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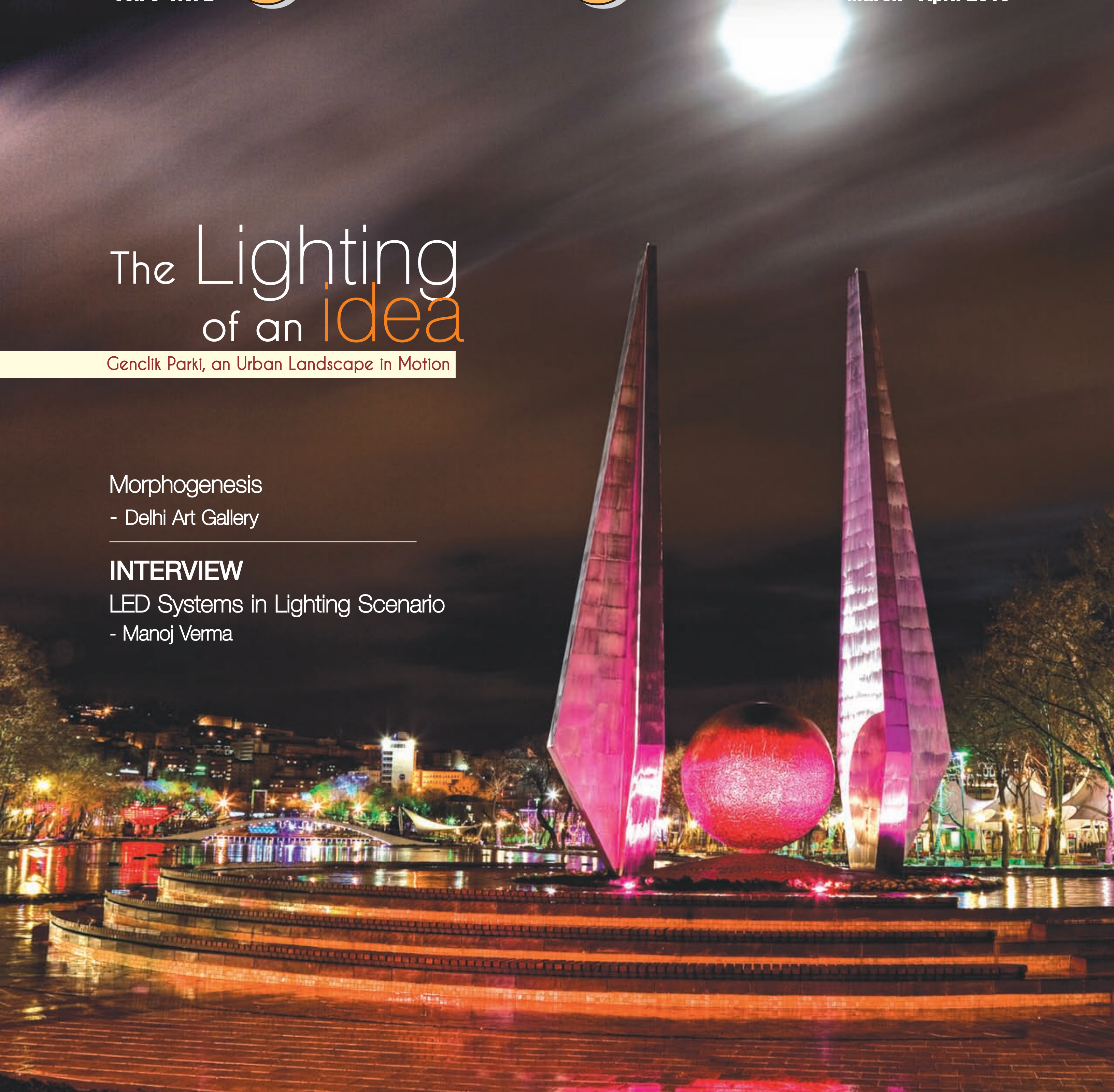

