

Second e-guide in a series • December 2014

# LED Lighting Technology Ushers in a New Age

From specialized to commonplace usage, the journey of LED continues to improve and evolve while remaining well within the grasp of budget-conscious specifiers and end users.



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# LED Lighting Technology Ushers in a New Age

From specialized to commonplace usage, the journey of LED continues to improve and evolve while remaining well within the grasp of budget-conscious specifiers and end users

Celebration Church, Jacksonville, Fla, lighting designed and installed by Wave.

*Image courtesy of Chroma-Q, distributed in North America by A.C. Lighting.*

## By Christian Doering

LEDs (Light Emitting Diodes) are taking over all kinds of lighting tasks, from portable flashlights to San Francisco's Bay Bridge, currently the world's largest light sculpture with 25,000 LEDs. More and more churches are using LEDs for both theatrical lighting and architectural applications, both interior and exterior. However it's deployed, LED technology offers more creative options than halogen or other incandescent lamps, and is cheaper to operate. For new construction, there's no going back: the savings on electrical and HVAC infrastructure systems, and the ongoing operational cost savings, are too compelling. Retrofits are more complicated: LEDs do cost more

up front than halogens, especially the ones you already own. In addition, you might have to throw out your dimmer racks and replace them with a DMX control system (LED manufacturers have started to address this problem). How fast will savings on power bills (in some cases, sweetened by rebates from the power company), maintenance, lamp replacement and labor allow you to recoup your initial investment? Time to get out your spreadsheet—many LED vendors are ready to help you do the math.

### LED Technology

Of course you know that LED stands for Light Emitting Diode, but what do those

words mean? Let's start with the Diode, a silicon crystal that's been split into two semiconductors. On the N-type side, impurities have been mixed into the silicon in order to add free electrons (which have a negative charge, hence the N). The other side is a P-type, with different impurities that create positively charged "holes" for free electrons to flow into. That's your diode. In Light Emitting Diodes, when an electron from the N side falls into a hole on the P side, one or more photons are emitted. Applying electrical current to an LED creates a steady flow of electrons from the N side to the P side and a corresponding steady output of photons: light.

This phenomenon has become so important that the 2014 Nobel Prize in Physics was awarded to three scientists who invented blue LEDs. Among other things, their invention enabled the production of color-mixing RGB LED luminaires. LEDs are efficient, needing fewer watts per lumen than either incandescent or fluorescent lamps. Incandescents produce light when electrical current heats a filament sealed inside a gas-filled bulb: the process uses lots of power and produces plenty of heat along with the light. Fluorescent lamps use electrical voltage (not current) to excite phosphors inside a vacuum: more efficient, but not as bright, and typically flickering at the same frequency as the AC line that they're plugged into. Also, fluorescent phosphors don't produce the full spectrum of visible light.

LEDs are a disruptive technology: when they appeared on the scene they were dim and expensive. Now they're very bright, and still expensive compared to incandescents or fluorescents, at least until you compare operating costs over the useful lifespan. But the cost/performance ratio continues to improve, and there are even more applications on the horizon: a team of researchers at Edinburgh University has developed a way to

use LEDs for wireless Ethernet transmission. LiFi could soon be faster than WiFi, and as easy to install as screwing in a light bulb.

In fact, LED technology is evolving so rapidly that products can double efficiency in as little as three months, according to Mark De Lorenzo of Osram Sylvania. "At the moment," he reports, "the lumens-per-watt ratio with LEDs is about 25%. With halogen lighting, it's between 7% and 12%."

### Energy Management and Creation Care

"There are so many benefits to choosing LED for house lighting and theatrical lighting applications," says A.C. Lighting, Inc.'s Fred Mikeska, who also points out financial benefits of using LEDs. "In addition to the obvious savings in lower electrical use, infrastructure savings can also be substantial as LED systems allow for smaller mains power and HVAC systems when the facility is designed from the ground up around an LED-based lighting system."

