



POWER OVER ETHERNET LIGHTING – EVOLUTION OR REVOLUTION?



Lighting made a huge leap forward early in the 20th century when scientists learned how to generate usable light by passing electrical current through a thin strand of metal contained in a sealed glass chamber (aka, the light bulb). During the past century, lighting technology has been rendered reasonably safe through the implementation of measures that regulate how the products are built, how they are installed, and how people interact with them. The system of regulations, products standards and installation codes seeks a balance between desirable lighting technology characteristics (maximum light quantity, quality and flexibility), safety considerations (including fires and the risk of injuries), and undesirable characteristics (excessive operating costs, resource consumption, and toxic waste at the end of useful life). The development of highly efficient LEDs in the 21st century is showing itself to be a very positive game-changer, and the regulatory system is doing its best to keep pace with this technology and facilitate its deployment.

At the same time, wired communications technology has also come a long way, from the telegraph to telephone to fax machine, and then more recently to the digital world. The electrical power demands of communication systems have always been much lower than that of systems required to do mechanical work, such as moving, heating, cooling and lighting. As a result, wired communications systems generally require fewer safeguards to prevent injuries and property damage.

Power over Ethernet (PoE) lighting exemplifies the convergence of highly efficient (low power demand) lighting and sophisticated digital control and communication equipment. These technologies (low voltage lighting and Ethernet communications) are already fully deployed and accepted at both the product standard and installation code level. Many applicable regulations have prescriptive rules that establish expectations and set the stage for acceptance or rejection of products, based on how well or how clearly they conform to these expectations.

This white paper explores some of the compliance issues raised by the anticipated deployment of PoE lighting

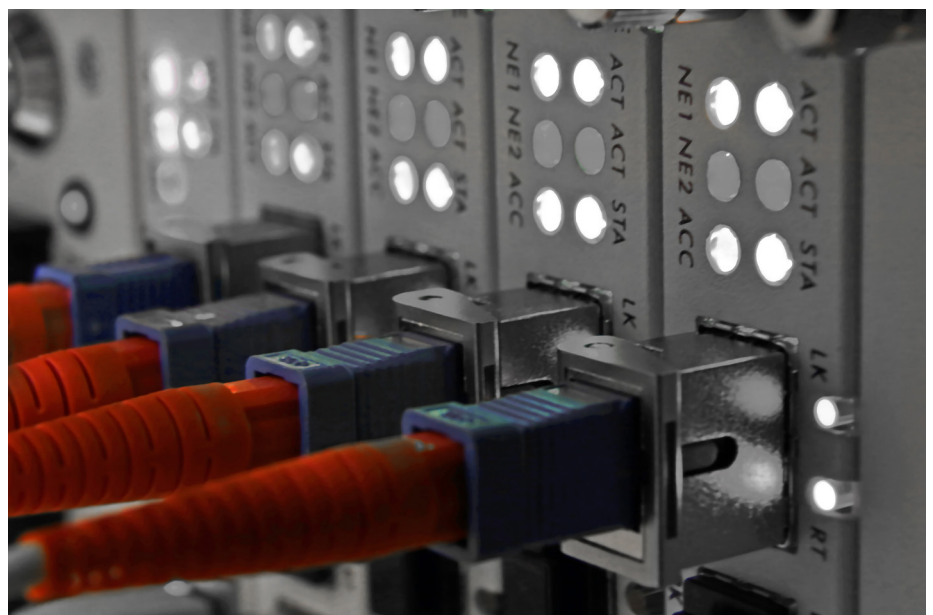
technology, and presents a pathway for demonstrating compliance with the current regulations and codes.

Power vs. Communication

In its simplest form, the basic concept behind a control system is its ability to manage a large amount of power with a small amount of effort. One set of tools and techniques is used to gather the energy, and a different set of tools and techniques are used to release it. The releasing tools – the control system – allow for more accurate timing and

delivery precision because the energy levels involved are more refined and manageable.

