

2012 LED Lighting TAG Recommendations

May 2012

These are recommendations for technologies presented and scored at the E3T LED Lighting Technical Advisory Group (LED TAG) scoring session on May 31st, 2012.

LED Linear Commercial Office Lighting (includes troffers and pendants) - 401	Overall Score:
<p>DESCRIPTION</p> <p>BPA probably powers at least a couple million troffers, and troffers are probably the most common commercial fixture type, which are used in offices, halls, classrooms, stores, manufacturing, etc.</p> <p>At the present time, electronically ballasted high performance T8 and T5 fluorescent systems are mainly used to replace T12 lamps and magnetic ballasts and 1st generation, which are also called 700 series or basic grade, T8 lamps and generic electronic ballasts. In the northwest, about half of installed fixtures have T12 systems and most of the rest have basic grade T8 systems. At this time, LED troffers and hard-wired kits are often twice to three times the initial price as their high performance fluorescent equivalents, but as this document explains, there are maintenance and other factors, which can offset initial costs on many projects.</p> <p>Equivalent rebates for both high performance fluorescent and LED systems will give end-customers the best comprehensive solutions.</p> <p>For some new construction projects and remodels several LED troffer models can already be considered good and cost effective, especially when dimming is desired. Later this year and in 2013 with improved LPW and lower prices, LED troffers and hard-wired troffer kits should be able to compete well with and maybe start to overtake high performance fluorescent in many projects.</p> <p>LED troffers and hard-wired kits typically consume 25 – 70W and can replace or retrofit fixtures with 38 – 144W, depending on if existing is T8 or T12, if existing is overlit, existing fixture efficiency, etc.</p> <p>LED linear commercial office lighting includes the following product types:</p> <ul style="list-style-type: none">• Troffers (which are similar to much smaller quantity surface mount and down light only pendant fixtures)• Hard-wired troffer kits• Suspended direct/direct light fixtures• LED T8s• Task lights for task – ambient lighting <p>What LED can bring to the market better than any other technology is dimming and CCT or Kelvin changing, but we understand that they will not be used in most retrofit applications.</p>	

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Fluorescent dimming ballasts get inefficient as they dim due to lamp cathode heating, which is needed about at about .70 ballast factor (BF) and lower. For example, dimming a group of dimming ballast to 50% light level consumes 20 – 30% more wattage than turning off every other equivalent fixed output ballast. Also dimming fluorescent ballasts are expensive. With good quality drivers, LED fixtures can maintain or even improve LPW when dimmed. Sometimes there is no or just slight additional cost for a dimming driver. Flicker can be an issue with dimmable LED, and the industry is working toward relevant flicker standards.

Philips, especially in Europe, has been doing a lot of research with dimming and Kelvin changing in hospitals and schools. Light levels and Kelvin are increased and decreased at certain times of the day for better hospital patient sleeping and student performance. So far this has been done with fluorescent, but Philips and others know that LEDs are best for this. Philips/Lumileds office in San Jose CA was the featured project in the LightFair Seminar on remodeling a 1980s office building. They have Kelvin changing as a focal feature in a central gathering zone, visible from other parts of the space.

Variable light output and warm white to cool white Kelvin changing LED fixtures may become a significant for retrofits and new construction in the near future. People really need to see and play with these fixtures in order to get an appreciation of them. Some manufacturers do not charge extra for dimming and Kelvin changing, although controls can cost extra. The following diagram is from the 'Human Centric Lighting', which will be published in the June edition of Architectural SSL Magazine. If anybody would like to get a draft of that before publication, please contact Stan Walerczyk.



No additional energy savings are predicated with Kelvin changing, but LPW is typically about the same with these fixtures compared to fixed Kelvin fixtures.

The Kelvin changing feature could also help the light from different fixtures match and work well the wall and other interior colors. Maybe with Kelvin changing, manufacturers would not have to make each model type with different fixed CCT.

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BIG PICTURE

Since it will be a solid state lighting (SSL) world very soon, and many people will be prone to make poorly informed decisions, it will be very beneficial if BPA helps encourage good decisions, and sooner is probably better than later.

There are numerous interior and exterior LED products that may look appealing, but are low quality and may be expensive. Even some high quality products could be installed in the wrong layouts and applications. Plus, many LED products are incompatible with many types of controls.

