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TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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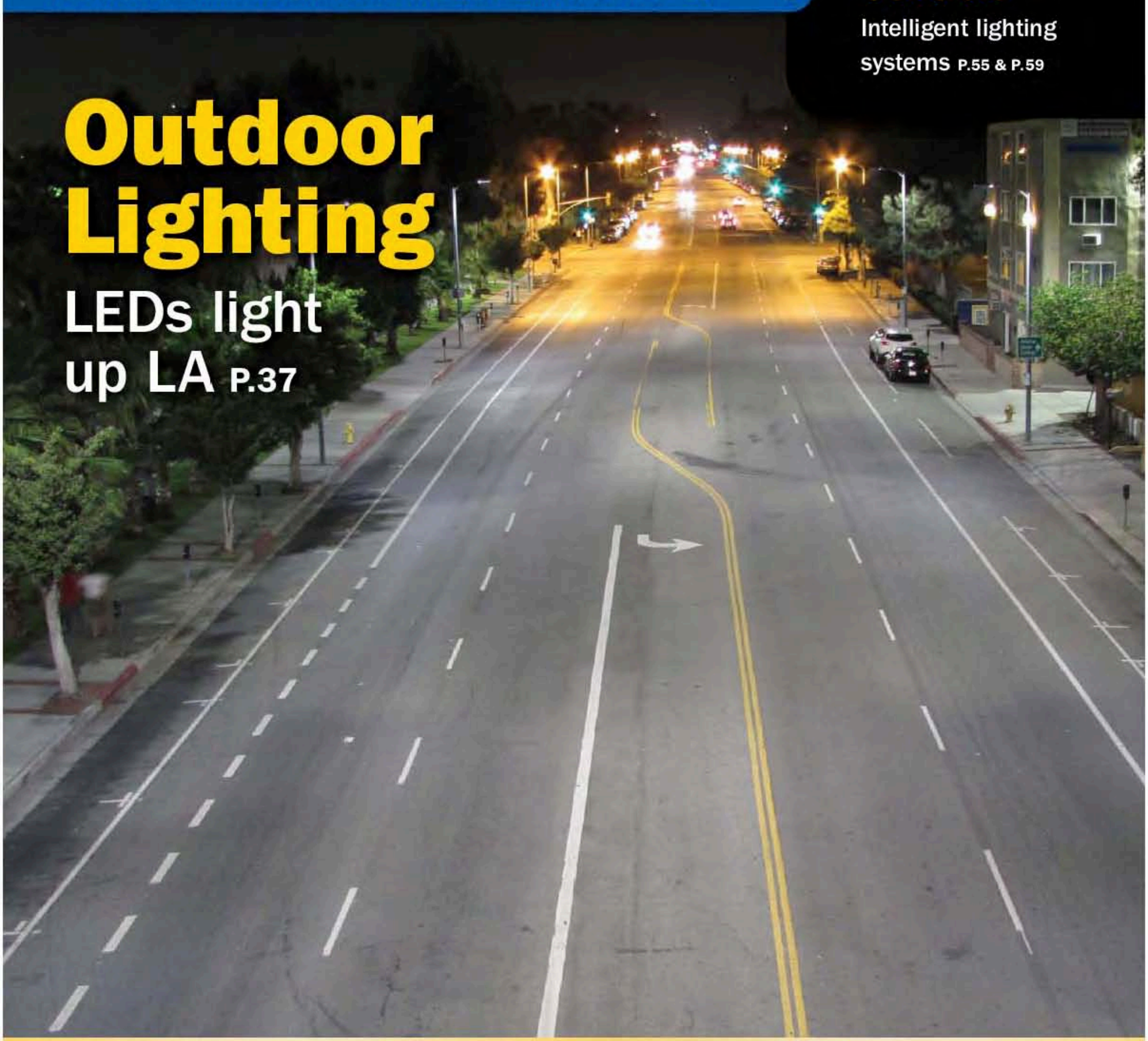

