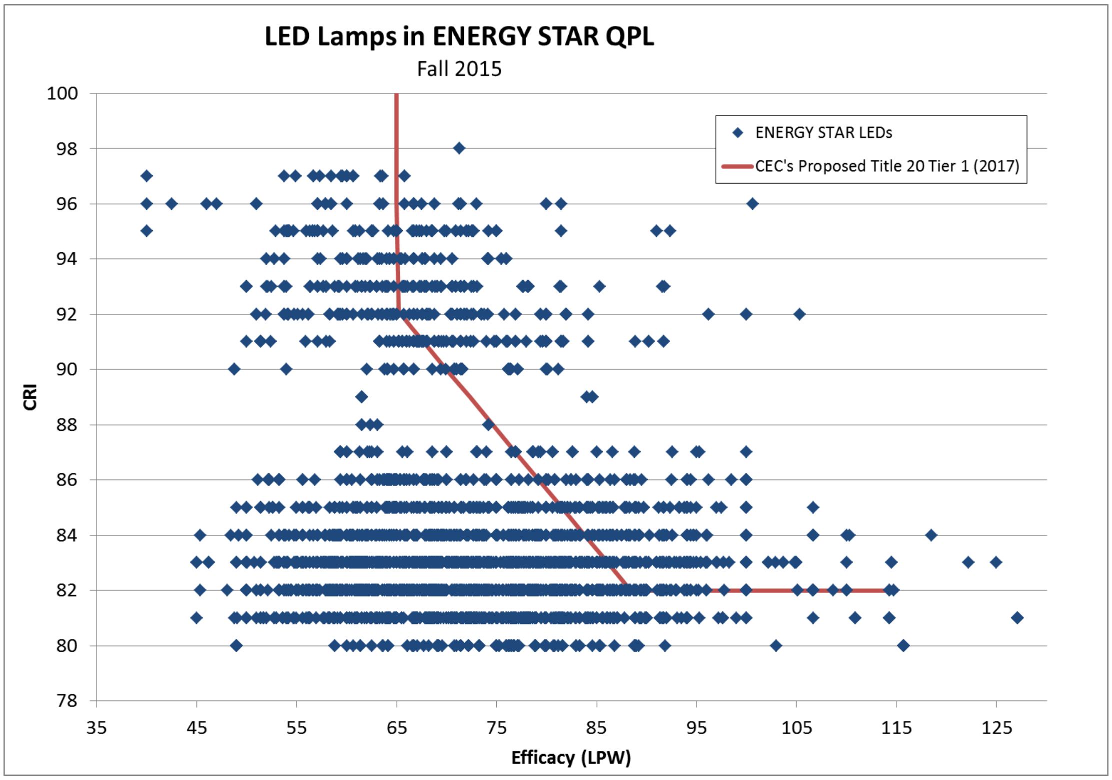
1. **We support EPA's proposal to strengthen the efficacy and color rendering requirements for LED lamps to better reflect the developments of the LED lamp market.**

We agree with EPA's proposal to strengthen efficacy requirements for LEDs in order for ENERGY STAR to continue to have meaning and influence in a rapidly improving and evolving LED market. Efficacy requirements that have been appropriate for both CFLs and LEDs in recent years are no longer relevant for LEDs, since they have been shown to be capable of significantly outperforming CFLs. We also support EPA's proposal to utilize a trade-off approach through which products with lower CRI (less than 90) are required to hit higher efficacy targets. This approach reflects the reality that higher CRI products more closely approximate the light of the incumbent, filament-based light sources that maintain a large market share in the U.S. Because of the importance of color accuracy to many people and in many applications, and because improving the color accuracy of LEDs does tend to result in a slight loss in efficacy, we agree that high CRI products should have slightly lower efficacy requirements, as proposed in the latest interim draft of the Version 2.0 ENERGY STAR specification.

However, we would recommend that ENERGY STAR incorporate an equation-based approach rather than a step function, so that as CRI increases between 80 and 90, the efficacy decreases accordingly. We believe the proposal currently up for adoption by the California Energy Commission in Title 20 (shown in Figure 1 below), is a good model for the Version 2.0 ENERGY STAR specification. The calculation for this sloped line is the sum of efficacy plus 2.3 times CRI, and the minimum proposed score is 277.