With fluorescent technology, if an end-customer gets new fluorescent troffers or a retrofit, and is disappointed with the results, often the fix can be relatively easy and inexpensive. Different color or lumen lamps or higher or lower BF ballast can often fix the problem.

But with LED, if an inappropriate troffer or kit is installed, it can be quite frustrating, expensive and lengthy to fix the problem. Because of the expense and time, many end-customers may be stuck with the poorly performing LED system and tell others the problem, which could give LED at least a partial black eye.

So, it is important to get it right the first time with LED.

Light levels, distribution, glare, color qualities, flicker, controls, long term color consistency and lumen maintenance are just some of the factors that need to be properly considered.

CBEA and DLC have tried to mandate minimum lumens in different sized LED troffers, but that kind of approach can be counter productive. One reason for their recommendations was to try to ensure sufficient light in retail applications with a one for one replacement or retrofit strategy. However, many existing offices and other areas are overlit, so fewer lumens per troffer may be appropriate for some applications.

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RECOMMENDATIONS

EDUCATION, ETC.

BPA could consider:

- *Education, which could include seminars for end-customers, utility staff, contractors, specifiers, distributors and others, easy access for end-customers to the various DOE documents, importance of LM79 and maybe writing additional helpful documents*
 - *Many organizations, including DOE, Lighting Design Lab, Portland General Electric, Energy Trust of Oregon, Sacramento Municipal Utility District and California investor owned utilities offer various seminars and webinars for free or at small cost*
 - *Helping people design lighting systems that support human needs and preferences is important*
- *Only providing the rebate if the light levels meet IES recommendations or if the end-customer is satisfied in addition to minimum requirements by BPA, LDL, DLC, etc.*
 - *Sacramento Municipal Utility District has been doing this*
- *Hands on approach, which can include Knowledgeable staff or consultants checking plans before purchase and installation*
 - *Energy Trust of Oregon has been doing this*
- *Pilot rebate program, which could include providing samples for free or at cost to end-customers and/or using volume discount pricing, so customers, especially small ones can get decent pricing*
 - *BPA could offer incentives for LED mock-ups, which could help users get it right the first time*
 - *Recording some performance measurements, obtaining additional information, and building a catalog of sampled products with user feedback could be included*
 - *Numerous utilities and other organizations have done upstream rebates on CFLs and other products*
 - *Pacific Gas & Electric and other California investor owned utilities have been using its large volume discounts, so towns and small cities can get good pricing on LED streetlights and installation*
 - *These utilities also provide free design services*
- *Getting some high profile installations that are easily accessible by the public*
 - *Case studies would also be helpful*

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NEW LED TROFFER & HARD-WIRED LED TROFFER KITS

Initial Lumens Per Watt & Wattage Savings

The best bare lamp fluorescent T8 lamp and ballast systems provide about 100 initial LPW, and out of troffer or kits, it may be about 80 LPW. Typical fluorescent troffers may only provide 60 – 70 LPW.

Currently numerous LED troffers and hard-wired troffer kits provide about 90 LPW out of the fixture. There are some that provide 100 and even 110 LPW, but they can be \$50 - \$100 more expensive due to the extra LEDs driven at a lower drive current. Even with 90 LPW, LED troffers and kits may be able to reduce wattage up to 50%, and sometimes even more if the existing space is considerably overlit, uses T12s, etc. Additional energy may be able to be saved with controls.

However, some LED troffers or kits could save less than 10% of the existing wattage or could actually increase wattage if the lighting project is not properly specified. For example, since the DLC has mandated at least 4000 lumens out of 2x4 LED troffers, manufacturers have designed their 2x4 LED troffer for that. $4000 \text{ lumens} / 90 \text{ LPW} = 44\text{W}$, which is more wattage than a 2x4 troffer with two fluorescent 28W F32T8s and high performance .77 BF ballast. LED troffers and kits, which drive current can be set at the factory or on the job site, are often the best solution.

It may not be good to mandate at least 90 LPW now. While most LED troffers and kits shine most of the light straight down in a cosine pattern, which is not good for uniformity between fixtures, at least the Philips Ledalite Pique has a good downward batwing distribution, which is very good for uniformity, but it only has about 85 LPW.