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INTERVIEW

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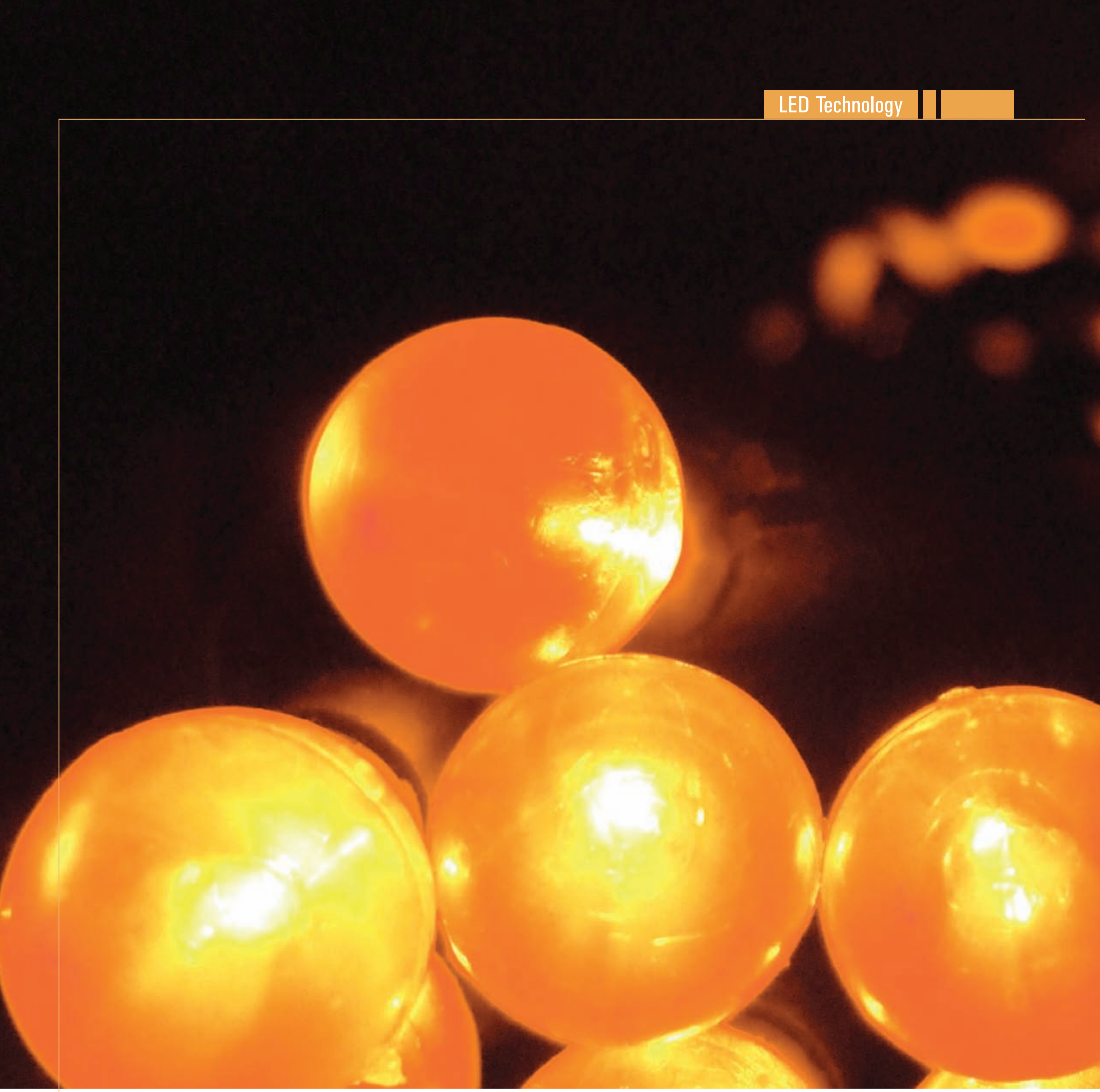
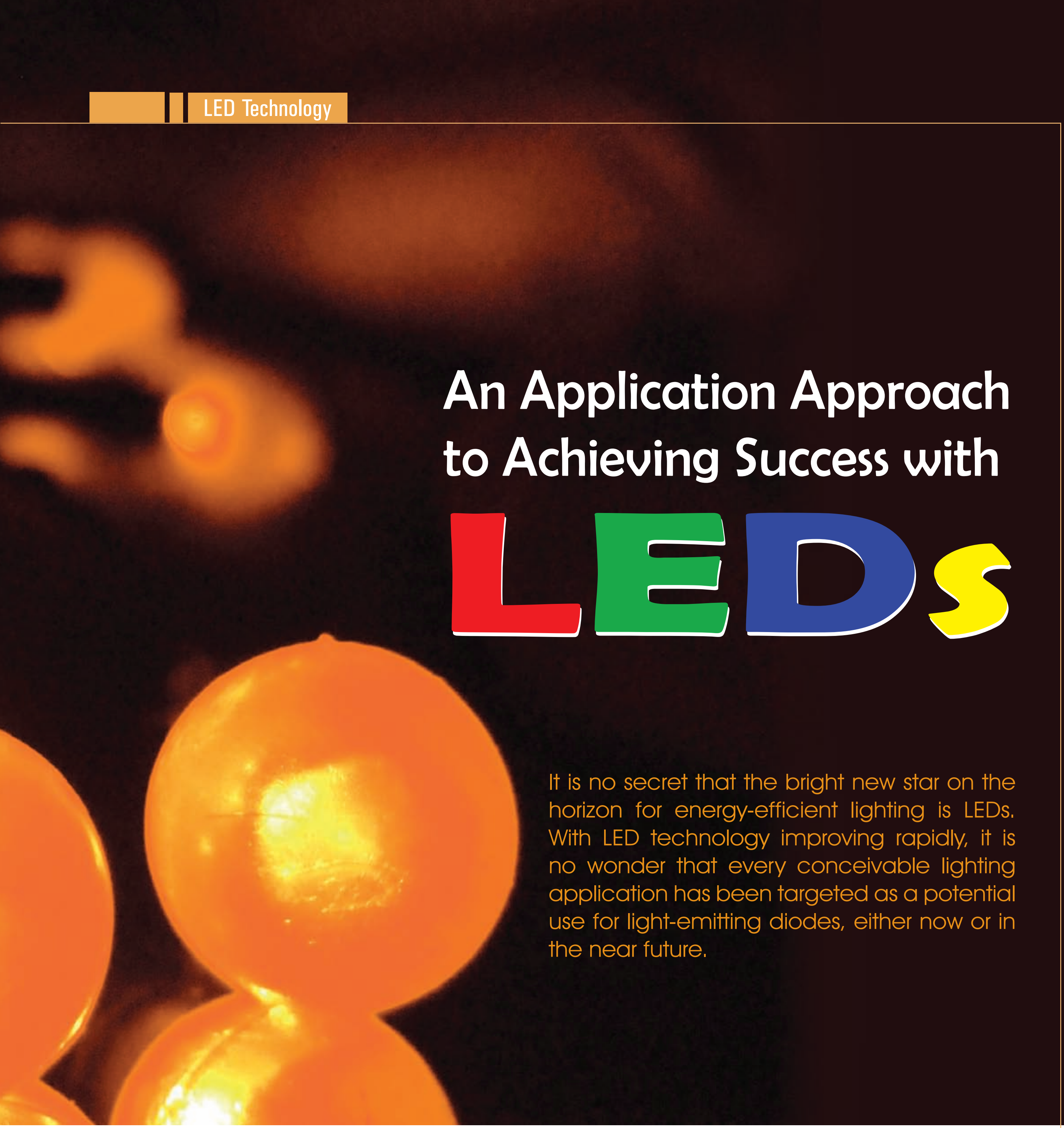
A Chary Publication