[2] http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/15-day_language/revised_express_terms/
[3] http://docketpublic.energy.ca.gov/PublicDocuments/15-AAER-06/TN206375_20151015T152718_Express_Terms_45_Day_Languge.pdf

Figure 1. Proposed Efficacy and CRI tradeoff equation



As shown in Figure 1, a large number of current ENERGY STAR products already meet this performance level, though it is a relatively small percentage of the total market. This proposed level would ensure that the EPA Lamps Specification actually pushes market towards the highest performers. EPA's current efficacy/CRI proposal would not be as aggressive; EPA estimated it would be met by the majority (60% to 75%) of the LED market.

We also recommend that EPA adopt stronger minimum color rendering requirements for LED lamps. Specifically, we recommend that EPA adopt requirements that help move the market away from the 80 CRI baseline that has been used for many years with CFLs and LEDs and which has not proven effective at replacing incandescent lamps in color sensitive applications where consumers continue to prefer filament lamps. We recommend that EPA adopt a minimum CRI of at least 82 (R_a), as well as a minimum score of at least 72 for each individual color sample R_1 through R_8 in the CRI metric. Because the CRI score is an average of these eight values, two lamps with a CRI of 80 can have dramatically different color performance. One may render several individual colors very well (e.g. with scores greater than 90), but other colors quite poorly (e.g. with scores less than 65), while another 80 CRI product might render all color adequately (mid-80s).[4] It is therefore important to adopt minimum requirements for each color sample to improve the effectiveness of the requirement and to ensure that it successfully improves overall color fidelity across the range of colors.

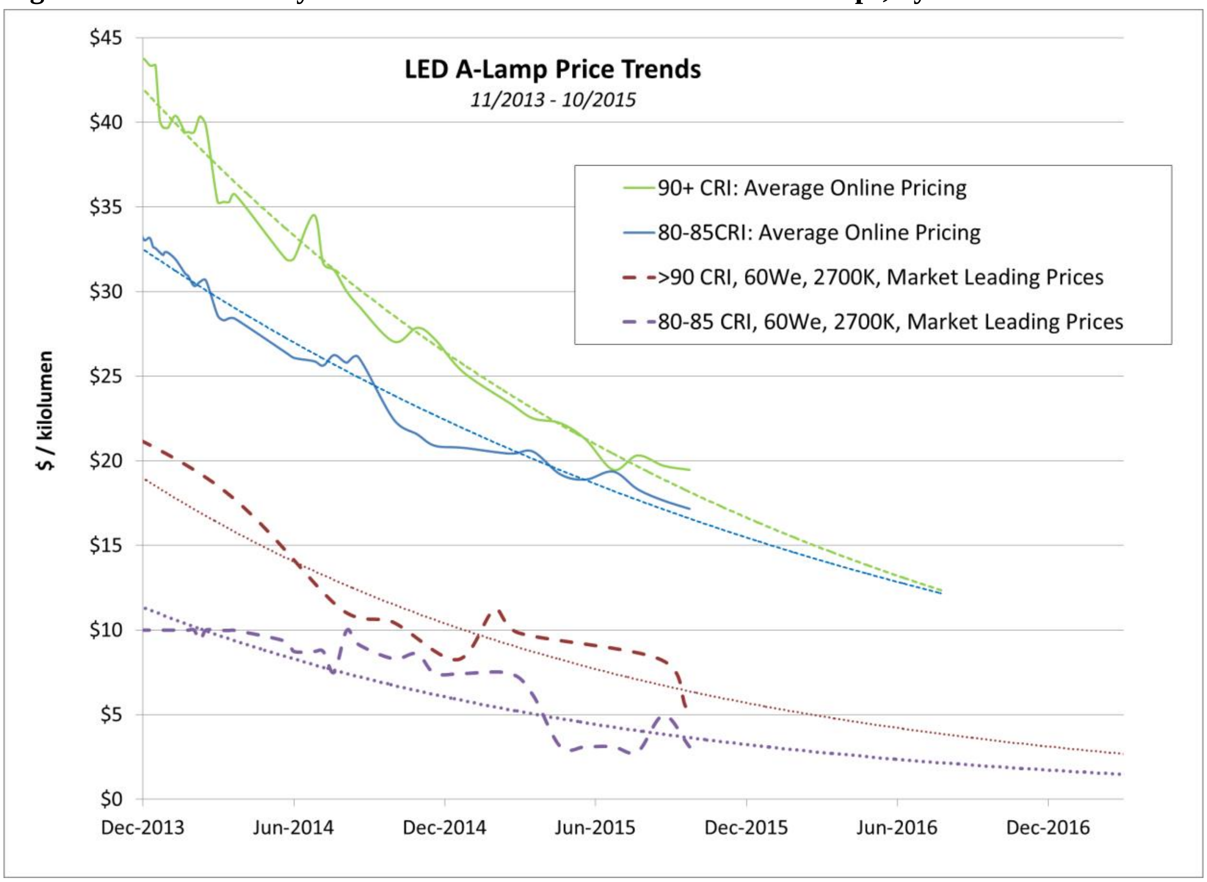
[4] We note that this is especially true at lower CRI values, for example 80 and below. At a higher CRI value such as 90, there is little room to "hide" or offset very poor performance in some colors by providing extremely high values in other colors, because 100 is the best that can be achieved for any one color sample.