The GE Lumination, which produces good workplane illuminance uniformity, and some other edgelit LED troffers currently only provide 70+ LPW, but edgelit technology is improving.

By 4Q12 most LED troffers and kits will probably provide at least 100 LPW.

Also, manufacturers should be improving uniformity.

By 4Q12 BPA could consider requiring at least 90 initial LPW, and maybe certain uniformity standards for some applications.

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Long Term Light Levels

High performance T8 and T5 lamps only lose up to 10% of initial lumens by end of rated life, which can be considered L90. When these lamps have burned out, they are replaced with new lamps, which have 100% of initial lumens.

Most LED troffers and kits are rated at L70, which is when they have lost 30% of initial lumens. For many office, school, retail, etc. applications, it will either be the right amount of light initially and underlit at end of rated life or overlit initially and the right amount of light at end of rated life with most LED troffers. Neither is ideal, but there are already some improvements. One example is the Acuity LED troffers and troffer kits that can be easily connected to the Acuity nLight control system for constant lumens, which can save wattage to near end of life if the system is properly installed and commissioned. Another example is Finelite's HPR LED troffer that achieves L90 at 100,000 hours.

*BPA could consider mandating L90 information for LED troffers and kits.
(If L90 is only at 25,000 hours, BPA could decide to rebate that product)*

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Cost - Parts

All of the costs quoted below are parts costs to contractors or good-sized end users before rebate. This pricing is based on about 50% increase over distributor net pricing from manufacturers. But pricing to distributors, contractors and good-sized end users vary greatly, depending on quantity, competition between manufacturers, if a manufacturer wants to low-ball in order to get a specific showcase project, amount of hand holding any party has to do, etc. Some end-users will buy product from distribution and do installation in-house or have a contractor do it labor only. Some contractors make more of their money on labor than product mark-up than other contractors. Some manufacturers will sell direct to contractors and good-sized end users without going through rep agencies or distributors. Costs do not include controllers or additional wiring or wireless devices, which are necessary for dimming.

For most retrofit projects, LED troffers are too expensive to replace existing fluorescent troffers.

But for new construction or gut rehabs, when new troffers are required, LED troffers do not cost much more than new high performance fluorescent troffers, especially when dimming is necessary. During 4Q12 to first half of 2013 a high performance fixed BF fluorescent troffer with lamp(s) may cost \$110 - \$180 and the dimming version of that \$170 - \$240. A good LED troffer may cost \$190 - \$270 then. Most LED troffers come standard with dimming, which can be used or not. After first half of 2013 LED troffer pricing should continue to drop, but probably at a slower pace, while fluorescent lamp prices may continue to increase, but fluorescent lamp pricing is a small part of the equation.

A basic grade fluorescent troffer with clear prismatic lens, generic fixed BF ballast and 2 basic grade T8s may cost about \$50 - \$75.

Although several manufacturers are offering hard-wired LED kits for about the same and sometimes slightly higher cost than equivalent LED troffers, those prices are too high for most retrofit projects even in Hawaii and Alaska, where electricity can be \$.30/KWH.

For retrofits, the maximum cost for even an upscale nondimming and fixed color hard-wired LED kit, which can be used to eliminate parabolic louvers, probably needs to be \$100. A dimming and Kelvin changing version of an upscale kit may be cost effective at \$125 - \$150. A basic grade kit for many projects probably needs to be in the \$60- \$75 range. Several manufacturers think they can reach these goals by the end of 1Q13

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Cost – Labor

Installation labor rates can greatly vary between new fixtures and kits. For union and some types of prevailing wages, the labor rate can be \$55 - \$95 per hour to install new fixtures, while it can be \$30 - \$50 for retrofitting existing fixtures. Labor may even cost less, if done by some in-house staff. Although there are a lot of factors to consider on various specific projects, it may take professionals 20 minutes to replace or retrofit each fixture.

Plus if there is asbestos in the ceiling, it is usually a good idea not to replace troffers. Even without asbestos, troffer replacement can create more dust and waste than a retrofit kit.

Rated Life & Warranty

Many people think that LED troffers and kits will last longer at a lower long term cost than fluorescent troffers, but that is not always the case.