Indeed, LEDs are beginning to compete with traditional light sources, particularly incandescent, in a growing number of applications. Yet the success of a lighting technology cannot stand solely on metrics, which traditionally have specified performance in the laboratory rather than in the field. If we are to look at the traditional metric numbers alone-efficacy, CRI, and CCT being the most prominent-even technologies with outstanding numbers may fail. Why? Because a given technology has to provide benefit and value to the application in-context. Overall, the effectiveness of a given technology depends upon its application and not upon its intrinsic characteristics.

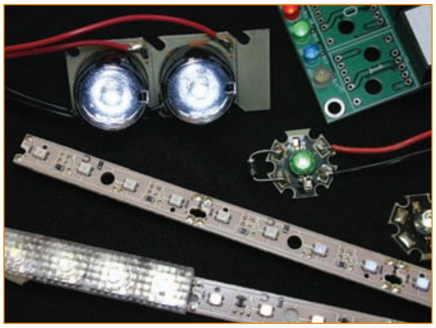


An Application Approach to Achieving Success with LEDs

It is no secret that the bright new star on the horizon for energy-efficient lighting is LEDs. With LED technology improving rapidly, it is no wonder that every conceivable lighting application has been targeted as a potential use for light-emitting diodes, either now or in the near future.

Unique LED attributes and important considerations

One of the reasons why LEDs are finding success is because they can offer long life, energy savings, and distinctive features to create unique solutions that were not possible in the past with traditional light sources. However, that does not necessarily mean LEDs are the best answer in every situation. Each technology excels at some aspect over other technologies. For example, some light sources produce light more efficiently, others last longer, and yet others have better color properties. Packaging options are also important, including a wide range of wattages, light outputs and sizes, which facilitates their use in many applications with different requirements. Therefore, the



application's requirements have to dictate the technology used, rather than trying to use technology in a one-size-fits-all approach.

In essence then, effective lighting design is about knowing where, when and how to apply the right technology to fulfill the application's requirements. Innovation is important, but balancing application requirements with the budget and a client's preferences often means that designers are looking for more than just long life and energy savings. According to Freyssinier and colleagues (2009), lighting designers and specifiers ask the following questions when considering a technology or fixture for a given project:

- Does it provide greater flexibility than other technologies or fixtures?
- Is photometric data available?
- Does it have a pleasing appearance?
- How much would the lighting installation cost overall (initial and maintained)?
- Is the fixture easy to relamp?
- Is this fixture appropriate for retrofit or new construction?

Overall, designers and specifiers are interested in the system as it performs in real-life applications, not just the component performance in the lab. The performance aspects important in application include photometric (e.g., light output, intensity, color, start-up, UV and infrared), electrical (e.g., power conditioning needs, burning cycle effects, dimming, warm-up and restrike times, safety), thermal, life, and economics (Freyssinier et al. 2009).

In terms of photometric characteristics, many LED products today can compete favorably with traditional light sources. As a direct current device, they are well suited for photovoltaic and or other DC systems. They are ideal in spaces with frequent on-off switching (a problem for fluorescent lamp life) and where short start-up and warm-up times are desirable. LEDs also lend themselves well to different electronic control strategies, such as occupancy sensors, load-shedding, and continuous or multi-level dimming. None of these seem to affect the LED or necessitate special requirements.

Unlike any other light source, LEDs have the potential for extremely long life. Thermal management is key to useful LED life, since heat negatively affects LED light output, color and lumen maintenance (Narendran et al. 2007; Narendran and Gu 2005). Long life is also a key economic aspect, generally contributing to a lower total cost of ownership over the life of the system (Freyssinier et al. 2009). Users generally care about system performance as a whole, and the useful life of system-integrated LEDs will depend on their packaging and thermal management, the drive current, and the operating environment (e.g., temperature, humidity). Presently, many manufacturers' data sheets for LED lighting systems claim very long lifetimes, from 30,000 to 50,000 hours. Typically, these numbers are reported by the manufacturers of the individual LED and the system manufacturers simply repeat the same numbers. But once an LED is integrated into a system, the lifetime may be significantly shorter depending on the temperature at its junction. Furthermore, system reliability depends not only on the LED performance over time, but also the performance of the LED driver and other components that comprise the entire fixture. A system's reliability is only as good as the weakest component, making it critical to consider the possible failure of every major system component.

One study has explored the failure modes of standalone LED drivers and how to predict their life through an accelerated life test (Han and Narendran 2009). The driver converts unregulated AC voltage from an electrical outlet to DC constant current output and is an integral part of any LED lighting system. The study's researchers found that electrolytic capacitors used at the driver's output stage had the highest probability of failure, making them the "weakest link" in the LED driver, determining the life of the driver and thus the life of the entire lighting system. Because heat is a vital factor in electrolytic capacitor lifetime, the study sought to establish a relationship between the capacitor's pin temperature and the useful life of the driver.

