Photo 1: LEDs can be designed to mimic skylights or windows. Photo ©The Sky Factory, Community North Hospital, Indianapolis
Photo 2: LEDs can be color tuned to maximize plant growth for indoor agriculture. Photo courtesy of GE Lighting

What's Next for Solid-State Lighting?

James Brodrick, U.S. Department of Energy

As we stand on the brink of a lighting revolution spearheaded by light-emitting diode (LED) technology, one question on everyone's minds is: what's next for solid-state lighting (SSL)? Formerly just an intriguing possibility, SSL has come so far so fast that its U.S. market share had already reached three percent in 2013—and that share is rapidly rising, as performance continues to improve across multiple characteristics while prices continue to drop.

What has people even more excited are the ways SSL is being used for purposes beyond traditional illumination.

That was a hot topic at the U.S. Department of Energy's (DOE) ninth annual SSL Market Development Workshop, which was held in Detroit a few months ago. Many of the speakers emphasized that, thanks in large part to SSL, we're beginning to regard lighting not merely as a source of illumination, but rather as a multifunction device we can use to improve our mood, health, productivity, and much more.

In a panel on that topic, Steven Lockley, PhD, of Harvard University, explained that light exerts a powerful effect on our bodies, mainly through special nonvisual cells in the eye that are particularly sensitive to light in the blue range (at a peak of 480 nm) and that play a major part in regulating our circadian rhythm. LED lighting has an advantage over other lighting technologies in this regard, because it's easily color-tunable and dimmable—which is why it may be more effective at regulating the sleep cycle, combating seasonal affective disorder, and mitigating jet lag.

Dr. Lockley's fellow panelists—lighting consultant John Hwang of Planled and lighting designer Leslie North of Aurora Lighting Design—discussed how this spectral tuning can be used to benefit specific populations, such as hospital patients and professional athletes, while others in Detroit mentioned other potential uses ranging from improving productivity in the workplace and classroom, to facilitating the growing of crops and the breeding of livestock.

Another hot topic in Detroit was the advent of "smart lighting," a aspect of which involves the pairing of SSL with automated controls that adjust the light level based on actual conditions. Such functionality is becoming increasingly common, both because of the added energy savings it brings and because SSL has the potential to be more controllable than other lighting technologies.

But smart lighting also has the potential to go well beyond energy savings. According to workshop speaker Partha Dutta of Rensselaer Polytechnic Institute's Smart Lighting Engineering Research Center, it could also interface with building management systems, transmit high-speed wireless data, fine-tune occupancy and functional sensing, and make us healthier and more productive.

We're Not There Yet

These visions of the future are intriguing and enticing, but we're not there yet. Lighting control systems have long suffered from the assumption that they are simply "plug and play." While SSL-based systems hold the potential to be "smarter" than earlier lighting controls systems, good system design and planning will remain critical to success.

If insufficient time and attention are given to the installation, startup, or commissioning needs of the chosen lighting devices, many systems will not meet user expectations and may not function optimally. The integration of intelligence and even sensors directly into luminaires is reducing, but not eliminating, some of the historical design and planning needs, and the automation they provide has performance limitations.

The increased sophistication of these future lighting systems will change the paradigm for how we design, install, and maintain them, but there are other factors that could prevent them from achieving their full potential. The application of new SSL and/or lighting control technology to existing lighting infrastructure continues to present challenges related to compatibility, interoperability, and interchangeability among lighting system components.

All of the following assumptions need to be checked when applying new technology:

- devices are compatible with existing infrastructure,
- devices from different manufacturers that need to work together (e.g., to exchange data) are indeed sufficiently interoperable, and
- devices that seem to perform the same function and even have similar specifications are, in fact, interchangeable.

The frustration caused by these challenges can lead to significant market adoption barriers. For example, the compatibility issues that many LED integral lamps have with the installed base of phase-cut dimmers has led some early adopters to mistrust the dimmability claims of these products.

Interoperability—Key to Smart Lighting

Interoperability, in particular, is crucial to enabling smart lighting and realizing the full potential of SSL technology.

At present, most lighting control systems use proprietary hardware and/or software, thereby requiring the potential user to make a substantial investment in products from a single vendor, which then locks them in for future purchases. The user must continue to buy from that same vendor to ensure that new system components work well with those purchased previously. This lack of interoperability increases user risk when considering new installations, especially in instances where user needs are not fully understood at the time of specification or are likely to change over time. If the chosen vendor cannot support changing needs, the user may be faced with the decision to start over from scratch or live with an existing, increasingly unsuitable system.

Many lighting controls are marketed as complying with one or more standards. However, lighting specifiers and users often do not fully understand what some of these standards ensure. For example, the 0-10V standard[1] does not specify when, or even whether, a luminaire should turn off; as a result, when two luminaires are presented with the same control signal, one may turn off, while the other may go to a low lighting level. Similarly, the DALI standard[2] has not historically required compliance testing, leading to different manufacturers developing different "versions" of DALI products, which are often not interoperable.

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Efforts to bring more interoperability to the lighting control market are already underway within the ZigBee Alliance, LonMark International, the TALQ Consortium, the Connected Lighting Alliance, and others. While interoperability may be perceived to be less important for relatively small, self-contained lighting systems (e.g., those servicing a single conference room or even building floor), the challenges promise to increase over time as more systems become interconnected in support of net-zero building, smart-city, smart-grid, and intelligent transportation initiatives.

With LED lighting systems and luminaires evolving into multifunction devices more akin to computers than lights, it's important that we make sure the quality of the light doesn't suffer. The same goes for the energy savings. DOE estimates that by 2030, SSL could cut national lighting electricity use nearly in half, which would save 3,000 trillion Btus a year, compared to 188 trillion Btus saved as a result of LED adoption in 2013. These numbers don't even include the effect of increased use of controls.

Tradeoffs are not necessary; we can have the energy savings of SSL as well as its other benefits, but only if we work together now to address the key issues.

Mr. Brodrick is the lighting program manager for the U.S. Department of Energy, Building Technologies Program.

[1] 0-10V dimming interface for LED

[2] DALI is a worldwide standard, specified by the International Electrotechnical Commission (IEC). DALI protocol is set out in IEC 62386.