There are extra long life fluorescent T8 lamps, which are rated for up to 62,000 hours at 12 hour cycle with program start ballasts. Electronic ballasts are rated for about 65,000 hours. So two lamps and one ballast in a troffer could be group replaced every 50,000 hours at about \$50 parts and labor, which would be \$100 at 100,000 hours. The metal, lens, lamp holders, hinges, etc. could last well over 100,000 hours.

The parts and labor costs to replace a 50,000, and even 75,000, hour LED troffer will be greater. At current prices, a 100,000 hour rated LED troffer with a 10 year warranty is really required to be a better value than fluorescent. Finelite is offering both in its HPR LED troffers. If Finelite can do it, so can other manufacturers.

The typical warranty on linear fluorescent T8 electronic ballasts is five years parts and labor. The labor part is usually \$10. The typical warranty on LEDs and drivers is only five years parts and nothing for labor.

For some people to switch to LED troffer or kits, maybe the rated life and warranty need to be better than for fluorescent systems. For example, may the LED life should be at least 60,000 hours and the parts and labor warranty needs to be at least six years.

BPA could consider sliding bonus rebates for LED troffers and kits which have 60,000 – 100,000 rated hours at L90 and 6 – 10 year warranties, maybe including a labor credit. That could really help push the industry in a good direction.

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Serviceability & Upgradeable

It is easy to replace LEDs and drivers from below some troffers and kits for maintenance and as a retrofit to save additional energy as LEDs get better down the road.

But some LED troffers and kits have the drivers above the ceiling tiles and the LEDs are not easily replaced, which is more costly for the owner to service.

Even if BPA cannot mandate easy maintenance and upgrades, maybe it provide a bonus rebate for models that allow maintenance and upgrades from below the troffer, without moving any ceiling tiles.

Human Centric Lighting

At least the Galaxia's dimming and Kelvin changing LED troffers, marketed in the USA by PlanLED, do not cost more than fixed Kelvin dimming LED troffers. If Galaxia can do that, so can other manufacturers.

There is some work on dimming and Kelvin changing LED troffer kits, which may cost \$125 - \$150 by 4Q12 or 1Q13.

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Rebates

Our working group firmly believes that rebates for at least the first one or two years for LED troffers and kits should be based on KWH saved and not a fixed prescriptive amount. Especially with daylight harvesting and peak load shedding, customized is better. The customized rate could be as good as the highest with fluorescent retrofits.

Maybe at least \$.20/KWH saved over the first year would be good.

Although a customized amount takes more time and effort to process, much can be learned in the process and all technologies play on an even field.

BPA could also consider comprehensive whole building rebates and/or rebates that are based on certain power densities below current applicable energy code, like ASHRAE, instead of compared to existing wattages.

Currently DLC and CBEA have minimum lumens for 2x2, 1x4 and 2x4 troffers, which are unrealistic for many applications, especially with good task lights. DLC may change its minimal lumens this June or later. LDL does not have any minimum lumens, which is a much better approach, but products only stay on the LDL list for a year, before they are expected to move to DLC.

With or without minimum lumen requirements, it is very important that a good amount of light is provided cost effectively.

DLC has no category for troffer kits, but it is working to add that category.

Hopefully the BPA will not require any minimum lumens in LED troffers or kits.

Although it is probably not necessary, maybe it would be good for BPA to get feedback on at least one target project with dimming and Kelvin changing LED troffers and task lights, before offering the general rebate on them.

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Existing T12 Wattages

The existing and proposed T12 system wattages that Levin Nock from BPA showed the rest of our working group seems very high for at least most medium to large customers.

At least the California large investor owned utilities have been using energy saving lamps and energy saving magnetic ballasts for base cases. For example, 2 4' bipin T12 lamps with magnetic ballast is considered to be 72W, which is the wattage with 2 F34T12 lamps and energy saving ballast. Even if the customer is using 40W lamps and standard magnetic ballast, which has higher wattage, 72W is used in rebate calculations.

This is the link to Pacific Gas & Electric's Appendix B. Southern California Edison and San Diego Gas & Electric have practically identical documents.

