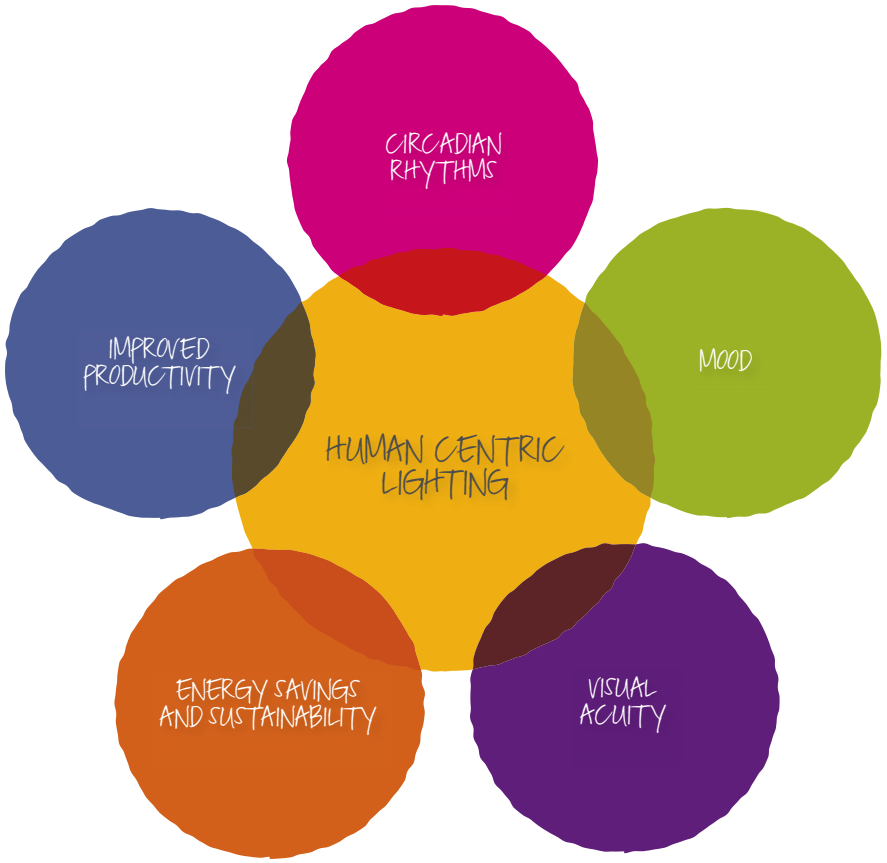


HUMAN CENTRIC LIGHTING

Thanks to developments in solid-state lighting there now exists a whole new capability to dim and "tune" correlated color temperature—commonly called Kelvin changing or shifting. More importantly, this sea change can really improve conditions for people.

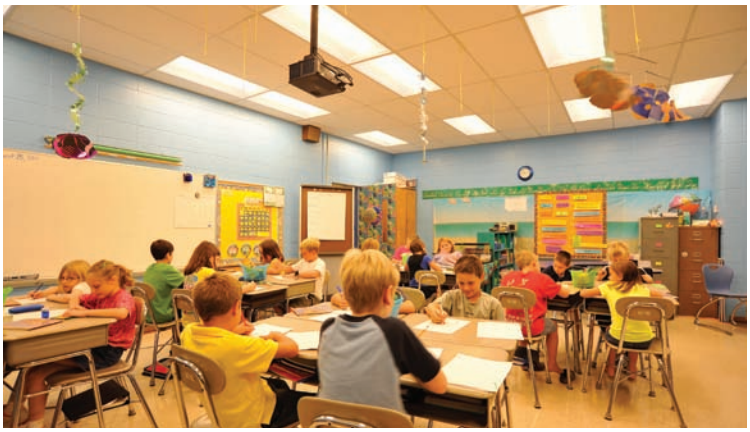
By Stan Walerczyk, CLEP, LC, Principal, Lighting Wizards

Claiming that better lighting can improve health is a big supposition. That said, it is not outlandish to state that carefully designed lighting can aid, even correct, circadian rhythms in human beings.