For additional research on the importance of color rendering in lighting, please refer to the following resources:

- High Color Rendering Means Better Vision without More Power; Whitehead, Lorne. et. al; 2014[5]
- LED Lamp Quality, Response to CEC's Draft Staff Report and September 29, 2014 Stakeholder Workshop (Page 5-14)[6]

A wide array of LED lamps meeting these proposed efficacy and CRI standards are available and reasonably priced. LED prices continue to fall at a rate of about 30-50% per year, and pricing for lamps with high CRI is dropping faster than pricing of lower CRI lamps. Based on online retail and performance data the CA IOUs have been collecting since 2013, and as shown below in Figure 2, the *average* online pricing for 90+ CRI lamps is quickly catching up to 80-85 CRI lamps, as is pricing of the *market leading* 90+ CRI lamps.

Figure 2. CA IOU Analysis of Online Retail Price Data for LED lamps, by CRI bin



[5] http://cltc.ucdavis.edu/sites/default/files/files/publication/leukos-feb2015-high-color-rendering-enable-better-vision.pdf

[6] http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/documents/2014-09-29_workshop/comments/California_IOUs_Response_to_the_CECs_Draft_Regulations_regarding_LED_Lamps_2014-11-18_TN-73993.pdf

Specifically, the following are low priced products that meet these proposed efficacy and color rendering requirements, from both large and small manufacturers, selling at both large and small retailers:

- Feit High CRI A19 lamp; $3.96 per lamp at Home Depot ($11.88 3-pack)[7] – full price, pre-rebate
- Philips Slimstyle A19 High CRI; $6.65 per lamp at Home Depot ($19.97 3-pack)[8] – full price, pre-rebate
- TCP High CRI A19; $8.40[9] -- full price, pre-rebate
- Optolight High CRI A19; $6.80[10] – full price, pre-rebate

2. We recommend that EPA maintain a separate tier of specifications that can be met by CFLs or that EPA delay the implementation of Version 2.0 to allow more time for ENERGY STAR CFL certification before CFLs are phased out of the program.

The CA IOUs rely on the ENERGY STAR label to establish eligibility for CFLs in our incentive programs, and we intend to continue to do so through 2017. Though we anticipate eventually phasing CFLs out of our programs in favor of LEDs, they currently still play a critical role in the high efficacy lighting market. CFLs are still the cheapest high efficacy lamp type, and still represent a significant portion of national lamp sales (far more then LEDs).[11] However, the latest EPA proposal would likely prevent CFLs from meeting the ENERGY STAR specification, so we would no longer be able to reference ENERGY STAR for our CFL programs. Additionally, we believe this would have negative consequences for the CFL market because it would remove much of the incentive for manufacturers to produce CFLs that meet many of the other quality or performance-related metrics that are currently in the ENERGY STAR specification (including safety requirements, toxics reductions, light color, lifetime, run-up time, power factor, lumen equivalency and others). For these reasons we recommend that EPA adopt a separate set of requirements for CFLs that can be reasonably met by today's higher performing CFLs (that is, consistent with the requirements that were included in early drafts of the Version 2.0 specification: 65 lpw and 80 CRI). If EPA decides not to maintain a separate specification for CFLs, we recommend that the implementation date for Version 2.0 be delayed by six months to a year in order to allow CFLs to continue earning the ENERGY STAR well into 2017, before being phased out of the program.

3. We recommend that EPA adopt the same lumen equivalencies that were adopted in the Energy Independence and Security Act of 2007 (EISA 2007).

To avoid confusion among consumers and others as to what constitutes an equivalent lumen ranges, we recommend that EPA adopt the same lumen equivalencies that were adopted in EISA 2007. Those levels are shown in Table 1 below.