At different elevated temperatures, the researchers monitored the capacitor's output current ripple, which affects the input current to the LED and the LED's light output and efficacy. As the capacitor degrades, its capacitance decreases and its equivalent series resistance (the sum of electrolytic resistance, dielectric loss, and electrode resistance) increases, leading to an increase in output current ripple. By establishing the sudden and rapid increase point of current ripple as the end-of-life criterion, it was possible to predict the lifetime of the electrolytic capacitor, and hence the life of the LED driver (Fig. 1) (Han and Narendran 2009). In most applications, one can expect the LED driver to last 10,000 hours in the best case. Therefore, it begs the

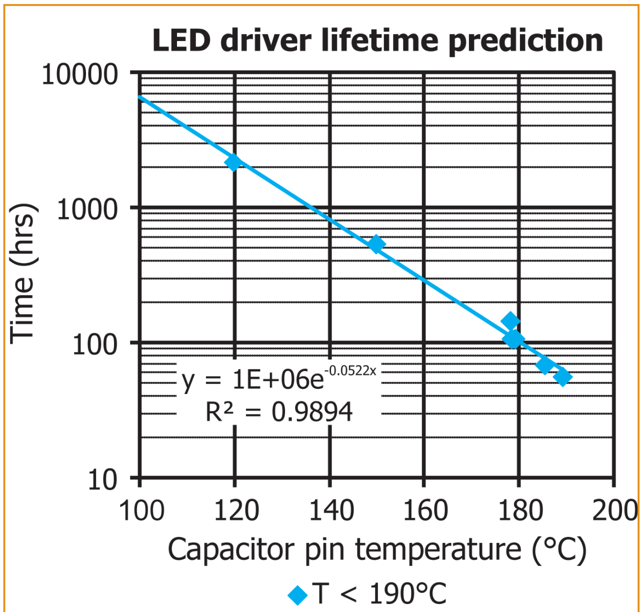


Fig. 1: Lifetime prediction for an LED driver as a function of capacitor temperature. By extrapolation, the predicted lifetime at 85°C ambient temperature (100°C at the capacitor's pin temperature) is approximately 7,000 hours

question of whether the reported life values for complete LED systems are reasonable.

Applications that can benefit now from LEDs

Given the importance of system- and application-based performance, where are LEDs finding success today? LED technology advances and market activities have enabled five white-light applications using LEDs (Freyssinier et al. 2009):

- Outdoor area and parking lot lighting
- Decorative lighting (using LED lamps and light engines)
- Under-cabinet lighting
- Directional lighting
- Freezer/refrigerator display case lighting

All these have benefited from LEDs for different reasons, with LEDs surpassing traditional technologies in at least one aspect for the application. For example, LED lighting in supermarket freezer cases is displacing fluorescent lighting because LEDs perform better in cold temperatures than fluorescent and can be used more effectively with occupancy and dimming controls. Small size, energy efficiency, and low light output requirements have been a boon for LEDs in decorative lighting, such as chandeliers and wall sconces. Under-cabinet and directional lighting benefit from the optical directionality of LEDs, which can allow for more efficient delivery of light to the task area. Outdoor area and parking lot lighting with LEDs is becoming more commonplace because LEDs can provide better light pollution control, color rendering, and subjective preference than traditional high-pressure sodium lighting. They also can be optimized for "visual effectiveness" based on new research into vision in low lighting conditions.

Defining success: A look at alternative metrics using "Application Efficacy"

One way that LEDs can find success in the marketplace is by considering alternative metrics. Traditional metrics such as luminous efficacy (lumens per watt) and luminaire system efficacy (system lumens divided by input power) are the most common ways of evaluating a technology and a fixture, respectively. The problem with these methods is that they are sufficient when conducting an "on the shelf" comparison of one technology or fixture against another, but they may not be sufficient in comparing their light distribution or how they deliver light to the application's task area. Secondly, traditional metrics and standards have been established using traditional technologies, and their methods are good indicators of those technologies' long-term performance, such as life. However, because LEDs are inherently different in structure and operation than traditional light sources, the traditional evaluation methods may not be suitable for testing LEDs. Therefore, "application-based" evaluation methods that can be employed for all light source technologies may judge products more accurately. Application-based methods are founded on a concept called application efficacy, which considers the total lumens reaching a task area (Rea and Bullough 2001). These methods would also allow for more appropriate comparisons between fixtures using different light sources, such as comparing a compact fluorescent downlight with an LED downlight, because the same method would have been used to test each.