Over time, people have evolved in harmony with the Earth's natural lighting cycle, which has low light levels and low correlated color temperatures (CCT) in the early morning, high light levels and high CCTs at mid day, low light levels and low CCTs during evening, and extremely low light levels and a medium CCT under moonlight. These varying light levels are at the heart of a human being's 24-hour internal clock, otherwise defined as circadian rhythm. Until 200 years ago, 90% of our waking time was spent outside. Now most of us spend 90% of our time indoors with electric lighting. While we're at work, our lighting is usually set at one light level with a constant CCT—this is not consistent with circadian rhythms. Without regular and direct exposure to such dynamic lighting, the circadian rhythm can be disrupted, which could lead to health issues. Specifically, light and darkness control hormone production. During the day, with a natural circadian rhythm, appropriate amounts of dopamine are secreted for pleasure, alertness and muscle coordination; seratonin for impulse control and carbohydrate cravings; and cortisol for stress response. During the night, melatonin allows for sleep, and refreshes our body.

Recent research, specifically, the discovery of intrinsically photosensitive retinal ganglion cells (ipRGC) in our bodies, has been found to be very important in setting one's internal clock, so to speak. They are especially responsive to light that is rich in blue content, the mid-day sky, for example, which can be up to 10,000K. This is particularly notable in that blue light content suppresses melatonin and encourages dopamine, serotonin, and cortisol production, meaning greater exposure to it during the day can lead people to be more alert and productive at work, or even during night shifts. At the same time, at night, such melatonin disruption can create sleep issues.

◁ PLANNED PARTICIPATION
At Saltillo Elementary School near Tupelo, Miss., Philip's SchoolVision system was installed as part of a study by the University of Mississippi.
Image courtesy Philips



◁ LOW-KEY/UPTEMPO
Four different light settings were implemented, including "calm" (above), and "normal" (left). The study found that students exposed to the varying lighting experienced increases in performance 33% higher than students in the control group.
Image courtesy Philips

Philips has done some research in this area complete with case studies involving high and low CCT fluorescent lamps with dimming electronic ballasts, that can provide a full range of very warm white, to white light, rich in blue content. Its HealWell study, used in healthcare patient rooms, for example, uses high-lumen, high-CCT lighting for morning to mid-afternoon illumination, and lower-lumen, lower CCT lighting for late afternoon. Results from at least one European hospital show improved patient satisfaction and support recovery in patient rooms.

Philips' SchoolVision program has found similar results. Implemented in several European, and at least one American, school, lighting is set at 12,000K for the first 30 minutes in the morning to shut down remnants of the children's sleep cycle and "turn on" their day cycle. For "normal" study and learning activity times, color temperatures are set between 5000- to 6500K. The light level can be doubled for literacy instructions. After recess and during rest time, classrooms are set to 2700K for a calming effect. Results, so far, have demonstrated increased academic performance.

These specific studies were done using various CCT fluorescent lamps in each fixture and dimming ballasts, which works well. Philips is also developing similar solutions using LED systems. The issue is color rendering toward the 12,000K range. That said, the "bright side" of LEDs, opposed to fluorescent, is that the former can maintain or increase lumens per watt when dimmed, as long as the drivers maintain a good power factor when dimmed. Drivers that minimize flicker can be very important during dimming. Changing CCTs with LEDs is easy with either RGB or low and high Kelvin white LEDs, when dimming one more than the other.