Mikeska continues, "The savings from LED-based lighting solutions are not limited to new construction, however, as savings extend to retrofit systems, as well. Chroma-Q has developed an in-depth ROI calculator for prospective customers for both new-build and retrofit applications. By calculating the savings for a 10-year period, our ROI calculator makes it easy for church administrators to see the payback period and savings over 10 years. With power company rebates, customers can see payback in as little as one year. In addition to providing creative worship teams with the ability to seamlessly transform the look and feel of their worship space through the use of color and light, LED-based lighting systems help to reduce the carbon footprint of the facility."

"ETC's website includes information on how to find power company rebate programs, as well as data on how much energy can be





# Shine an inspirational light in your sanctuary

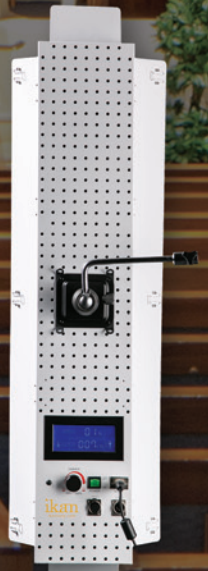


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The LED theatrical lighting reduced power use by **50%-90%**.

saved with LED lighting,” says ETC Architectural Product Manager Bryan Palmer.

Based on the box on the following page, we can see that for congregations of a similar size, a contemporary service could require significantly more cooling capacity than a traditional service.

The Department of Energy’s Gateway program compared LED and halogen incandescent lighting in both backstage and onstage applications in a recent study by the Pacific Northwest Laboratory at University of Florida’s School of Theatre and Dance. The study first monitored energy use over a performance season with previously installed

halogen luminaires. Then LED counterparts were chosen and installed, and the control systems were adapted for use with solid-state lighting. “The LED theatrical lighting reduced power use by 50%–90% in lighting cues that would otherwise employ conventional colored theatrical gels in halogen instruments,” the study concludes. “Audience visual impressions of the halogen and LED side-lighting were almost identical, although the lighting designers observed that skin tones may not be as naturalistic under some LED color selections.” To view or download the complete report, click on the link at the end of this white paper.

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## Common numbers used in HVAC calculations

**1 watt** is 3.41214 BTU/hr

**1 ton of cooling**, a common unit in North American refrigeration and air conditioning applications, is 12,000 BTU/hr (3.52 kW)

A resting seated person generates **350 BTU/hr of heat**

Light office work raises the personal output to **420 BTU/hr**

Light work done standing up produces about **640 BTU/hr**

Walking at 3 mph: **1,040 BTU/hr**

Strenuous athletic activity: **1,800 BTU/hr**

“Many cities and counties have energy codes that limit the amount of power that can be used within a particular space,” Philips’ Tom Stanziano points out. “Limiting wattage or amperage allows the HVAC to run more efficiently without excessive power demand during peak months. HVAC capacity is calculated in British Thermal Units (BTUs). When sizing an HVAC system, one must factor in the wattage drawn by the lighting system, the number of people the space can hold, and the activity level of the occupants.”

De Lorenzo points out: “Since theatrical lighting is legally defined as special-purpose lighting, it’s exempt from most environmental regulations.”

### Maintenance Costs

“Over time, the initial cost of LED lamps is offset by several kinds of savings,” says Stanziano. “These include lower power consumption and reduced maintenance and labor costs due to extended lamp life.”

De Lorenzo emphasizes, “Along with the light source, there are other components such as fans and converters that can require repair or replacement of a fixture.” As David Higgins of Pathway Connectivity explains, “An LED fixture is based on solid-state technology, which is far more complex than electro/mechanical ‘cans’ with a socket where an incandescent bulb is inserted and black, white and green wires come out the back. The LEDs, the PCB, the cooling technology and the power supply or driver are packaged together to make a luminaire. Actually, what wears out is the PCB assembly on which the LEDs are mounted.”