LED momentum builds at annual Street and Area Lighting Conference

Presentations at the IES Street and Area Lighting Conference were predominantly centered on LEDs, and there were first-hand opportunities to view SSL installations, reports **MAURY WRIGHT.**

In late September, the Illuminating Engineering Society (IES) held the annual Street and Area Lighting Conference (SALC) in Huntington Beach, California with a crowd of more than 600 attendees focused increasingly on LED-based street lights. Attendees from utilities, municipalities, lighting manufacturers, and design houses shared information on how to successfully migrate to energy-saving SSL technology. Moreover, the presentations made it increasingly clear that SSL can deliver superior lighting despite obstacles that still must be overcome.

The most compelling presentations at SALC were all focused on actual LED street light installations. Californian cities including Huntington Beach, Los Angeles and San Jose made presentations, and we'll get into some of that detail shortly. Moreover, both the Electric Power Research Institute (EPRI) and the Climate Group's LightSavers Global Consortium presented trial data. The exhibits at SALC are limited by the IES to a relatively small area, but LEDs also dominated that space.

The Los Angeles LED project

Following SALC, the US Department of Energy (DOE) took advantage of the crowd in town for SALC week to hold the first workshop of the DOE Municipal Solid-State Street Lighting Consortium. The City of Los Angeles Bureau of Street Lighting hosted the workshop. On Thursday night prior to the workshop, Bureau Director Ed Ebrahimian hosted a tour of some Los Angeles LED installations for a bus full of representatives from municipalities involved in LightSavers and selected media representatives.

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FIG. 1. **HPS street lights on Hoover Street in Los Angeles near the University of Southern California campus leaves dark areas along the major street.**

Let's start our dive into SALC week details with the Los Angeles project, which is the largest LED street-light project in the world. The city has around 210,000 street lights and plans to retrofit 140,000 with LEDs – ultimately all of the standard cobra-head lights. As Ebrahimian explained, the Bureau has already installed more than 20,000 LED street lights.

Prior to the start of the LED project, Los Angeles used 190 million kWh per year to power its street lights at a cost of $17 million annually. According to Ebrahimian, the city's goals include 40% energy savings and a reduction in maintenance costs. When the 140,000-fixture program is complete, the Bureau expects to save $10 million annually, comprising $7.5 million in energy and $2.5 million in maintenance. Moreover the project will reduce carbon emissions by 40,500 tons.

Ebrahimian's team has developed a comprehensive specification to guide purchases of LED luminaires (the specification is available at http://bsl.lacity.org). Key specifications include 4300K color temperature, 6-year warranty, 70% of initial lumen output at 50,000 hours, and 40% energy savings.

Energy and cost savings

The program has already yielded some data that indicates the energy savings are achievable and that installation costs are coming down. With 20,000 units installed, the LEDs are actually delivering an energy saving of 55%, as opposed to the projected 40%.

Ebrahimian also discussed the cost of the retrofits. Los Angeles is currently paying just under $500 per installed LED street light. The materials, including the luminaire, make up the bulk of the cost, coming in at $423. Engi-

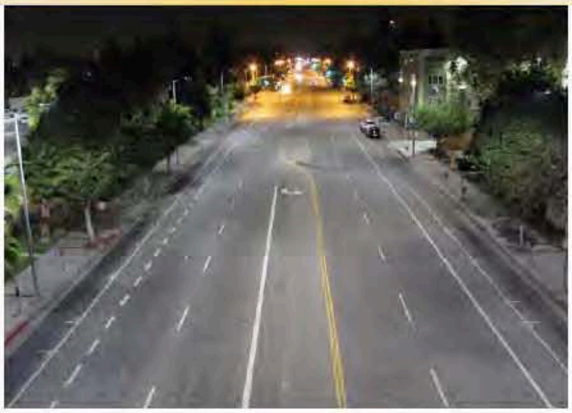

FIG. 2. The LED retrofit on Hoover Street delivers more uniform light and better visibility.

neering adds $30 and labor adds $43.