Researching this topic resulted in a recent trip to South Korea, and visits to manufacturers Galaxia and Prism, who currently offer dimmable and color-shifting LED fixtures in the range of 3000 to 6500K. The Galaxia Smart LED troffer, and Prism's TL-4400 non-Kelvin-shifting task light—distributed in the United States by PlanLED—were acknowledged by the Next Generation Luminaires Design Competition, and this was before dimming and Kelvin shifting models were introduced. Also at Lightfair, Lighting Science

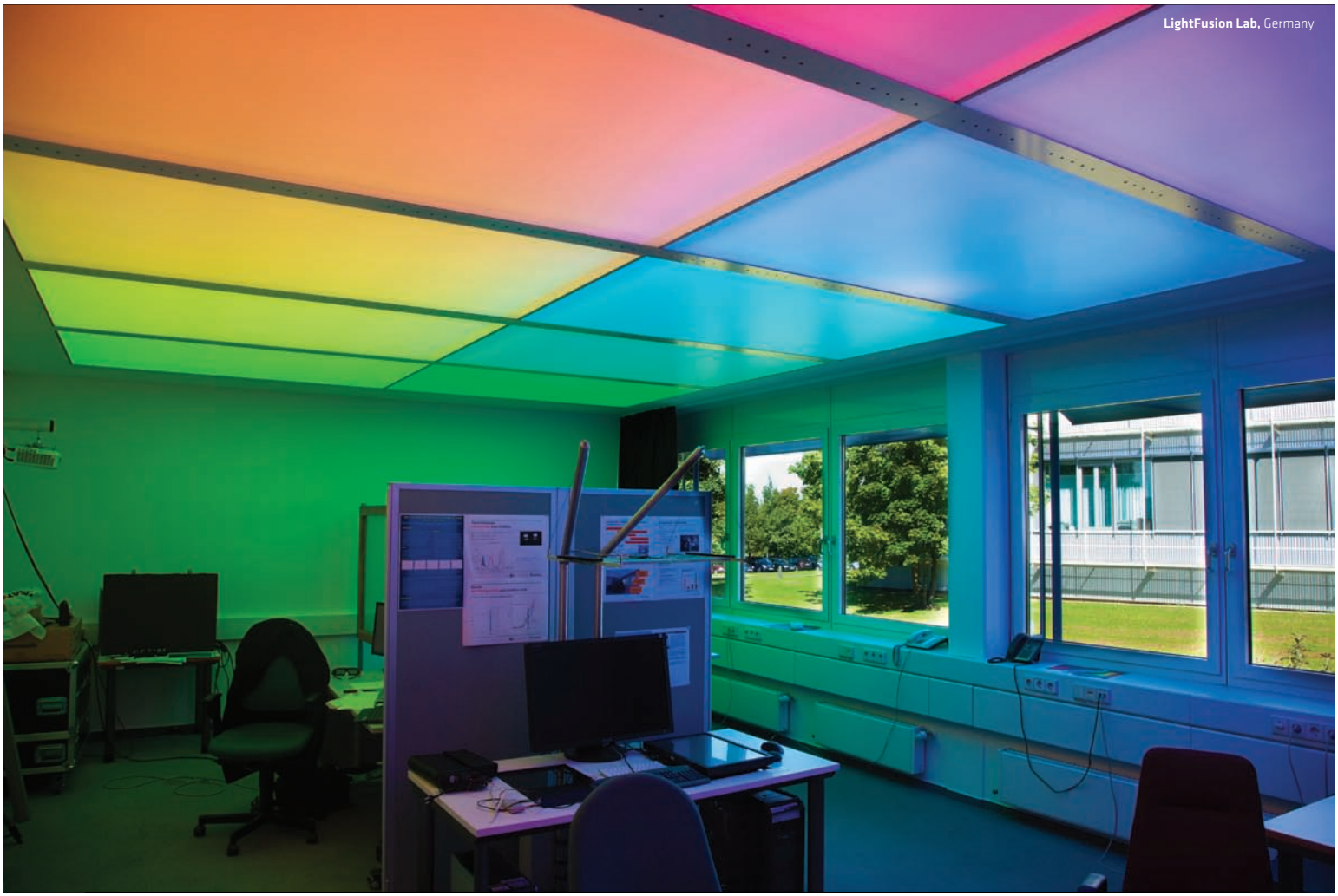
◁ FOCAL POINT
As the Venn diagram above notes, beyond building performance, lighting is at the core of many elements that affect human physiology and performance.