“Our luminaires are rated for an L70 of 50,000 hours,” says Mikeska, “but we have some installations that have been running for over 60,000 hours now without needing to replace their LEDs. Our engineers are careful never to overdrive the LED itself, and we concentrate on optimal thermal design to maximize lifespan and minimize color shift.”

Whereas the lifespan of incandescent lights such as halogens is typically measured in hundreds of hours, LEDs can last up to 100,000 hours. An LED’s life is usually specified as L70, the average time for a luminaire to lose 30% of the brightness it had when first turned on. Replacing conventional fixtures with LEDs should make climbing ladders or bringing in scaffolding a less frequent chore. But the Department of Energy (DOE), in its Solid State Lighting Fact Sheet, points out that useful lifespan and reliability (the rate of random failures among installed units) are not the same thing. Properly designed and manufactured products will have a short early failure or





“infant mortality” window so that defective items can be culled during “burn-in,” prior to shipping. During their long, useful life, well-designed and carefully built products will have a low rate of random failures. The useful life will be followed by a brief wearing-out period, enabling end-of-life planning and replacement. To view or download the DOE’s Fact Sheet, click on the link at the end of this white paper.

### Retrofitting Existing Facilities

“Control can be a bigger cost factor than power,” according to Palmer. “LEDs do use less power, but if the new luminaires require data for control, they won’t be compatible with existing dimming racks. That could require pulling new wire. Our GDS ArcSystem provides wireless control for LED luminaires, so houses of worship don’t have to add wiring when switching to LED lighting. Another cost-effective solution is to retrofit

dimmers with our Electronic Reverse-Phase Control Module, which provides reverse-phase, angle dimming of electronic transformer circuits such as LEDs.”

Chauvet Professional has also launched LED products that work with existing control systems, says Ben Dickmann. “To make things easier for venues that have been hesitant about jumping into LED, new fixtures in our Ovation Series are LED-powered, but will work on either a traditional dimming system or on newer constant-power and DMX systems.” The new ellipsoidal and Fresnel fixtures auto-sense the type of power they’re connected to.

### Evaluating ROI

“In the past, we would budget the lighting system components and electrical separately,” Stanziano reports. “That made the initial cost of the lighting system seem low. On a cost-per-fixture basis, incandescent





“The longer it takes to recoup the initial investment, the **higher the TCO.**” – Eric Loader, Sales Director, Elation Lighting

light is still cheaper. But we can no longer look at the electrical and lighting systems as two separate budget items, because both purchase and operating costs are so closely related. When viewed this way, initial purchase cost is slightly higher for LED, but long-term ROI outweighs the cost.”

Elation Sales Director Eric Loader recommends you look at Total Cost of Ownership (TCO). “The longer it takes to recoup the initial investment, the higher the TCO,” Loader says.

In De Lorenzo’s opinion, LED is more compelling in new construction projects where the energy and HVAC infrastructure can be designed from the ground up. “Because LEDs use significantly less energy, the cost of landing electrical power in the building goes down,” he points out. “LEDs typically run on line voltage, whereas halogen lights need dimming racks that are typically 400 Volt drops.”