The Los Angeles Bureau has its own engineering and installation crews. The Bureau had expected that crews could each handle 20 retrofits per day, but in actuality each crew is managing 30. The Bureau had originally projected a seven-year payback period. Now Ebrahimian expects the payback to drop to six years or less based on increased energy savings and declining installation cost due both to the efficient crews and to steadily-declining SSL fixture prices.

Note also that the Los Angeles installation exclusively uses luminaires equipped with ROAM network connectivity for remote monitoring. The remote monitoring should add to maintenance savings because the Bureau can easily detect failed luminaires; however, the City has yet to experience failure of an LED luminaire. Moreover, the city plans to move to dimmable luminaires in the future, which could also multiply the energy savings.

Ebrahimian also presented positive data points about the light quality in the LED installations. The Bureau had expected some negative feedback from the community, but most has been very positive. The LED luminaires are delivering more uniform illumination, and Ebrahimian referred to the results as the "carpeted effect" where very few dark spots are seen on the street. The before and after photos of the installation in Hoover Street in Los Angeles (Fig. 1 and Fig. 2) show the lack of uniformity with the previously-used HPS lights. Moreover, the tour Ebrahimian hosted after SALC seemed to confirm, to the naked eye, claims about superior visibility and uniformity in LED-lit areas.

There was one other point of feedback that's not quantified but is impressive none the less. Ebrahimian was asked if the LED lighting had resulted in any measurable decrease in crime. He responded that he is planning to specifically study that angle going forward. But he reported that the officer in charge of Los Angeles police helicopters estimated a 5-fold improvement in visibility from the air.

Measured data counts

While some of the Los Angeles results include directly-measured data, Tom Geist, Senior Project Manager at EPRI, presented a precautionary tale of potential problems with SSL that emphasized the need to measure everything about a transition to SSL. Regarding SSL in street lighting, he said, "Show me the data verifying energy savings. Show me the data for [SSL] being equivalent or better lighting. Show me the data that LED street lights are reliable."

Geist's point is that the industry should have concrete answers to all of these points before moving to large-scale LED deployments. He detailed a number of concerns starting with the longevity of installed products. He points out that the first mercury-vapor street lights were installed in 1938, and that 13% are still installed according to the DOE. Geist said, "If LEDs are adopted they could be with us for a long time. The decisions we make now we will have to live with for a long time."

Geist has other concerns related to the driver electronics. He believes that the LED drivers being deployed today aren't as efficient as power supplies used in other products. For example, the power supplies being used in PCs today must be 92% efficient over the range of 10% to 100% loading. Yet EPRI evaluated LED drivers operating from 120V, 240V, and 277V inputs and found in each case that driver efficiency dropped considerably at light loads.

The issue here is that a key energy-saving attribute of SSL is the ability to dim the lights. But, according to the EPRI data, typical drivers are only around 70% efficient at 20% loads whereas efficiency approaches 90% near full load. The LED driver typically represents 10% of fixture energy usage. Geist sees drivers as wasting energy needlessly, and impacting the energy you might save by dimming the LEDs. Geist recommends "the use of specifications to force improved efficiency."

Geist sprung a few other surprises on the SALC audience. According to EPRI tests, LED fixtures require more power during the winter with colder ambient temperatures. He reported that some fixtures required more than 6% additional power in cold temperatures. Geist couldn't explain the cause, and cold ambient temperatures are generally considered a good thing for LED luminaires. Questioned after his presentation, Geist said that the LEDs may also be brighter in colder ambient environments.

The 480V AC supply that is used to power some street lights was a final obstacle noted by Geist. He stated that the autotransformer required to step-down the AC voltage to 277V increases fixture power consumption by just over 7%. Of course, street-light designs could move to a power supply designed to work at a higher line voltage and mitigate that power increase to some degree. Moreover, some street light installations already use a lower line voltage.