Scores Support Study

Elementary school students performed better in oral reading fluency achievement, a key component of reading comprehension, when exposed to a higher quality of classroom light, according to a study by Philips and the University of Mississippi. The study, "The Relationship of Dynamic Lighting and Oral Reading Fluency," was conducted by the university's Center of Excellence in Literacy Instruction using the Philips SchoolVision dynamic lighting system for the classroom.

Eighty-four 3rd grade children in four different classrooms at Saltillo Elementary School, near Tupelo, were randomly assigned to two different lighting settings throughout the year. Students exposed to lighting with higher light intensity and light temperature levels had, by the end of the year, increases in performance that were 33% higher than the increases in performance of the control group. "Light settings vary greatly in classrooms, and the results of this study raise important questions on how lighting is selected for optimizing teaching and learning," says Michael Mott with the University of Mississippi.

The system adjusts light and color temperature to mimic the dynamics of daylight, influencing a student's mood and helping to improve the learning environment. The system features preset lighting levels for various classroom situations and activities. The research built on other recent studies and the findings were similar to results released earlier this year by the Centre for Performance at Work at City University London.
For more, visit www.philips.com/schoolvision.



ANIMATED ENVIRONMENT

At the LightFusion Lab in Germany, the company is using Fraunhofer's Virtual Sky system to create a dynamic environment. Not only can the system create color, it can also replicate a blue sky effect–clouds included–or a simple white light luminous environment. Photo: Steve Krappitz

Group, Lumentix and Global Lighting Technologies featured similar offerings. Other manufacturers may already have or will probably offer similar fixtures. Dimming and Kelvin shifting hard-wired LED troffer kits are also being developed. Why is this important? Imagine coming back from lunch and feeling groggy. Instead of drinking coffee or some other caffeine stimulant, it may work to simply increase a fixture's CCT and light level. Such "tuning" could be accomplished every day and controlled in an office, hospital or home setting to match the CCT outside the building throughout most of the day, which may help keep proper internal clock alignment.

Conversely, the intensity and color temperature of any lighting-related product must be considered. Why? Many people have a hard time going to sleep at night. Why? One culprit may be computers and pads that are used up to three hours before going to bed. Most of these devices are relatively bright and have high content of blue light. Red light at night can be better. Some hospital ICU halls and nurse stations have red or amber light at night for this reason.

Mood Setting

Beyond energy levels in people, lighting is being studied as to how it affects people's moods. It's been shown, especially in medical settings such as MRI chambers, that nature scenes can help people feel less nervous. On the lighting side, several companies use films over fluorescent troffers to create such scenes. The problem is that not enough light gets through such

△ **HIGH TECH**

The Virtual Sky System consists of 50-cm. square panels each with 288 RGBW LEDs so it can create more than 16 million hues. A matte film diffuses the light and hides the individual LED pixels.

films and lenses, so a relatively high wattage is necessary. LED is probably a better source for such applications.

But much more impressive is Fraunhofer's virtual sky system which uses RGB LEDs to create very dramatic, and certainly dynamic, spaces, be it "blue sky" or some variation of color. Hopefully, the roughly $1,000-per-sq.-yd. price will come down in the not-so-distant future.

Productivity Gains?