<http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ief/>

Now that new ballasts for many T12 lamps need to be electronic and production of most T12 lamps will be stopped this summer, at least the California investor grade utilities may consider the base case wattage for existing T12 systems, the same as for T8 lamps and generic electronic ballasts. For example, instead of 72W for 2 4' bipin T12 lamps and magnetic ballast, the base case wattage would be 59, which it is for 2 32W F32T8 lamps and generic standard BF electronic ballast.

Even in California, a good number of small businesses still get their T12 lamps from a big box type of store, and often buy 40W 4' bipin T12 lamps. This is probably similar in the northwest.

The average 40W savings with LED listed in the description is based on half of the existing fixtures having energy saving T12 lamps and energy saving magnetic ballasting and the other half having T8 lamps and electronic ballasting.

The accompanying feasibility tables use F34T12 lamps and energy saving magnetic ballasts for T12 systems.

BPA could consider significantly reducing its base wattages for T12 systems, and if that is done, maybe higher than \$.20/KWH saved over the first year rebate would be good.

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Cost Effectiveness

Simple payback and its inverse, return on investment, just based on electrical savings, are inferior financial tools for most LED projects, because those first level tools do not include any benefits after the payback period.

The furnished excel file has nine feasibility studies based on common troffer types with both T8s and T12s. It is considered that T8s and T12s have a 50/50 split in the commercial market in the northwest. That will change this summer, when manufacturing of most T12s is stopped.

\$.08/KWH is used in these feasibility studies, which reflect what some utilities that buy power from PBA charge end-customers, including various miscellaneous charges. Plus electric rates will probably increase in the future. If BPA wants to use another rate, just change that one cell in each study.

Often the option with the best payback based just on electrical savings has the worst long-term benefit, and the option with the worst simple payback just based on electricity has the best long-term comprehensive benefit.

If an office worker makes \$50,000 a year, and productivity can be improved, just five minutes per day, which is 1% of an eight hour shift, that is a \$500 improvement per person, year after year, which dwarfs electrical savings, installed costs and rebates.

It is important to state that new troffers or a retrofit with LED or another technology will not always improve worker satisfaction or productivity.

Since most parabolic troffers have so many problems, including very low fixture efficiency, cave effective (which makes the space seem shorter and gloomy from dark ceilings and upper walls), insufficient vertical footcandles and overhead glare, they can be cost effectively retrofitted or replaced with numerous fluorescent or LED solutions. Some upscale LED kits cost about the same as upscale fluorescent kits.

Controls

In most good retrofits and even new construction, especially with below \$.15/KWH rate, the wattage is so low that often inexpensive occupancy sensors are not cost effective, and dimming controls for daylight harvesting, task tuning and peak load shedding can cost a lot for little extra energy savings.

But it looks like some new energy codes will mandate controls across the country. (Some dimming and control manufacturers may have been doing a good lobbying job)

Dimming with Kelvin changing may help more for improved circadian rhythms and mood than for energy savings.

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Product Availability

Troffers

Numerous manufacturers currently offer dimming and fixed Kelvin LED 2x4, 2x2 and 1x4 troffers. Below is a very partial listing.

- Acuity
- Cooper
- Cree
- Hubbell
- Philips
- Finelite
- GE
- Lunera
- Maxlite

Acuity, Cooper, Hubbell and Philips are the big four, each with several brands. Plus more manufacturers in this country and around the world are developing them.

Galaxia, which won a Next Generation Luminaires award at Lightfair, is one manufacturer of dimming and Kelvin changing LED troffers. The Galaxia troffer is already DLC approved. Several other manufacturers are developing this kind of troffer.



The number of LED troffers approved by DLC and LDL is now quite limited, but that should significantly increase by 4Q12 and later.

A new and well designed LED downlight surface or pendant fixture line is the Cree CS series.

Some offshore and second tier manufacturers have designed troffers for LED T8s.

Hopefully BPA will not allow new troffers designed for LED T8s at least until many of the safety and other issues with LED T8s are resolved if they can be resolved.

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Troffer Kits

Although the manufacturers and models of LED troffer kits is currently relatively small, based on what was seen and discussed at Lightfair earlier this month and other sources, they will significantly increase. Here is a partial current list.