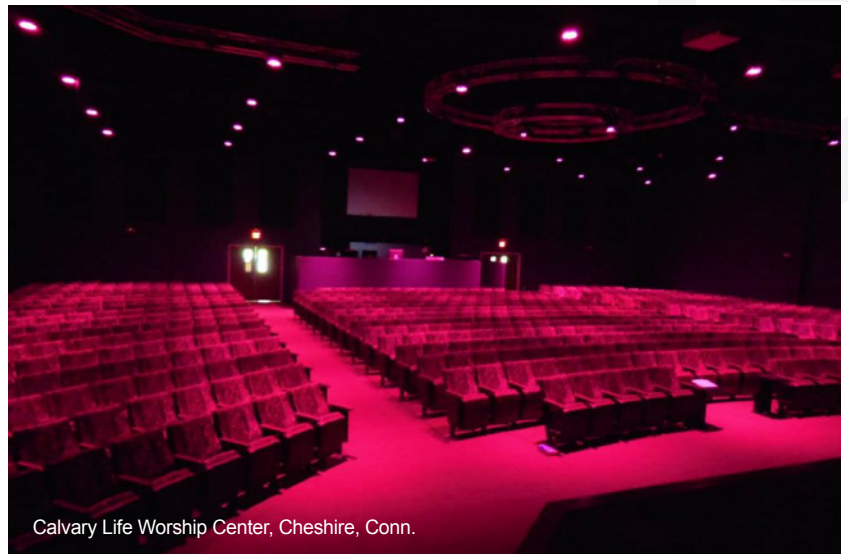
“Lighting designers and consultants always try to anticipate future growth,” reports Stanziano, “though sometimes it’s like looking into a crystal ball. Adding more power to a building at the correct location was always extremely costly, difficult, and sometimes impossible. Adding a significant number of lighting fixtures meant adding dimmer cabinets, which meant adding a larger transformer, which meant paying the city or county to bring in larger service from the street into the building. LEDs have changed the way we design for the future. Now, instead of trying to anticipate power consumption levels, we are trying to anticipate control channels (DMX universes) that may be needed.”

## THEATRICAL LIGHTING

Osram Sylvania continues to support a wide range of incandescent luminaires, says De Lorenzo of the company’s Display Optics Group. “It’s true LEDs offer lower operating costs,” he says. “But many of our customers don’t have the kind of capital budget that would allow them to upgrade. If all I’ve got is a maintenance budget, it doesn’t make sense to waste the whole thing on one or two LED fixtures.”

## Are LEDs More User-friendly for a New Volunteer?

“Yes and no,” according to Dave Higgins, founding partner of Pathway Connectivity. “Often, fewer lighting fixtures need to be installed, and there aren’t the issues of gel frame and replacement lamp logistics. However, there is a learning curve with LED color technology. Data wiring and luminaire addressing are now required, and traditional control consoles designed for dimmers are not appropriate for LEDs.”



Calvary Life Worship Center, Cheshire, Conn.

Image courtesy of Advanced Systems and Technology, Chicago, and Elation Professional.



“Yes and no,” echoes Dickmann. “Yes, because there are no lamps to replace, no gels or gobos to wear out after a couple of weeks, and no burning your hand by touching a fixture that’s been on more than 10 minutes. No, because most LED fixtures aren’t as simple as ‘plug in and move the fader.’ There are fixture personalities and DMX addressing to consider. For someone who’s new to lighting, but technically savvy, it shouldn’t be hard to pick up the basics of personality features like color mixing and programming. In terms of output, not only are LEDs generally more efficient, but red-shift is no longer a concern, and you will also not have to deal with changing color temperatures based on the age of the lamp in the fixture.”

“LED fixtures offer more creative options,” says Stanziano, “but that doesn’t necessarily make them user-friendly. Many LED products

have several control functions and multiple modes that unlock levels of functionality. Partly as a result, control consoles are becoming more sophisticated, which makes them harder to learn.”

“You can have up to 20 control channels on an LED,” De Lorenzo points out. “And you have to know DMX in order to use these lights properly.”

### How Close to Incandescent Can LED Get?

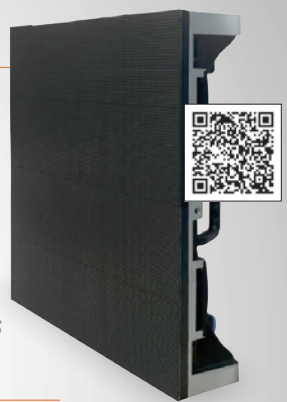
That depends partly on what kind of ruler you’re using to measure the distance. The traditional measurement for lighting color is the Color Rendering Index, or CRI. It measures ability of a fixture to generate light that matches each of eight pastel shades. “CRI is widely used,” says De Lorenzo, “and the best LEDs are now scoring