Application - based methods are starting to take hold in lighting standards. At this time, application-based standards for outdoor lighting are now under consideration in the United States and in South Asia. One proposed outdoor lighting application method has been developed by the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), an international consortium of lighting and LED industry companies, government and energy-efficiency organizations, organized by the Lighting Research Center at Rensselaer Polytechnic Institute. ASSIST's parking lot luminaire evaluation method (ASSIST 2009), called LSAE (luminaire system application efficacy), builds on the concept of application efficacy and is applicable to any light source

type. The LSAE metric counts only the lumens that reach the target area and meet the application lighting requirements (e.g., IES RP-20-98, Lighting for Parking Facilities), divided by the total input power to the luminaire. In the case of a parking lot, the application environment is crucial because high luminous efficacy does not necessarily translate to energy savings. For example, if light is wasted by directing it where it is not wanted or needed, such as up to the sky or onto a neighboring property, then it cannot be considered truly energy efficient. The premise of the ASSIST metric is that a well-designed luminaire should direct most light to the task area while meeting the parking lot application's light level and uniformity requirements.

To show the usefulness of its proposed metric, ASSIST compared six commercially available outdoor fixtures in the United States, calculating their LSAE value for a 600 foot by 400 foot parking lot. Calculations were made using commercial software and a configuration of two fixtures per pole at the fixture's optimum mounting height. Light level and uniformity requirements were set following the Illuminating Engineering Society of North America's RP-20-98 criteria (IESNA 1998). Fig. 2 shows lighting power density (W/ft^2) as a function of the LSAE value for the six fixtures. The LSAE values plotted show a correlation between higher efficacy and lower lighting power density, meaning that within a specific application, it is possible to compare and rank order luminaires. Overall, LSAE accurately predicts energy use and the ability to meet application recommendations.

ASSIST has spent the last several years developing application-based testing and evaluation methods. ASSIST's proposed methods for a variety of applications are available for free download from the ASSIST recommended website: http://www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp.

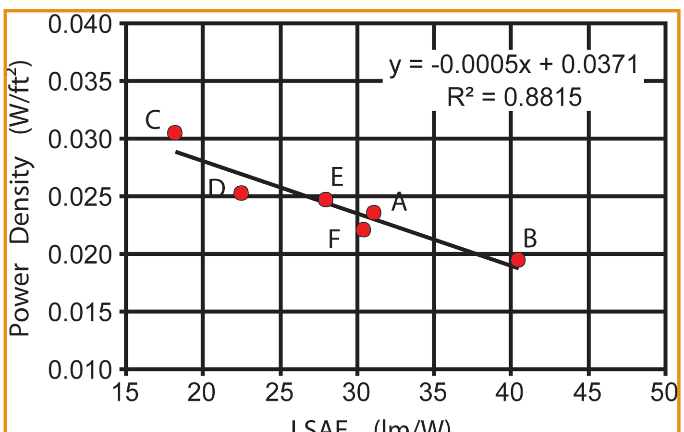


Fig. 2. Power density of a 600 ft by 400 ft parking lot as a function of LSAE value (ASSIST 2009)

Education is an important step to realizing success with LED lighting

A key component to the future success of LED lighting applications will be education for both those in the LED and lighting industries and for consumers and end-users interested in LED lighting. In the United States, the Lighting Research Center (LRC) has been running its twice yearly LED Lighting Institute for nearly a decade now. This three-day, hands-on workshop provides in-depth knowledge about LED technology, system integration and application-based testing methods. Participants get to build their own LED light fixtures in-house with the guidance of LRC lighting scientists and experts. At the end of the course, participants receive three continuing education credits from the LRC. For details, visit the LED Lighting Institute website: http://www.lrc.rpi.edu/education/outreachEducation/LEDInstitute.asp.