Compared to power distribution systems, electrical control and communication circuits generate far less heat and can be effective at far lower voltages. The National Electrical Code (officially titled ANSI/NFPA 70, but usually referred to as the NEC) recognizes these characteristics and relieves these circuits from many of the fire and electric shock injury safeguards typically applied to power systems. NEC Article 725 applies to these



limited power circuits, and is explained in Section 725.1 of the Code as follows:

“The circuits described herein are characterized by usage and electrical power limitations that differentiate them from electric light and power circuits; therefore, alternative requirements to those of Chapters 1 through 4 are given with regard to minimum wire sizes, ampacity adjustment and correction factors, overcurrent protection, insulation requirements, and wiring methods and materials.”

Until recently, facility lighting has required power levels beyond the capacity permitted under NEC Article 725. A typical facility lighting system has multiple luminaires operating directly from a shared 15- or 20 amp, 120- or 277 volt AC branch circuit, as well as separate control inputs for sensing daylight, occupancy, or time of day in order to more effectively manage energy consumption.

However, improvements in LED luminaire efficiency now make it feasible for these luminaires to operate within Article 725 power limits. This allows them to be managed by sophisticated digital power sources with their own control circuit intelligence, thereby reducing the need for separately routed control inputs. The potential to use lighter weight communication cables without a protective conduit, as permitted under Article 725, can also provide significant cost and labor savings.

PoE Lighting Development

Ethernet cables and connectors were originally designed and deployed for

computer communications, utilizing a similar look-and-feel to that found in legacy telephone wires and connectors. In 2003, IEEE 802.3af was published, limiting the transmission of power over these cables to 15.4 watts, a level nonetheless sufficient to operate small equipment under most circumstances without the need for a separate power unit. This development directly facilitated the evolution of standalone communications equipment with limited functionality, i.e., telephones, to full-fledged networked communications devices, each operating with individual IP (internet protocol) addresses.

To meet the power demands of other new network-capable devices, such as wireless access points and security cameras, an upgraded version of the standard, IEEE 802.3at, was published in 2009, increasing the transmitted power limit to 30 W (or an estimated 25.5 W after cable losses). Designated as PoE+ or PoE Plus, the source of this power (power sourcing equipment, or PSE) is typically referred to as an Ethernet switch. This switch is responsible for directing electronic communications traffic based on the IP addresses embedded in the signal, as well as the protocols (sometimes referred to as a handshake) between the switch and the devices to which it is connected (the powered device, or PD).

The next generation standard, IEEE 802.3bt, which is expected to be published in 2016, will boost the power transmission limit up to 95 W, primarily by doubling from two to four the number of paired conductors used for power transmission within the cable. This

technology is commonly referred to as 4P POE or 4-pair PoE. Other powering schemes, such as Power over HDBaseT (PoH) are also under development and are expected to be available in the near future.

These higher power levels open up PoE to even more classes of equipment, potentially eliminating the need for many of the individual AC-to-DC power converters that supply digital equipment throughout the commercial environment. Because every such power converter generates a measurable amount of waste heat, the potential energy savings associated with reducing the number of individual conversion devices is significant. Further, while the capabilities of power sourcing equipment are expanding, the power demands of potential candidates for this technology are decreasing due to improvements in energy efficiency. A specific example can be found in highly efficient LED luminaires that are capable of operating at low voltage input levels. The widespread deployment of LED luminaires makes them ideal candidates for PoE applications.

PoE Efficiency, Safety and Addressability

Today, the energy savings attributable to the use of LED lighting are well established. Although the relatively high price of LED lighting compared with that of legacy lighting technologies remains a challenge, this consideration is being offset by other factors, such as a longer expected operating life, reduced energy consumption, better color rendition,

dimmability, and less hazardous material to deal with at their end of life. These factors are widely considered by both facility managers and consumers when it comes to purchasing new or replacement lighting.

Further, the digital, discrete and modular nature of LED lighting technology can provide greatly expanded control options that can further reduce overall system energy consumption. Efficiency improvements within LED technology take three forms. First, LEDs limit the amount of waste heat from the conversion of electrical current to light within the diode itself. As new materials and thermal management designs continue to evolve, LEDs hold even more potential to reduce energy conversion losses.

Second, LEDs offers unique advantages in its directionality and its direct current (DC) operation. Legacy lighting technologies such as incandescent, fluorescent and high-intensity discharge (HID) emit light in all directions and rely on a luminaire's optics to direct light toward a specific location. However, every effort to redirect or reflect light involves some losses due to energy absorption or interference. Although light emitted from an LED is omnidirectional, the LED's small light emitting surface permits the optical elements to be designed with far greater precision, thereby more efficiently directing the luminaire's light output.