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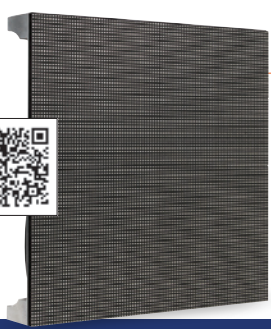
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Over the past five years we have seen LED products get very close to mimicking the color of the incandescent lamp, but LEDs are **still not quite bright enough.**” – Tom Stanziano, Mid-Atlantic Southeast Regional Manager, Philips Entertainment

in the 90s. But even some very high-CRI LEDs don't look good on all skin tones. A year ago, LEDs weren't very close to incandescent. But now with the addition of phosphors to blue LEDs, we're seeing some very true whites.”

“We have focused very strongly on color consistency [from] fixture to fixture, and consistent calibration from batch to batch,” says Mikeska. “Chroma-Q has focused on color consistency fixture to fixture, and consistent calibration from batch to batch. Many Chroma-Q fixtures utilize RGBA (red, green, blue and amber) LEDs while the studio fixtures utilize white LEDs.

New-generation products are achieving very high CRIs, but other indexes such as the Color Quality Scale (CQS) in development by the National Institute of Standards and Technology and the International Commission on Illumination (CIE), which developed the CRI, are going to be more useful for LEDs.”

A.C. Lighting is now using RBGA LEDs in some of its products. “With careful choice of frequencies, we are seeing some very accurate colors,” Mikeska reports. “One of our lines is called Studio Force Variable Phosphor: these luminaires let the programmer switch from daylight to tungsten color temperature, and they also have plus/minus green controls that help to balance skin tones.”

Mikeska adds, “In Europe, the TLCI [Television Lighting Consistency Index] is used more than in other regions.” Unlike CRI and CQS, the TLCI takes the color response curves of the video camera into account, instead of basing measurements on the hu-

man eye, which responds differently to various visible wavelengths than video Charge Coupled Devices (CCDs) do.

“LEDs that have a ‘W’ (white) component and an ‘A’ (amber) component can get very close to incandescent,” says Higgins. “It is difficult if not impossible to get ‘white’ from an RGB system because there are red, green and blue spikes, but the full frequency spectrum is not produced.”

“Over the past five years we have seen LED products get very close to mimicking the color of the incandescent lamp,” Stanziano reports, “but LEDs are still not quite bright enough.”

“ETC has spent years experimenting to create LED luminaires that produce a vast array of colors,” says ETC's Matt Armendariz-Kerr, “including light that resembles incandescents, light that can naturally illuminate skin tones, and output that stays the same from the time they're switched on until they're shut off and throughout the lifespan of the fixture.”

“ETC's x7 Color System combines up to seven LED colors to expand the color capabilities and create more natural-looking light,” says Stanziano. “The mix of emitters in Source Four LED Series 2 luminaires takes that concept even further, generating light that nearly matches incandescent light and can be used anywhere.”

### How Do LEDs Affect Video Production?

Somewhat like fluorescents, LEDs save energy by constantly switching on and off. But LEDs can do this much more quickly than fluorescents. If the switching driver is prop-



erly designed, the flickering will be invisible even with HD video cameras.

“LEDs can also require ‘painting’ the cameras to diminish noticeable blue, gray or purple tints, especially on skin tones,” says Armendariz-Kerr. “ETC LED luminaires include a special flicker-free mode that makes them usable with high-speed cameras. Their color-mixing capabilities also simplify filming, because adjustments can be made at the fixture to get the right coloring on screen and on each individual skin tone.”

Chroma-Q LED luminaires from A.C. Lighting have adjustable frequencies that go up to 6 kHz, reports Mikeska. “We also focus on very smooth dimming,” he says, “because that can be visible on camera as well.”