In South Asia, the Regional Centre for Lighting (RCL) opened last year in Sri Lanka through the collaborative efforts of the U.S. Agency for International Development (USAID), the Sri Lanka Sustainable Energy Authority (SLSEA), and the LRC. The RCL's mission is to advance sustainable lighting and make it affordable in South Asia to improve the well-being of the citizens and the countries within the region: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

The RCL conducts several lighting training courses, including the Sustainable Lighting Institute, an intensive five-day program designed to teach the latest advances and applications in lighting and demonstrate how these techniques and methods can be applied to achieve reliable, clean and efficient lighting throughout South Asia; and the LED Lighting Seminar for Manufacturers in South Asia, a three-day seminar and training on LED technology, operation, and application for lighting system and electronic component manufacturers in South Asia.

In both courses, professors from the LRC, with assistance by faculty from Sri Lanka's University of Moratuwa, teach and share information on cutting-edge technology and applications for both residential and outdoor lighting. Upon completion, participants earn continuing education units and receive a continuing education certificate from the LRC.

The next RCL lighting workshop will be the LED Lighting Seminar for Manufacturers in South Asia, held in Colombo, Sri Lanka, June 28-30, 2010. The training will be designed to meet the needs of engineers, technicians, and product designers/developers concerning electrical, optical, thermal, and other issues involved in the design, development, and manufacture of LED lighting systems and subsystems. The workshop also will assist manufacturers in identifying potential market opportunities within the LED lighting industry and help them to expand their capabilities to address those opportunities. For more information, visit http://www.rclsa.net.

Looking to future

In general, LED system performance, as measured in application, will be key to the future success of LED lighting. While LEDs can provide many benefits over traditional lighting technologies, general illumination applications are still a difficult road for LEDs to maneuver. Success will be ultimately defined by correctly matching a technology with an application's requirements, rather than by comparing one technology's characteristics against another without any context.

There is no doubt that LEDs will start replacing traditional light sources in South Asian countries in the coming years. The rate of market transformation will depend on several factors, including meeting customer expectations, availability, and affordability. Many experts are predicting that the transformation rate will be rapid given the promise of LEDs and the global pace of manufacturing affordable products.

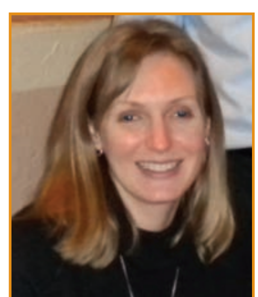
However, one challenge many countries will face is protecting their consumers from over-promised and under-delivered products. Market spoilers can set back good technologies for many years. Creating a product quality labeling program along with market watchdog programs that prevent market spoilage is essential for nurturing technology to provide maximum benefits for consumers and the region. In the United States, the LRC's National Lighting Product Information Program (http://www.lrc.rpi.edu/nlpip) and the Program for the Evaluation and Analysis of Residential Lighting (http://www.lrc.rpi.edu/programs/PEARL/) have sought to independently test and provide objective data on lighting product performance. The RCL, with help from the LRC, is hoping to create such programs in Sri Lanka and share that experience and knowledge with other countries in the region.

About the Lighting Research Center.

The Lighting Research Center (LRC) is part of Rensselaer Polytechnic Institute of Troy, New York, and is the leading university-based research center devoted to lighting. The LRC offers the world's premier graduate education in lighting, including one- and two-year master's programs and a PhD program. Since 1988 the LRC has built an international reputation as a reliable source for objective information about lighting technologies, applications, and products. The LRC also provides training programs for government agencies, utilities, contractors, lighting designers, and other lighting professionals. ■

Participants and faculty during the Regional Centre for Lighting's Sustainable Lighting Institute, Sri Lanka, January 2010

Jennifer Taylor, MSc, is a senior communications specialist for the Lighting Research Center at Rensselaer Polytechnic Institute, Troy, New York, since 2003. She works primarily in the field of solid-state lighting and LEDs, and has worked with the LRC's solid-state lighting team to produce ASSIST test methods, application guidelines, journal articles, research summaries, and other publications about LED lighting.



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