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[7] http://www.homedepot.com/p/Feit-Electric-60W-Equivalent-Soft-White-A19-Dimmable-LED-Light-Bulb-3-Pack-AGOM760-927-LED-3-48/206397929
[8] http://www.homedepot.com/p/Philips-SlimStyle-60W-Equivalent-Soft-White-A19-Dimmable-LED-with-CRI-90-Light-Bulb-E-3-Pack-458083/206198807;jsessionid=CAD8C7D39EA67F74917ACCDB98937F28
[9] https://www.energyavenue.com/TCP-Lighting/LED11A19DOD27K95
[10] http://www.amazon.com/OptoLight-10W-LED-Long-lasting-Bulb/dp/B013EWP4QK
[11] https://www.nema.org/news/Pages/First-Quarter-Proves-to-be-a-Mixed-Bag-for-Consumer-Lamp-Indexes.aspx

Table 1. Incandescent lumen equivalencies from EISA 2007

Incandescent equivalence	Lumen minimum
40 W	310
60 W	750
75 W	1050
100 W	1490
150 W	2500

4. **We do not support EPA's proposal to drop power factor requirements for LED lamps to 0.6 for lower wattage products. We recommend that EPA increase the power factor requirement to 0.9 for LED lamps, or at the very least maintain a power factor requirement of 0.7.**

As LED efficacy continues to improve, the vast majority of LED lamps in 2017 and beyond will be under 10W, so the proposed drop to 0.6 power factor for lamps <10W will apply to millions of lamps and represent a significant loss of national savings. As explained in more detail in the following subsections, we support higher power factor requirements for LED lamps for the following reasons:

- Lamps with lower power factor waste energy relative to lamps of the same wattage with higher power factor due to increased line losses resulting from higher current draws.
- There is no incremental end user price for higher power factor in LED lamps, and many of the cheapest products currently available on the market have high power factor.
- Products are widely available at high power factor levels; dropping the requirement below 0.7 would be a significant step backwards.
- Loads with leading and lagging power factor do not "cancel each other out" consistently or reliably if they are non-linear loads (such as LED lamps).
- Contrary to comments submitted to EPA, power factor need not be sacrificed to ensure lamps provide low flicker operation. Testing completed by PG&E found many products with both high power factor and very low flicker. No relationship between power factor and flicker was observed in the test data.

4.a LED lamps with lower power factor draw more current than lamps with high power factor (assuming equal wattage), and therefore waste energy due to the line losses associated with higher current draw (I^2R losses).

Poor power factor (significantly less than 1.0), results in increased current flow in distribution circuits by creating additional reactive displacement current and/or waveform distortion related current that does no useful work. A product with a 0.5 power factor draws twice as much current as a product of the same wattage with perfect power factor. This additional current results in unnecessary power and energy loss in distribution circuit wiring as a result of its resistance. This power loss is a function of the current squared times the resistance of the wiring (I^2R losses). When considering the distribution circuit loss associated with LED lamps it is not realistic to value its loss individually, because multiple lamps are usually installed on the same circuit (for example a track or a string of 8 or 10 downlight cans, or a dining room ceiling fixture with 4 to 6 sockets, or multiple table lamps or ceiling fixtures). If two or more of the same lower power factor lamps are present on a circuit, the losses go up as the square of the number of lamps – two 10W lamps (or one 20W lamp) will result in four times the losses that one 10W lamp would. Three lamps would result in nine times the losses of one lamp.

We conducted an analysis to quantify these potential losses. First we selected an outlet centrally located in a single family home and measured the line voltage reduction as a function of current when a resistive load was increased from zero to a little over 500 Watts. We used a high precision Yokogawa WT110 Digital Power Meter to measure voltage and current, which allowed us to calculate the source resistance of the distribution circuit (resistance is equal to voltage divided by current). The average measured resistance was .586 ohms.

Next, we calculated the current flow when adding LED lamps to a circuit with that assumed resistance. The incremental magnitude of the losses depends on how much current is flowing through the circuit (from other equipment). Most residential circuits are designed to carry a maximum of 15 Amps, or 1800 Watts at the normal line voltage of 120 Volts. It's unrealistic to assume that circuits will be operating at full design load when small incremental loads of poor power factor (LED lamps) are added. Conversely, it's not realistic to assume that they are operating at no load, where the incremental losses associated with poor power factor are indeed small. Overhead lighting and portable lighting is often on the same circuit as power outlets in residential buildings, so it is common for lights to operate on the same circuit as refrigerators, televisions, set top boxes, space heaters, etc. For the purpose of this analysis, distribution circuits are assumed to be operating at just under 1/3 of maximum capacity (under 5 Amps, and 500 Watts), when LED lamps are added. We developed this analysis for a scenario where four 8W LED lamps are added to this circuit with progressively lower power factors (0.9, 0.7, and 0.5).