### LED Shadows

“LED color can be adjusted to make the video look better, but more fixtures may

be needed to reach the desired intensity,” Stanziano advises. “This increases shadowing.” Stanziano is referring to chromatic shadowing: the multi-colored edges that occur when the light from an LED’s separate RGB elements reaches a nearby object from slightly different angles. At a distance, the angle of incidence from all three elements is nearly the same, so shadow edges look more natural. But when the light is close to the object, the shadow edges can have a distinct shade or sometimes a rainbow of multiple shades. Manufacturers have developed both optical and solid-state solutions to homogenize the different colors within the fixture, so that what emerges is a consistent color that casts a consistent shadow.

“Multiple shadows can easily be avoided by not purchasing cost-driven products,” says Higgins. “Cost-driven products take things like optics, beam integration and



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source masking out of the fixture.”

“Putting open-face LED wash fixtures too close to the object they’re lighting can result in shadowing,” admits Armendariz-Kerr. “Locating them farther away can make a more homogenized beam. It’s often preferred to shield them from the congregation, so the light doesn’t become a distraction. The light—not the fixtures—is what is important. The optical technology at work in ETC Source Four LED luminaires combats the shadowing issue and creates an even beam.”

“High quality optics, including light tubes that blend the beams before the light emerges from the fixture, are the best current emulations of the kind of white produced by a glowing halogen lamp,” says De Lorenzo. “LEDs generally have an easier time producing low-temperature white in the 3,200 Kelvin range: the high temperatures around 10,000 K are still challenging LED lighting engineering teams.”

“Most LED products use multiple pixels, which will create multiple shadows,” says Stanziano. “When placing fixtures, the designer must decide the purpose of the light. As a backlight or wash, RGB shadowing may be acceptable. But in a front position, a fixture that uses a different LED chip may be needed to avoid the rainbow shadow. A diffusion filter can minimize the shadow, but won’t eliminate it completely.”

### Intensity Loss and Color Shift

“Color rendering is crucial for video applications,” Higgins points out. “This is where it gets tricky: there are hundreds of products marketed for high-CRI applications that are

of dubious quality. The real quality measures include things such as binning standards, the black body line, gamut, +/- green and delta UV. If your lighting vendor can’t explain those terms, then it is time to get in touch with an educated and ethical supplier.”

“Every manufacturer uses a ‘binning’ process to ensure consistent light output and color,” says Stanziano. “Most LEDs have a rating of 50,000 hours, but some products overdrive the elements to increase light intensity, which also decreases the lifespan by as much as half. Even under normal operating conditions LED color will start to fade and lose intensity. But other internal components could fail before we ever notice the difference.”

“Poor thermal management can cause both intensity loss and color shift,” says Armendariz-Kerr. “ETC LED luminaires are designed to operate within thermal limits, and are color calibrated. Our Selador Desire luminaires include a Red Shift function, so if they’re used in a house of worship alongside conventional fixtures, they can mimic the same intensity.”

### Control and Building Automation Systems Integration

“Smart” buildings increasingly remember to turn lights, HVAC and other systems on and off in response to occupancy, daylight levels and other environmental factors. Lighting controls, in most cases, are now designed to interface easily with other building management systems. Using the same sensors, control stations and other hardware can reduce overall costs and

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make it easier to keep track of what's happening system-wide.

"Most energy codes require some type of automatic shutoff, whether from an architectural control panel, an occupancy sensor or a building automation system," Stanziano points out. Clock-based controls turn lights on and off based on a schedule: occupancy sensors turn them on and off based on whether the monitored area is occupied. Daylight harvesting is another effective way to save energy by using a photo sensor to measure light levels and signal a controller to adjust the lighting system. Architectural control panels can add flexibility—a control station can be programmed to create repeatable lighting scenes for pushbutton recall. Programmable light sensors can be used for daylight harvesting applications."