Scotty the EPRI rover

Despite the obstacles of which he warned, Geist ultimately presented positive results from some EPRI tests. EPRI is in the process of planning and conducting test installations at upwards of twenty US sites in collaboration with utilities. Some have already produced results and the agency is using an innovative remote-controlled vehicle called Scotty to gather the data (Fig. 3).

EPRI has modified and augmented a

FIG. 3. The EPRI Scotty remote-controlled rover can automate the measurement of light levels based on a virtual rectangular grid comprised of squares at street level.

Photo courtesy of Clanton & Associates

FIG. 4. **Small objects of different colors, shown here under low-pressure sodium lights, helped San Jose measure detection distance under various light types.**

model vehicle for the express purpose of measuring street-light performance. The rover is equipped with photopic and scotopic light sensors. Moreover the vehicle carries a differentially-augmented GPS receiver with accuracy at the centimeter level. And the vehicle has a Wi-Fi node and small computer system that takes light measurements and transmits them to a notebook computer.

EPRI deploys Scotty to automate the capture of measurements on a grid pattern at street level. Most of the tests to date have captured data in the center of each 5-foot-square element of a rectangular grid although the system could support 2-foot granularity. According to Geist, EPRI staff have to perform a 3-point calibration at a test site, and Scotty and the notebook computer automatically handle the remainder of the data gathering.

Geist presented data from a couple of test sites where Scotty has been deployed. In Reed Hook, New York, EPRI has a trial where a 147W LED fixture is replacing a 220W metal-halide luminaire. Based on data gathered by Scotty and measured energy usage, the LED fixture will yield 30% energy saving and what Geist termed "much improved lighting." And in this case the much improved lighting statement is based on the fully-characterized lighting grid evaluated for both types of light by EPRI software that processes the data gathered by Scotty.

When light levels lie

Of course not everyone is so sure that the street-lighting segment should be solely focused on light levels. Laura Stuchinsky, Sustainability Officer at the City of San Jose, and consultant Nancy Clanton of Clanton & Associates presented recent research that suggests that LEDs can be safely operated at lower light levels.

San Jose had trialed some LED street

lights previously and concluded that the economics of installing the lights wouldn't pay off unless the city could find a way to bolster savings beyond SSL efficiency and dimming. Specifically, San Jose conducted research into the effect of lowering light-output levels. Clanton had worked previously on trials in San Diego, California and Anchorage, Alaska and suspected that color temperature and spectrum issues might come into play. So San Jose pursued a new test that would compare existing low-pressure sodium (LPS) lights with 4000K induction lights, and 3500K, 4000K, and 5000K LED lights.

The trial included a detailed evaluation by volunteers based on an extensive list of questions. The respondents clearly disliked the LPS lights. San Jose had originally installed LPS to appease the nearby Lick Observatory. The volunteers greatly preferred the white or broad-spectrum LED lights with the warmest 3500K luminaire being the most preferred.

The evaluations were followed by tests conducted by Ronald Gibbons of the Virginia Tech Transportation Institute. Gibbons and his team equipped a car with a GPS system and meters for luminance and illuminance measurements. Volunteers that ride in the car have a push button to signal the data-gathering system when the volunteer spots a small-target test object. The test determines what is called the detection distance.

FIG. 5. The Kim street light mounts small groups of LEDs inside a MicroEmitter reflector module (inset) that directs light to a larger reflector to form the desired beam pattern.

Small object detection

The photo in Fig. 4 depicts the colored test objects under LPS lights. In the actual tests, the objects were located randomly along the test site. Gibbons' team verified that the tests were run under each light source at equivalent levels of light output.

The team conducted identical tests two consecutive nights. The first night all of the lights were operated at levels equivalent to the legacy LPS levels. The second night the light levels were reduced 50%.

The team graphed the results of detection distance relative to energy usage in watts per linear foot. The quick result summary is that the LED luminaires generally offered the greatest detection distances, with the spread of all tests in the 40 to 70 meter range. At the high-setting used the first night, the LPS lights used about 2.1 watts per linear foot while the LEDs came in around the 1.1 level.