As shown in Table 2 below, our analysis found that the current draw on the residential circuit when 0.9 power factor lamps are installed is 4.46 Amps, the current when 0.7 PF lamps are installed is 4.55 Amps, and the current when 0.5 PF lamps are installed is 4.70 Amps. Given these current draws, and an assumed residential circuit with a resistance of 0.58 ohms, we calculated the power losses on the circuit in all three scenarios: 11.67W with 0.9F lamps, 12.12W with 0.7PF lamps, and 12.95W with 0.5 PF lamps. In other words, when using 0.5 PF lamps, the losses are about 1.27W greater than when using 0.9 PF lamps. Assuming 1,000 annual hours of operation, the losses are about 1.3 kWh per year. Assuming a 15 year LED lamp life, the lifetime losses would be over 19 kWh.

Table 2. Losses Calculated for LED Lamps with Different Power Factors on a Residential Circuit with a Resistance of 0.58 (ohms)

Base load wattage on circuit (other equipment, with 1.0 PF)	Assumed Watts of LED Lamps installed on circuit (4 * 8W lamps)	Assumed Power Factor of LED load	Total Watts	Base VA	LED VA (LED Wattage / Power Factor)	Total VA	Base Load Amps (assuming 120V)	LED Lamps Amps (assuming 120V)	Total Amps (assuming 120V)	Base Load Wattage Loss (I^2R losses, assuming 0.58 ohms)	Total Wattage Loss (assuming 0.58 ohms)	Wattage Loss from LED lamps, assuming 0.58 ohms)	Wattage Loss relative to 0.9 power factor LEDs (W)	Annual kWh losses relative to 0.9 PF (assuming 1,000 hours of operation)	kWh losses over 15 year life (assuming 1,000 hours per year)
500	32	0.90	532	500	36	536	4.17	0.30	4.46	10.18	11.67	1.50	NA	NA	NA
500	32	0.70	532	500	46	546	4.17	0.38	4.55	10.18	12.12	1.95	0.45	0.4	6.7
500	32	0.50	532	500	64	564	4.17	0.53	4.70	10.18	12.95	2.77	1.27	1.3	19.1

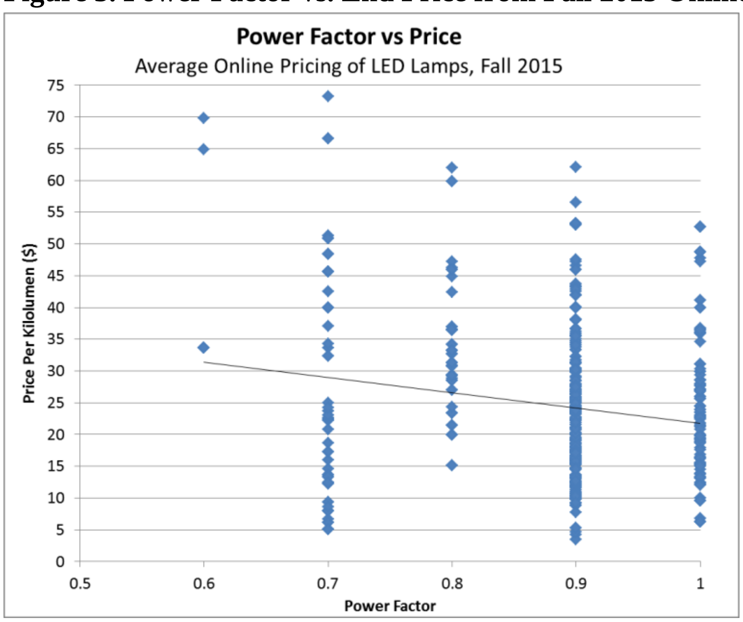
Assuming an electric rate over the next 15 years of about $0.17/kWh,[12] the cost savings in the above scenario resulting from increasing power factor from 0.5 to 0.9 is $3.25 cents. On a per lamp basis, the lifetime cost savings is about $0.81, far greater than the negligible cost to improve power factor in LED lamps (as discussed in item 4b, below). A savings of $0.81 is even more significant when considering that the total lamp costs are already often below $3-4 and continuing to drop.