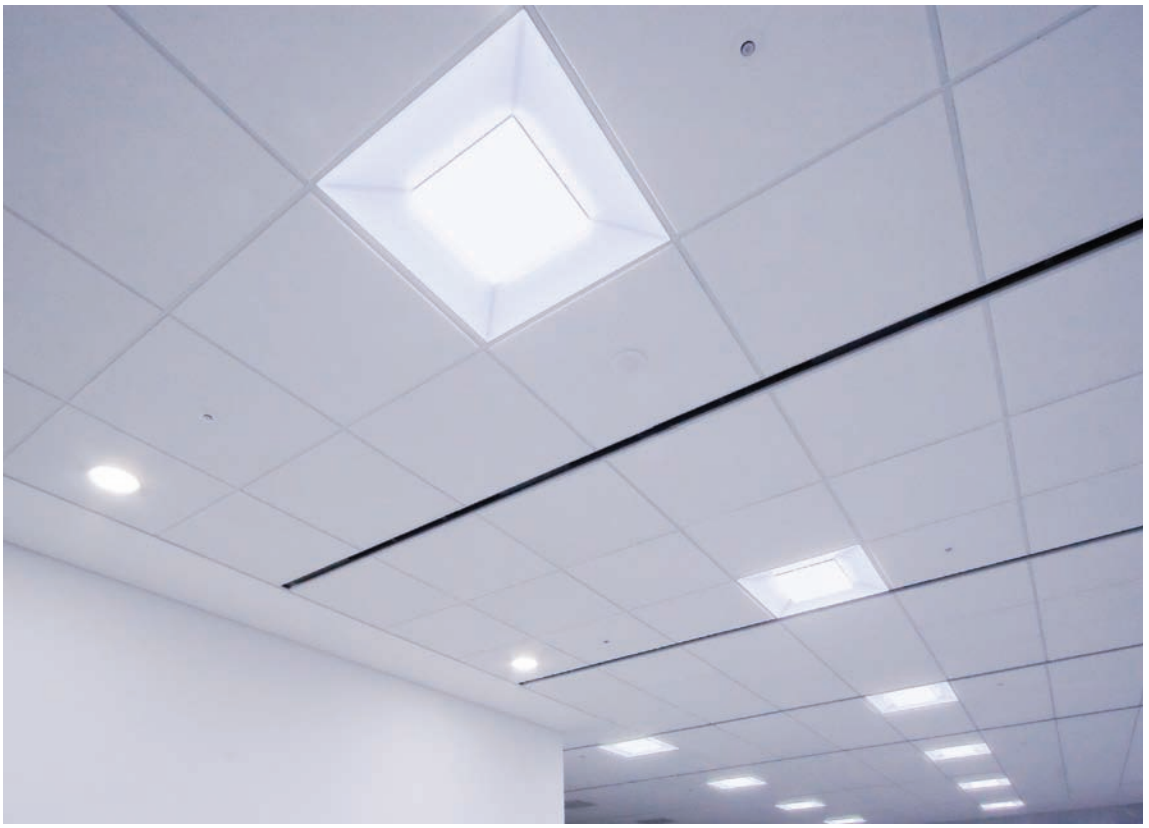
All of these technological advancement may help improve worker productivity. Granted, metrics for such improvements are difficult to evaluate, but just reducing 5 minutes of wasted time per day—say 1% of an eight-hour shift—could translate to a $500 savings per person per year for somebody making an annual $50,000. Such annual savings dwarf installed cost, electrical savings, maintenance savings and rebates.

Savings & Sustainability

On the subject of power savings, where do dimmable and Kelvin-shifting LED fixtures rate? Watts per sq. ft. can be low, especially when paired with similar task lights. Offices can have 0.4 watts per sq. ft., including both ambient and task lights.

Some of the dimming and Kelvin-shifting LED products cost about the same as their dimming and fixed-Kelvin equivalents. But there is an additional cost for local controls and labor. With such low power density and electric bills, complex and building wide controls are often not cost effective.

With such a low carbon footprint and no mercury, these LED fixtures are quite sustainable. That said, DOE has yet to determined if LEDs are more environmental friendly or cradle-to-cradle than incumbent technologies.



AWARD WINNER

Galaxia Electronic's tunable Smart LED troffer was a "recognized" Next Generation Lighting Awards winner at Lightfair. The dimmable fixture has a Kelvin-shifting range of 3000 to 6500K.