Third, because LEDs operate from direct current, LED luminaires can be made plug-and-play ready for DC power distribution systems that are now being deployed in some commercial facilities.

DC power distribution eliminates the conversion losses associated with converting alternating current (AC) power distribution to DC power at the branch or individual device level.

In addition to their potential for increased energy efficiency, LEDs also significantly reduce the risk of fire or injury. Individual LEDs function with a forward voltage that is typically near three volts. The threshold point at which a risk of electric shock injury becomes a concern for a DC circuit, either in a dry or damp location, is 60 volts. As such, lighting arrays that connect up to 20 LEDs in series are possible without triggering concerns about injury from electric shock. The light output of such an array, measured in lumens, can greatly exceed that of the typical 34 W high efficiency fluorescent tube lamp. This capability allows PoE luminaires to directly compete with fluorescent lighting within commercial environments. And, because the operating voltage is so much lower, fewer safeguards are needed to protect against electric shock during lamp replacement.

Finally, addressability is an important and distinguishable feature of PoE. An individual PoE switch may have a number of output ports, each of which is capable of two-way communication between the PSE and its connected equipment. These ports can individually control every LED feature available through a digital interface. As a digital device itself, the PSE can be programmed or remotely managed, thus permitting a much wider range of light level adjustments, scalable from an individual luminaire to facility-wide lighting.

Low Voltage Lighting—UL 2108

ANSI/UL 2108, Standard for Safety of Low Voltage Lighting Systems, addresses the minimum construction and performance requirements for luminaires whose input voltage is within the Class 2 voltage limits of NEC Tables 11(A) and 11(B) (30 Vac and 60 Vdc, respectively, for damp and dry locations). The Standard also requires that power output for low voltage lighting power units remains within those voltage limits under all anticipated use conditions.

UL 2108 was revised in July 2015 to explicitly require that PoE luminaires be subjected to the same investigative approach as that used with Class 2 luminaires. For the purpose of the Standard, PoE is defined as:

“A wiring system conforming to the Standard for Ethernet, IEEE 802.3 that uses category 5 (CAT 5) or similar cables and connectors to concurrently carry power and data, with voltage and power within the class 2 limits of the National Electrical Code, NFPA 70. Also covers POE+.”

The generic reference in UL 2108 to IEEE 802.3 is intended to include both IEEE 802.3af and IEEE 802.3at, as well as future generations of the standard. UL 2108 now also includes a reference to CAT 5 as an example of permitted output cable connection types for Class 2 power units. The Standard does not currently address other LAN cable-based communication protocols, such as HDBaseT, that operate within similar power limits but are not tied to the IEEE 802.3 standards. The text of UL 2108 may be expanded in the future to specifically address these other

approaches where the safety concerns are similar.

The 2015 edition of UL 2108 also expands the output marking requirements to allow any power unit whose output is limited to the NEC Class 2 levels to be marked "Suitable for Class 2 Wiring." A Class 2 marking had previously been reserved for only those outputs explicitly evaluated to UL 1310, the Standard for Class 2 Power Units, or UL 5085-3, the Standard for Class 2 and Class 3 Low Voltage Transformers. This modest revision in UL 2108 formally recognizes the other limited power circuit designations that align with the Class 2 wiring requirements of NEC Article 725, and explicitly acknowledges the significance of the electrical voltage, current, and power available from the output rather than the particular standard used to identify that output.

As a result of these revisions, UL 2108 is now fully positioned as a certification standard for PoE power units and PoE-powered luminaires installed in accordance with NEC Article 411. While a PSE may still function as a switch, it can now also be certified and approved as a lighting power unit.

The National Electrical Code

Article 725.121 of the 2014 NEC addresses power sources for Class 2 and Class 3 circuits, and is quite specific as to the types of power sources that are eligible to supply Class 2 wiring methods and materials (as subsequently identified under NEC Article 725.130). Subsection 725.121(A)(4) identifies a limited power circuit of "listed information technology (computer) equipment" as one such



eligible source. This subsection also includes an Informational Note which refers to UL 60950-1:2011 as a source for determining the applicable listing requirements for such equipment, stating "typically such circuits are used to interconnect information technology equipment for the purpose of exchanging information (data)."