The savings potential for low voltage lighting systems is dramatically larger. The above analysis assumes line voltage operation (120V). In the table above, the current is calculated by dividing the Volt-Amps by an assumed voltage of 120V. In a typical low voltage lighting system, the voltage is ten times lower (12V instead of 120V), so the current in the system is ten times higher. As discussed earlier, line losses increase as a function of the square of the current. Increasing current in a circuit by ten times increases the potential losses from poor power factor by a factor of one hundred.

4b. Increasing power factor of LED lamps does not appear to result in increased purchase prices for end users.

The CA IOUs continue to collect large amounts of price and performance data for LED lamps each month from online retailers. We also collect LED lamp data from the ENERGY STAR qualified product list and the Lighting Facts Database, and where possible, we match the performance data in these databases to the price points we find online for these products. Figure 3 shows all of the online price points we collected in Fall 2015, for all the products for which power factor data was available. This graph clearly shows that there is no incremental price for higher power factor in LED lamps. In fact, there appears to be a trend towards lower prices for high power factor products, and the cheapest products in the dataset have a power factor of 0.9. There are a number of 0.9 power factor lamps with a price per kilolumen below $5.

Figure 3. Power Factor vs. End Price from Fall 2015 Online Retail Data



[12] The forecasted weighted average electricity price for residential customers in California over the next 15 years (approximate life span of LED lamps) is $0.178 per kWh, based on the California Energy Commission's latest Energy Demand Forecast. http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-V1-CMF.pdf

That higher power factor does not appear to correspond with higher end user prices suggests that any incremental manufacturer cost associated with higher power factor designs is negligible. This trend is consistent with our past findings as well, both from previous online data collection, as well as interviews with manufacturers of driver integrated circuits (ICs). Through these discussions, we have learned that depending on the strategy utilized, estimates are that the manufacturer cost for high power factor is several cents or less per lamp, with the primary cost coming from a slight increase in the silicon area in the chip used for power factor correction circuitry. We encourage EPA to reach out to the manufacturers of high power factor LED driver ICs and solicit this information first-hand. Specifically, we recommend that EPA reach out to manufacturers such as Cirrus Logic, Power Integrations, Fairchild Semiconductor, Infineon, NXP, Texas Instruments, and Toshiba.

Furthermore, many of the lowest priced LED products available today have power factor above 0.7 – and many above 0.9. A review of the low price leaders currently offered at Home Depot revealed the following:

- The Home Depot EcoSmart A-lamp is under $5 has a 0.9 power factor[13]
- TCP's A-lamp is priced at $4.20 per lamp has a 0.7 power factor[14]
- Lighting Science Group's A-lamp is $3.75 per lamp and has a 0.9 power factor[15]
- Philips SlimStyle A19 is $5.97 and has a 0.9 power factor[16]

4c. Products are widely available at high power factor levels; dropping the requirement would be a significant step backwards.

As of October 2015, more than 82% of LED lamps in the ENERGY STAR qualified product list have a power factor above 0.9. This trend is also reflected in our analysis of products available online, as well as in the Department of Energy's Lighting Facts Database. Figure 3 above shows products available from nine online retailers as of fall 2015, and Figure 4 below, shows lamp data from the Lighting Facts Database from 2013 – October 2015. In our online data, less than 2% of lamps have a power factor below 0.7. In the Lighting Facts Database from the last three years, only about 10% of lamps have power factor below 0.7. Dropping the ENERGY STAR requirement below 0.7 would represent a significant step backwards for the LED lamp market and is not needed.