### **China: Manufacturer or Direct Supplier?**

These days, it's no secret that many major brands manufacture products in China. Some Chinese factories are attempting to sell direct into the U.S. market by offering very low initial purchase prices. But you may not save anything in the longer run. "Buying LED luminaires from China makes it more difficult to receive support if a product malfunctions," Armendariz-Kerr points out. "We provide 24/7 customer and technical support throughout the life of a product, which helps avoid the extra costs of product replacement."

"When you buy products at a lower price, they can cost you more in the long run," Loader points out. "It's important to find a company

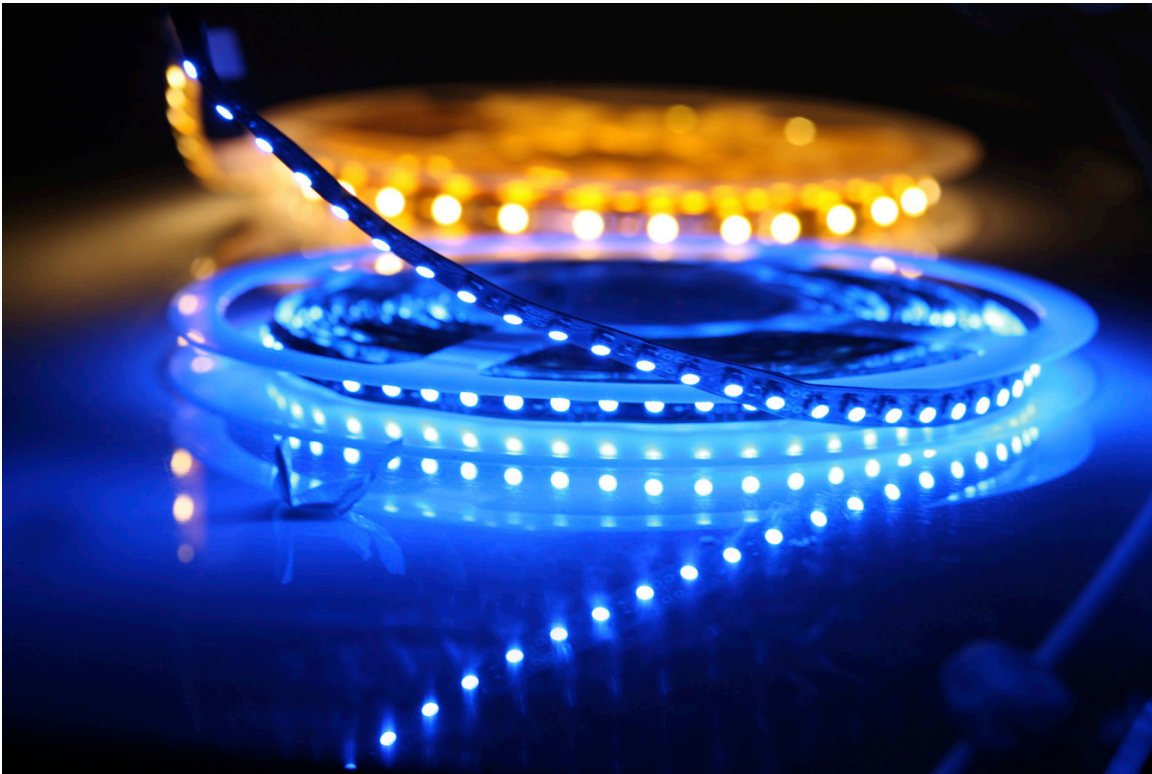
that provides after-sales service and support: and one that can support products long after they have stopped being produced. Otherwise, spare parts costs and/or delays in getting parts can become burdensome."

"Understanding what you are buying is key to any purchase," Stanziano advises. "While most LED products are manufactured in China, it's still best to buy local. You need to know that when it breaks, someone will be able to either repair or replace the light fixture."