Informational Notes within the NEC are added for explanatory purposes and do not establish mandatory requirements. However, both subsection 725.141(A)(4) and the Informational Note pose potential challenges for the deployment of PoE lighting. That's because equipment installers and code authorities (formally referred to within the NEC as Authorities Having Jurisdiction, or AHJs) do not generally consider a lighting power source as "information technology equipment," or that conductors supplying a luminaire are transmitting "data" for the purpose of "exchanging information."

A proposed revision for the 2017 edition of the NEC is intended to expand the scope of 725.121(A)(4) to include audio/video and communication equipment. These devices also fall within the scope of UL 62368-1, Standard for Safety of Audio/Video, Information, and Communication Technology Equipment, which is slated to replace UL 60950-1, Standard for Safety of Information Technology Equipment, in the near future. The proposed NEC revision goes even further to include industrial equipment, with an Informational Note that cites both UL 62368-1 and UL 61010-2-201, Standard for Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.

As of this writing (October 2015), the NEC Code Making Panel responsible for Article 725 has recommended adoption of this proposed revision, and is soliciting public comment prior to taking a final vote. This action signals the Panel's recognition that the features and performance of

power sources evaluated to the criteria in these standards applicable to limited power circuits are also valid for a variety of device types, not just information and communication technology equipment.

Another subsection within Article 725.121 appears to provide even broader application allowances for low power circuits. Subsection 725.121(A)(3) refers to “other listed equipment marked to identify the Class 2 or Class 3 power source,” with the exception of “limited power circuits of listed equipment where these circuits have energy levels rated at or below the limits established in Chapter 9, Table 11(A) and Table 11(B).” The Informational Note that follow this exception provides examples of “other listed equipment.” Although lighting equipment power sources are not listed among the examples, citing examples is intended for guidance only and does not constitute an exclusive list. Theoretically, this text provides installers and AHJs with the discretion to accept any listed equipment whose output is rated and marked as conforming with the limits found Tables 11(A) or 11(B).

NEC Tables 11(A) and 11(B) identify the electrical circuit parameters, including voltage, current and power, that qualify a circuit for the more limited suite of wiring method protection measures described in Article 725. Circuits that exceed the identified limits must otherwise conform to the more restrictive wiring methods found in NEC Chapter 3. The Tables and their associated Informational Notes include adjustment factors for different electrical waveforms, such as interrupted DC or combination AC+DC, and for

different environments, such as dry or wet locations. They also distinguish between circuits that contain an overcurrent protection device, e.g., a fuse, versus those whose current output is inherently limited. While there are some nuanced distinctions, these Tables generally align with electrical circuit parameters for Class 2 and limited power sources (LPS) found in various product standards. The accessible circuit connectors in modern electronic devices, such as USB, HDMI, Ethernet, firewire, etc., all operate within these same parameters

NEC Article 411

The current title of Article 411 is “Lighting Systems Operating at 30 Volts or Less and Lighting Equipment Connected to Class 2 Power Sources.” The Class 2 aspect of the title was added during the 2014 NEC revision cycle, a proposed 2017 revision recommends the title be simplified to “Low Voltage Lighting.”

Article 411 was originally developed to address landscape lighting systems supplied by an isolating power source with a maximum 30 V output. Since its original introduction, the scope of Article 411 has grown to cover a wider variety of low voltage lighting equipment and systems. Article 411 limits these systems to 25 amperes of low voltage current (appropriate for legacy landscape lighting strings of incandescent lamps), and requires the output to be isolated from the branch circuit and ungrounded.

These constraints are mirrored in the two associated UL product standards that directly reference Article 411, UL

1838, Standard for Safety of Low Voltage Landscape Lighting Systems, and UL 2108. NEC Section 411.3(B) requires Class 2 lighting systems to conform with Tables 11(A) or 11(B), and UL 2108 Table 3.1 mandates the same voltage limits. Therefore, PoE lighting technologies operating between 44 and 57 Vdc clearly fit within the scope of NEC Article 411.