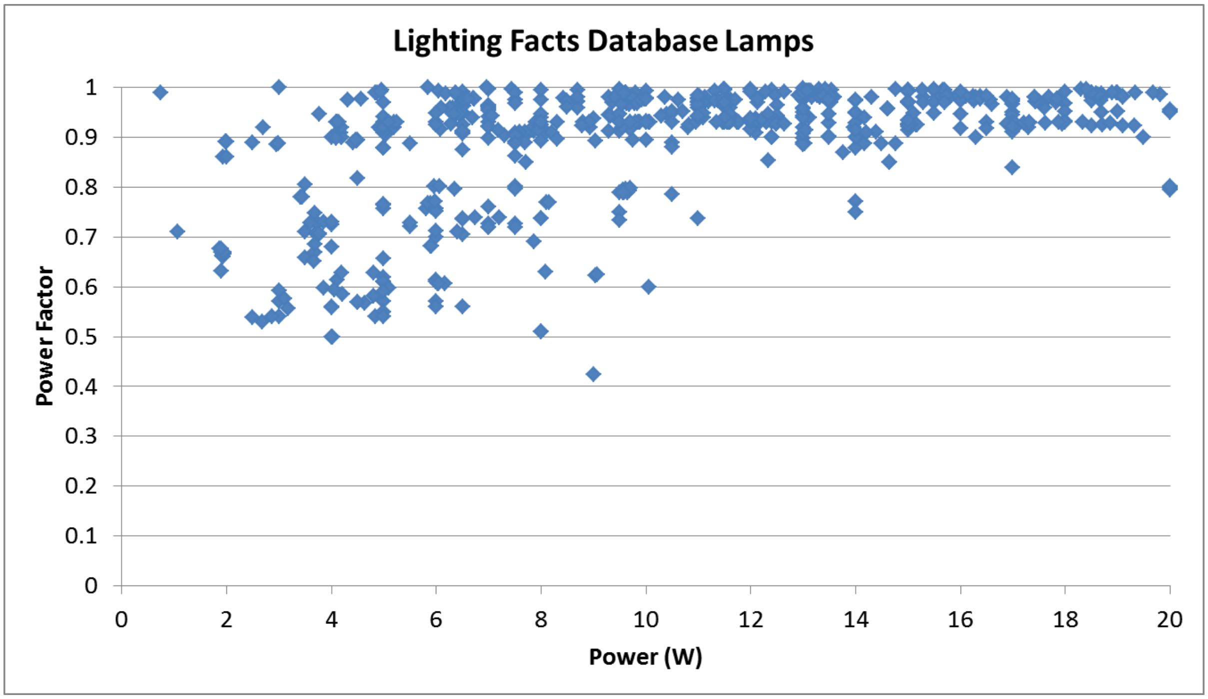
[13] http://www.homedepot.com/p/EcoSmart-60W-Equivalent-Soft-White-A19-Energy-Star-Dimmable-LED-Light-Bulb-4-Pack-A810SS-Q1D-01/206047134

[14] http://www.homedepot.com/p/TCP-60W-Equivalent-Soft-White-A19-Dimmable-Omni-LED-Light-Bulb-2-Pack-L9ADO27KYOW/206078974

[15] http://www.homedepot.com/p/Lighting-Science-60W-Equivalent-Soft-White-A19-LED-Light-Bulb-4-Pack-LS-A19-60WE-W27-120-FS1-4PK/206490426

[16] http://www.homedepot.com/p/Philips-SlimStyle-60W-Equivalent-Soft-White-A19-Dimmable-LED-Light-Bulb-E-452978/204730356

Figure 4. Power factor of lamps in the Lighting Facts Database from 2013-2015



Furthermore, our research has shown that high power factor driver performance is being provided by a wide array of driver IC manufacturers; there is no shortage of competition in this market. Our research found 19 different driver IC manufacturers supplying 0.90 PF drivers, including but not limited to:

- Cirrus Logic[17]
- Fairchild Semiconductor[18]
- Infineon[19]
- NXP[20]
- Power Integrations[21]
- Texas Instruments[22]
- Toshiba[23]

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17 http://www.cirrus.com/en/pubs/proDatasheet/CS1610-11-12-13_F6.pdf
18 https://www.fairchildsemi.com/datasheets/FL/FLS3217.pdf
19 http://www.infineon.com/dgdl/Datasheet_ICL8001G+vers+1.pdf?folderId=db3a304316f66ee801178c31a9af054a&fileId=db3a3043271faefd01273dce7b0e68f6
20 http://www.nxp.com/products/lighting_driver_and_controller_ics/ac_led_driver_ics_dimmable/SSL21082T.html
21 http://led-driver.power.com/products/lytswitch-family/lytswitch-4/
22 http://www.ti.com/product/tps92075
23 http://www.toshiba.com/taec/components/Datasheet/TC62D902FG.pdf

4d. Non-linear loads with leading and lagging power factor do not cancel each other out consistently or reliably.