"Osram Sylvania has invested significant resources in training Chinese factories to put our 6 Sigma quality controls in place," says De Lorenzo. "High product quality can also be achieved by thorough inspection of incoming components and finished goods, but this is often so expensive that it's actually







LEDs are being used for everything from architectural and stage lighting to accent lighting and digital signage.

cheaper to build in North America.”

Chroma-Q brand is distributed worldwide by A.C. Lighting. Mikeska says, “We work with our dealer network to provide support. The company has been manufacturing LED fixtures for over 10 years; all of the products have been designed, engineered and manufactured in Toronto, Canada.”

“With accessibility to overseas suppliers easier than ever on sourcing sites such as Alibaba, the temptation of lower sticker prices looms large,” admits Dickmann. “However, there are risks of hidden costs due to reliability and product safety issues. Most municipalities now require that lighting fixtures be safety-certified by a Nationally Recognized Testing Laboratory (NRTL) before they can be installed in a venue. These labs include UL, ETL, MET, and TUV. Their tests and standards are extremely rigorous, and only by getting a legitimate certificate can you be assured of a safe product. I have seen falsified certificates several times, so it’s always good to double check with the lab—the list of approved products is readily available.

“We do manufacture overseas, and people come to us almost daily after having poor experiences dealing direct with overseas vendors,” Dickmann continues. “While there are several very reputable manufacturers overseas, there are probably many more that are out to make a quick buck, will not stand behind their product, and may out-and-out lie to you. I have walked trade show floors here and in China and talked to factory representatives. I ask who they manufacture for, and they proceed to run off names of companies, but it’s obvious that this is untrue. They will even illegally use trademarks and copyrighted images to falsely represent their product. We have even had people contact us for parts or repair service because the supplier told them that they manufacture the same thing for us, which is not true. If you are able to purchase it on the Internet, it is not the same fixture that is sold under a legitimate brand name.”

Dickmann explains, “Factories will offer a super-low price, due up front because everything is built to order. They use your capital



to buy the materials to build your order, and shop for the cheapest components to maximize profits. There's no batch-to-batch continuity, so your next order may look the same on the outside, but its performance will probably be different. Once your products have been produced, 30–45 days later, you have to pay for shipping along with import and export duties due to both the Chinese and American governments," he warns. "These costs can be significant, and if you aren't versed in international commerce, the legal aspects can be tricky to navigate."

The problems continue, according to Dickmann. "After 45–60 days if shipping via sea, your LED luminaires are finally cleared by customs and delivered to your venue. If you find that some fixtures are DOA, you will most likely have no recourse. If the company is still operating under the same name, all sales are final, much like a mall kiosk. After weeks of run-around, you may be able to get 'free' parts (you only have to pay shipment and duties again). That's good, if you have someone on staff that can diagnose and repair the problems.

"Reputable ODM/OEMs have been in this business for decades, forging deep, exclusive relationships with overseas manufacturing partners. We spend months designing and refining the features and specifications of each product. During that time we have had the fixture certified by an NRTL so you will be assured of owning a safe product that will pass inspection. We travel to our manufacturing partner facilities several times each year to verify quality standards," he says.

At first glance, it may seem like you are paying more for a name brand, but when you consider the hidden costs of service, warranty repairs, shipping, freight and duties, certification and true customer support, purchasing from a reputable local business, whether or not it manufactures overseas, can be a bargain. Only by purchasing from a local dealer can you get the customer service that you need, with certified products, a true warranty, technical support and access to matched fixtures every time you buy—when you need them, not two months later. "We answer our phones and our emails and will be here to support you tomorrow, next month, and two or even five years from now," says Dickmann.

### Don't Get Left Behind

LED is an emerging technology, but it is already disrupting the lighting industry. As with other silicon-driven technologies, the pace of evolution is dizzying. But don't let that stop you from calculating the risks and rewards available right now. You may be surprised to find how attractive the LED proposition already is.

#### DOE publications on the Internet



**Solid State Lighting Technology Fact Sheet**  
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