NEC Article 725—Class 2 Wiring Methods

NEC Section 725.121(A) provides several options for determining whether a power source is eligible to supply a circuit using Class 2 wiring methods. The basic premise is that Class 2 circuits present a sufficiently low risk of fire and electric shock, so they can be safely routed through a building without most of the safeguards typically required of higher power circuits. As presented in a number of different product standards, there are several approaches that can be employed to establish that a power source conforms with the requirements of NEC 725.121(A).

Compliance with UL 1310 or UL 5085-3 results in marking the product output as Class 2. Use of a Class 2 transformer or power supply provides clear conformance with Subsections 725.121(A)(1) and (A)(2), respectively.

Power units more commonly used for consumer electronics, computing, multimedia, and communications equipment are typically evaluated to the requirements of UL 60950-1 or those of its planned successor UL 62368-1. These Standards incorporate an LPS evaluation program whose output parameter

requirements are aligned with the Class 2 parameters of NEC Tables 11(A) and 11(B). The use of the term LPS rather than Class 2 is intended to align the terminology used in the Standards with that of equivalent international standards, and does not represent any substantive difference in the level of power or safety involved. This alignment is also explicitly acknowledged by NEC 725.121(A)(4), which permits the LPS output of equipment certified under UL 60950-1 to supply Class 2 wiring and which parallels the allowance granted to Class 2 transformers and power supplies. A proposal currently under consideration for the 2017 NEC revision will expand the Informational Note associated with Article 725.121(A)(4) to include equipment certified in accordance with UL 62368-1.

There are still other options. UL 8750, Standard for the Safety of LED Equipment, is used to investigate and certify LED drivers. It is one of several UL standards that includes an evaluation program to assess whether internal circuitry is limited to the voltage and current levels permissible in Class 2 or LPS circuits. The UL 8750 low voltage, limited energy (LVLE) evaluation program is used within the context of the Standard to allow some latitude from otherwise required fire and electric shock safeguards, similar to the way in which the NEC exempts Class 2 circuits from otherwise required wiring protection methods. When an LVLE-compliant circuit is isolated from the branch circuit connection by a transformer and its output is limited to 100 VA, the circuit's output fully aligns with NEC Tables 11(A) or 11(B). This qualifies the LVLE circuit as compliant with

Class 2 wiring methods in accordance with previously noted exception to NEC 725.121(A)(3).

UL 2054, Standard for the Safety of Household and Commercial Batteries, has a limited power source test program whose output parameter requirements align with those of both UL 60950-1 and UL 62368-1. The Standard authorizes compliant battery packs to be marked LPS, which qualifies them to serve as a source for Class 2 wiring under the same exception to NEC 725.121(A)(3).

The limited available voltage and current carried by Class 2 circuits make them suitable for routing through a building without the more robust enclosures and grounding/bonding requirements required by NEC Chapter 3. Subsection 725.121(A) identifies several types of common power sources in order to simplify the specification and approval process. But the expanding list of exceptions and the reference to Tables 11(A) and (B) reflect the Code's tacit acknowledgement that it is the electrical characteristics of the power source, rather than the product

designation label applied to the source, that ultimately matters.

The cables that run from the PSE to the PD are Category Cables such as Cat 5, Cat 5e (which offers better crosstalk prevention), and Cat 6 or 6a (even quieter and with a higher top-end capacity). Each of these Category Cables have multiple twisted pairs of small conductors contained within an insulated jacket. They are commonly referred to as Ethernet cables and are usually certified as CM (communications) cables, often with additional suffix designations, such as CMR or CMP, to designate suitability for use within building risers or plenums. They were originally designed and are still predominantly used for applications covered by NEC Article 800, "Communication Circuits." They may also be certified as type CL, CLR, CLP, etc. However, the CM designation is more versatile and thus more commonly applied since the CM types are shown in NEC Figure 725.154(A) as eligible substitutes for the CL2 cables used for Class 2 circuits within Article 725.





For most building power distribution cables, the major concerns are current-generated heat and the insulation's ability to avoid breakdown that can lead to electric shock or ground faults. In the case of Cat 5 low voltage, low power communication cables, the concerns are more related to maintaining the integrity of the data. But the NEC and the product standards used to certify these cables require appropriate flame propagation and smoke generation testing to determine that they do not provide an unintended fire path as they travel through a building, or create an excessive amount of smoke if ignited.