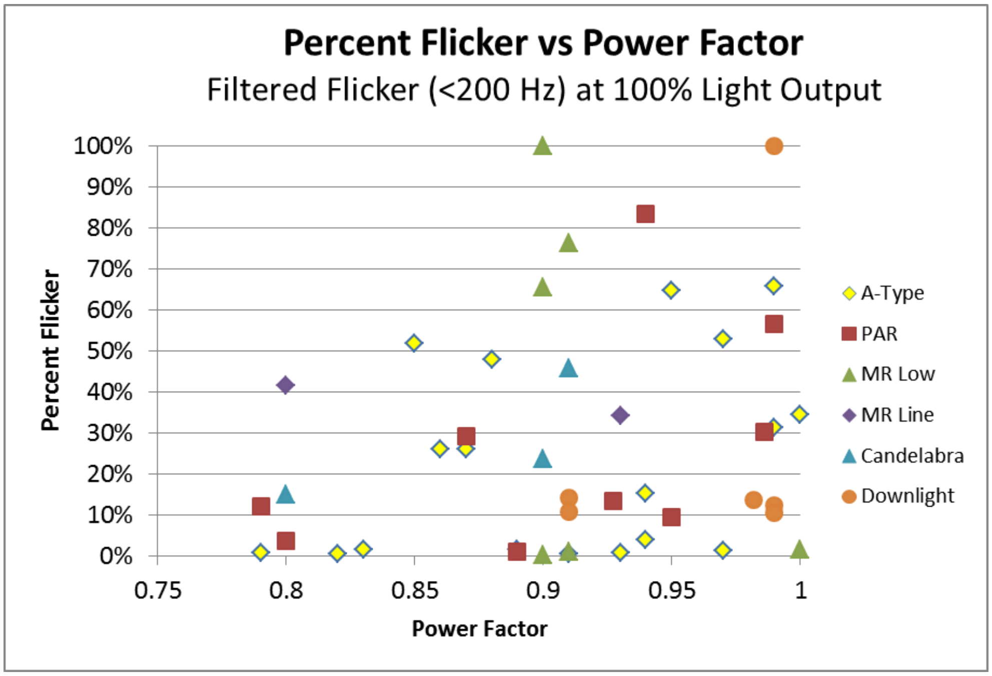
It is a misconception that a combination of leading and lagging power factors will cancel each other out or balance the grid. This is true to some extent when considering *displacement* power factor of linear loads, where sinusoidal current and voltage waveforms are out of phase with each other. Displacement power factor is generally associated with capacitive and inductive loads; inductive loads, like motors, have "lagging" power factor, where current lags behind voltage, while typical capacitive loads (capacitors, electronics) have "leading" power factor (where the current leads voltage). However, non-linear loads with poor power factor due to high levels of total harmonic distortion (generating *distortion* power factor rather than *displacement* power factor) cannot be cancelled out by loads with lagging power factor. CFL ballasts and LED drivers are examples of such non-linear loads (i.e. they draw current in short spikes which generally do not relate to the voltage waveform). For these types of non-linear loads, the combination of leading and lagging power factors will not cancel each other out predictably, consistently or effectively. Additionally, even among linear loads, there is no displacement effect unless the two types of linear-load equipment within a given metered circuit operate at exactly the same time. The low incidence of concurrent operation is rarely considered when the displacement argument is made.

4e. Testing completed by PG&E found many products with both high power factor and very low flicker proving it is possible and even common for products to perform well in both of these characteristics.

We understand that EPA has received comments from stakeholders suggesting that improving power factor results in increased levels of photometric flicker. We appreciate EPA's efforts to ensure that the ENERGY STAR specification does not have inadvertent negative impacts on an important product performance parameter such as flicker, but power factor need not be sacrificed to ensure lamps provide low flicker operation. Both metrics are important to ensure national savings from LED lamps, and both should be promoted by performance specifications such as ENERGY STAR.

PG&E has been conducting flicker testing on a variety of lamps including PAR lamps, MR lamps, candles, downlights, and A-lamps since 2014. A complete write-up of this flicker testing will be submitted to EPA separately; Figure 5 shows a summary of the flicker data, measured at full light output and filtered to identify low frequency flicker (<200 Hz), graphed against product power factor. In selecting products for this testing, we sought out products with higher power factor products (and in fact those are the most widely available), so there are few products below 0.85 represented in the graph. However, the testing clearly identified many products with both high power factor and very low flicker. California's low flicker operation standards requires flicker levels below 30% at frequencies less than 200 Hz, and we tested many products with high power factor (>0.9) that significantly outperformed this requirement (for example achieving flicker levels below 10%). The graph displays results at full light output but our testing found very similar results throughout the dimmed range. This data shows having low flicker is not a guarantee of having good power factor, and that improvements in power factor need not result in increased flicker.

Figure 5. Measured Percent Flicker (filtered < 200Hz) at full light output, plotted against power factor, by lamp type



In conclusion, we would like to reiterate our support to EPA for updating its ENERGY STAR Lamps Specification. We thank EPA for the opportunity to be involved in this process and encourage EPA to consider the recommendations outlined in this letter.

Sincerely,

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