Photo courtesy: PlanLED/Galaxia Electronics

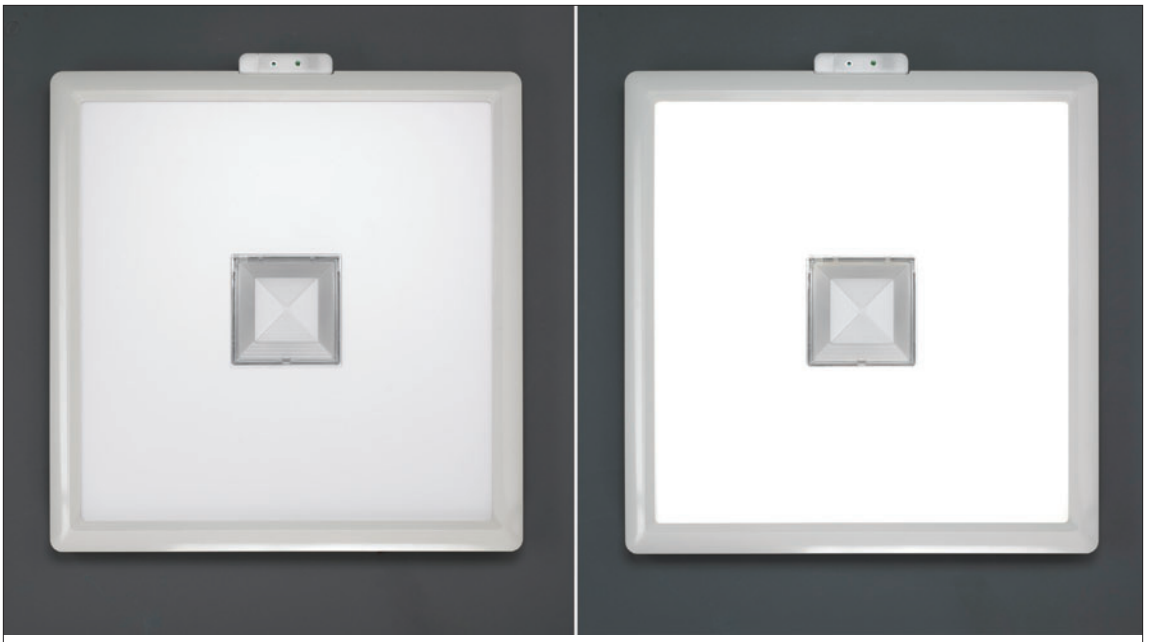
Visual Acuity

Beyond the way people feel or react based on color temperature and intensity, lighting, perhaps most significantly, affects visual acuity. Light sources that have relatively higher amounts of blue light stimulate the ipRGC photoreceptors, which in turn make the pupils of the eye smaller; this results in better visual acuity so a person can see more clearly under otherwise identical lighting conditions and measured photopic footcandle levels. The correlation of lamp spectral distribution and pupil size can be described by the scotopic/photopic (S/P) ratio of the lamp, and higher S/P values indicate more blue in the light spectrum. In general, the relative amount of blue light in a light source is also correlated with the CCT rating, although there are variations among lamp types. To illustrate this idea, consider being able to read one smaller row of letters on your eye doctor's Snellen chart. This could be accomplished with a 5000K fixture compared to 3500K fluorescent lighting under the same conditions.

The term used to describe using spectrum in lighting design to affect visual acuity is spectrally enhanced lighting. It can either improve visual acuity using the same light levels, or can be used to reduce the light level while maintaining the visual acuity, which is

△ **SMART COOKIE**

The Smart LED troffer has a CRI of 88.7, consumes 43 watts with an efficacy of 91.30 lm. per watt, and an overall light output of 3926 lumens according to NGL data. Photo courtesy: PlanLED/Galaxia



TUNABLE. At Lightfair, Global Lighting Technologies demonstrated a tunable white LED fixture it's developed in conjunction with Toshiba in Japan. It's not only dimmable, but it can be color-tuned as half the LEDs in the fixture are 2700K, and the other half are 6000K.

used to save energy. For example, in many applications 5000K can save about 20% more energy than equivalent 3500K. LEDs may add more versatility to this, since they have the ability to fine-tune the spectrum to activate the ipRGC photoreceptors even if warmer CCTs are prescribed.