The more significant results came the second night. The LEDs at 50% light level still afforded detection distance in the 60-meter neighborhood while the LPS distance dropped to 40 meters. Moreover, the energy consumption in the LED lights dropped to 0.5 watts per linear foot whereas the LPS figure remained over 2.0.

"We can detect objects at greater distances," stated Clanton. "The greater the spread in wavelengths, the better the detection." Clanton can't attribute the advantage of what she calls broad-spectrum light to a specific physiological effect for now, but she points out that Gibbons' team is doing further research.

Meanwhile San Jose hopes to use the findings to derive further energy savings with LEDs. Stuchinsky even described how San Jose will meet IES guidelines while dimming some lights. Some roadways that are considered high-capacity at rush hour are actually low-capacity later at night. So San Jose will used dimming technology to change the levels corresponding to different IES specifications at different hours. Clanton stated, "This opens the door to adaptive standards."

Utility LED tariffs

Still, Stuchinsky needs a break from the local utility to make SSL pay off. Today most utilities bill a fixed rate per street light that's calculated rather than measured. LED street lights with adaptive controls require cooperation by the utility to lower rates. Remote monitoring systems such as those being used in Los Angeles and San Jose can provide the metered power usage. But most utilities are moving slowly in developing new tariff levels.

Indeed, SALC included a "Utility LED Tariff Panel" on Tuesday morning with participation by We Energies of Milwaukee, WI; Pacific Gas & Electric (PG&E) headquartered in San Francisco, CA; DTE Energy of Detroit, MI; and Puget Sound Energy of Bellevue, WA.

Generally the panelists conceded that utilities are lagging behind the technology when it comes to tariffs for LEDs. PG&E presented by far the most proactive data but noted that there is no standardization among LED fixture types and the energy used. The utility for now is maintaining fixed-rate billing with new tariff levels created at 5W incre-

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ments. Clearly, however, the best answer going forward is remote metering.

There was also a presentation on incentives available to organizations that install SSL in street-lights and other lighting applications. Tom Coughlin, Program Manager of Energy Products for National Grid (a New England utility) described how taxpayer-funded energy-efficiency programs work. Moreover he discussed organizations such as the Design Lights Consortium that National Grid uses to gauge whether an SSL product qualifies for purchase incentives. For example, the utility offers $100 to $150 rebates for SSL luminaires purchased for deployment in parking garages.

Coughlin also discussed some experiences with SSL gathered in the field and how luminaires perform to their specifications. That led to an audience question on driver reliability and whether the driver should be covered under warranty. About failed drivers, Coughlin said, "We assume it will get replaced just like a ballast."

Street-light luminaire update

There was little new in the exhibit hall given that several major lighting trade shows took place recently. However, we did see a street-light design from Kim Lighting (a Hubbell Lighting Company) that we didn't mention in our recent story on street-light beam patterns (www.ledsmagazine.com/features/7/9/8). The Kim design (Fig. 5) mounts small groups of LEDs inside a reflector module that the company calls a MicroEmitter. The modules direct light at additional reflective surfaces to form the beam pattern. It's tough to judge the effectiveness of a design on an exhibit floor, but surely the Kim design has a thermal advantage with each MicroEmitter being bolted to aluminum and also serving as a heat sink.

Discussions at the conference would indicate that there is still much debate as to which luminaire designs work best. Los Angeles is currently installing BetaLED and Leotek luminaires. But Ebrahimian points out that the Bureau will continue to evaluate the latest products, and is looking for superior performance and low price. According to Ebrahimian, his team currently is in a third round of such evaluations, examining six new luminaires. Judging from the products being tested during a brief lab tour, both Kim and General Electric luminaires are part of the new evaluation, presumably alongside the incumbents and two others.

LINKS

Additional coverage of SALC on our website:
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