- Albeo's T8 LED conversion kit
- A.L.P.'s LED version of RDI kit
- Cree's CR troffer kit
- Energy Solutions International
- Energy Planning Associates' (aka Envirobrite's) LED version of Dialite kit
- Harris Lighting's troffer retrofit
- Lithonia's RTLED relight kit
- Philips Powerlux LED Line

Although there are many styles of hard-wired LED troffer kits, below is photo of the Albeo lightbar kit.



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SUSPENDED DIRECT/INDIRECT LED FIXTURES

Since there are so few of these fixtures, and they are expensive, they are only briefly discussed.

Currently, GE and Lunera are known to make edgelit LED suspended direct/indirect fixtures, which do not have very good LPW. This is photo of the GE Lumination.



In the future, LED suspended direct/indirect fixtures may become quite popular, because the LEDs and drivers would be in relatively cool conditioned space, instead of the hotter ceiling plenum space.

LED T8 LAMPS



Although LED T8 lamps have been getting better with lumens, LPW and lighting distribution, there are several safety and other issues that need to be resolved. Since these lamps are not really in this group's scope and time is limited, those issues will not be discussed.

As mentioned earlier, there are some LED troffers and other fixtures that are designed to use LED T8s.

For any application that LED T8s could be used, a hard-wired LED light bar or another type of kit or new fixture, that would not use fluorescent lamp holders, could probably be used.

Most rebate programs across the country do not rebate LED T8s.

Hopefully BPA will not rebate LED T8s as replacement lamps in new fixtures dedicated for them at least until all of the safety and other issues are resolved, if they can realistically be resolved.

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LED TASK LIGHTS

Task ambient lighting can often be the best way to use the least wattage, because LED troffers or kits can be much lower wattage, while providing good lighting and flexibility.

Many open offices can be considered glorified hallways that about 20 footcandles from the ambient lighting from the ceiling is often plenty of light for walking around and doing computer work. Often less light is better than more light, because less light can cause less glare on computer screens. When more light is desired for paper tasks, etc. task lights can be turned on, dimmed and sometimes aimed. Task lights are usually more efficient when the extra light is desired, because light levels are reduced as distance between light source and task increases. So much less wattage is usually required when the light source is only about two feet above old blueprints, etc., than from an ambient source that may be six feet above the task.

With good LED ambient and LED task lights, very low power densities can be achieved, like below .5 watts per square foot in many typical open offices.

But there are many significant limitations for task ambient lighting.

Many offices have areas with a lot of copy machines, file cabinets, etc. where task lighting may not work very well and at ambient lighting should provide at least 30 footcandles.

It may not be good to have too low of light levels from ambient sources in areas that do not get any daylight.

Task lights are not applicable in most classrooms, conference rooms, etc.

Task ambient lighting with LED task light fixtures can be a very hard sell in leased office spaces, because the tenants typically own office modules and existing fluorescent or incandescent task lights. And specific tenants can come and go.

What can be considered quite exciting is the new generation of LED undercabinet and desk mounted task lights.

Numerous manufacturers offer LED undercabinet and desk mount task lights. Some offer optional occupancy sensors. One very good example is Finelite's PLS system, which its Curve is shown



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Prism won a Next Generation Luminaires Award at Lightfair earlier this month for its fixed color dimmable desk mount task light.



Now Prism also has also warm to cool white changing models. Other manufacturers have or will develop similar products.

Hopefully BPA will consider a customized rebate program for LED task ambient systems.

LEVEL OF AGREEMENT

With the various experts in this working group with different focus and experience, we do not always agree on everything, which is okay

There is a difference of opinion how important the combination of dimming and Kelvin changing is for this BPA project.

Some people thought that task lighting should not be included in this scope.

Etc. Etc. Etc.

WORKING GROUP MEMBERS

Cindy Wills, Washington State University
Connie Samla, Sacramento Municipal Utility District
Dave Kunesh, North Coast Electric
Doug Oppedal, Evergreen Efficiency (Oregon Energy Trust)
Levin Nock, Aerotek contractor to BPA
Naomi Miller, Pacific Northwest National Labs (DOE)
Stan Walerczyk, Lighting Wizards (facilitator and main presenter)

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COMMENTS OR QUESTIONS