The Dept. of Energy has performed significant research on spectrally enhanced lighting since 1986. Many of these initiatives were done under the direction Brian Liebel, with whom this author has assisted since 2001. Recently, Rod Heller joined the effort and has been installing a relatively new fluorescent lamp with a CCT of 8000K. His research has shown that high CCT lighting is not only spectrally enhanced, but may also be good for circadian rhythms during work.

For example, in a computer-intensive environment at an insurance company, ambient light levels were lowered to 15 fc using 8000K lamps. Employees have noted they're able to see better, are not as tired at the end of the day, and sleep better at night.

Similarly, in a manufacturing operation, 8000K lamps were installed in a small area of the plant to test against the existing 5000K lamps. Employee preference for the 8000K lamps was so positive that the entire plant is being relamped. One major reason, beyond similar comments at the insurance office, was the fact that it became easier to see defects. In fact, the manufacturer's ISO 9000 inspector gave them high marks for their lighting based on visual acuity.

A colleague has specified at 5000K or higher CCT fluorescent lighting for many military and retrofit projects. Numerous other lighting professionals have done the same. Many lighting contractors, after having initial doubts, have also changed to the 5000K lamps as a standard once they have experienced the occupant satisfaction benefits and energy savings themselves.

One of the biggest questions on the use of spectrally enhanced lighting has been the acceptance of the calculation method by the Illuminating Engineering Society. As of this writing, the IES Visual Effects of Lamp Spectral Effects Committee, which has spent three years investigating how spectrum affects vision for interior lighting, has written a technical memorandum that has gone through several preliminary reviews, and is currently in its final review.

This is not to say such a publication will translate to universal acceptance of the benefits of spectrally enhanced lighting; some say that the research and case studies have had a Hawthorne Effect—where respondents modify their behavior simply because they know they're being studied. Others are also skeptical that smaller pupil size results in better visual acuity; some defer to alternative research that did not provide for the proper study controls; and still others "just don't like it." However, the overwhelming body of evidence is that the benefits of spectrally enhanced lighting are real and significant.

So where does LED come in? To date, all of the DOE research and case studies on spectrally enhanced lighting have been done with 5000K fluorescent lamps. We have observed that 4000K LED often looks more like 5000K fluorescent, which may be due to higher S/P ratios of LEDs vs. fluorescent lamps of the same CCT. The S/P values of light sources give an approximate value for the relative amount of blue light energy in a light source and correlate well with the ipRGC photoreceptors. S/P values for LED light sources will have to be determined in order to assess their ability to affect visual acuity.

Editor's Note:

Brian Liebel, PE, principal of the Lighting Partnership; and Rodney Heller, CLEP, LC, managing partner of Energy Performance Lighting, contributed to this piece. Liebel is the principal investigator for DOE's Spectrally Enhanced Lighting Program. Heller is the chair of the IES "Guidelines for Upgrading Lighting in Commercial and Institutional Spaces."

Video Links:

Healwell system:
www.newscenter.philips.com/main/standard/news/press/2011/20111122-healwell.wpd

Schoolvision:
www.youtube.com/watch?v=3lfc1y8q5l4&feature=related

www.wtva.com/content/mediacenter/default.aspx?videoId=6673@wtva.web.entriq.net&navCatId=17

Galaxia/Prism tunable fixtures:
www.youtube.com/watch?v=0PaKuOeuMg8

www.youtube.com/watch?v=8ccaNHv3f2o

www.youtube.com/watch?v=XMM66hdD168

DOE Research
www1.eere.energy.gov/buildings/spectrally_enhanced.html

Fraunhofer's Virtual Sky System
www.fastcoexist.com/1679095/can-natural-light-make-employees-more-productive