For a single cable, there is no real concern that the cable itself will be ignited from within. But, in cases in which many cables are bundled together, cumulative heat generation and the reduced ability of the confined cables to dissipate this heat can become a concern for degradation of the cable insulation's flame retardant and smoke limiting properties. The ability of bundled PoE cables to avoid long term insulation degradation is currently being studied, and is also a current topic for the NEC Code Making Panel 16 responsible for Article 800. The questions currently being explored include whether and to what extent bundled cables should be de-rated regarding the amount of current they are permitted to carry. The specifics of any changes are likely be worked out over the next several NEC Code revision cycles.

Code Authority Acceptance

All of the issues discussed above are important when it comes to PoE lighting. Code enforcement can often

be prescriptive and literal. While code authorities retain a great deal of discretion, clear and unequivocal determinations are easier when installations are explicitly permitted in the text of the Code. However, this is not always possible since technology often moves faster than the Code can adapt, and because the wide diversity of products and their applications places practical limits on what can be captured in a Code document before it becomes too unwieldy to use.

Ultimately, the NEC provides AHJs with sufficient discretion in such cases, as stated in Section 90.4, which reads (in part):

"The authority having jurisdiction for enforcement of the Code has the responsibility for making interpretations of the rules, for deciding on the approval of equipment and materials, and for granting the special permission contemplated in a number of the rules. By special permission, the authority having jurisdiction may waive specific requirements in this Code or permit alternative methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety."

PoE lighting technology has not yet garnered the attention of many of the NEC's Code Making Panels. Indeed, no public inputs on this topic were submitted for the 2017 revision cycle. But PoE lighting is not the first new technology to seek AHJ approval under the discretionary allowances provided for in the Code. For most AHJs, the final phrase of Section 90.4 holds the key to approval, that is, to provide assurances that "... equivalent objectives can be achieved by establishing

and maintaining effective safety."

PoE switches certified in accordance with UL 60950-1 have been routinely installed and approved within IT equipment rooms under NEC Article 645, "Information Technology Equipment". Section 645.3(D) explicitly permits the output of such equipment to use Class 2 wiring methods in accordance with Subsection 725.121(A) (4). Whether transmitted electrical energy is used to transfer files from one computer to another or to illuminate a space isn't relevant from a safety perspective. So an AHJ that is comfortable approving a PSE for data transmission activity under Section 645.3(D) has good cause to be comfortable approving the same equipment when that 'data' is used, some 30 – 100 meters away in the building, to create light.

Regarding PoE luminaires, the situation is greatly simplified as a result of recent revisions to UL 2108 that provide clear and unambiguous listing opportunities for PoE luminaires, thereby fulfilling the NEC 411.4 requirement that low voltage luminaires be listed. Other requirements discussed in this white paper relating to isolation, grounding, and concealed conductors still apply whether the power source is a PSE or traditional Class 2 transformer. Therefore, for a listed PoE luminaire, meeting the "equivalent objectives" threshold of Article 90.4 of the NEC should be a straightforward proposition.

Evolution or Revolution?

PoE lighting is simply an evolutionary concept in the context of the Internet of Things (IoT), and is a natural expansion



of the smart home environment in which everything, from appliances to heating systems and security, can be remotely monitored and controlled. The energy efficiency improvements in LED lighting now make it practical to add lighting controls to the list of smart home capabilities, and lighting technologies will produce further increases in energy efficiency as the number of user control and programming options proliferate.

In the context of lighting equipment, however, PoE has even larger, potentially game-changing potential. Luminaires have already been recognized as locations within a building infrastructure where electrical power, mechanical enclosures, and line-of-sight are all readily available. As a result, several different facility systems, such as security, energy management, and mobile communication, can potentially use luminaires as nodes where other equipment can be co-located. And, because of the vast communication capacity of a PoE network, all of these additional systems can not only be co-located within a luminaire but can also leverage a single, integrated wired or wireless communication system. In such a scenario, the potential savings in hardware, software, and interference avoidance may be considerable.

Just as a smart phone is no longer just a phone but a fully integrated mobile information and communications device, future luminaires will integrate all of this functionality into a single package. Effectively managing the communications interface will take time and will likely require various standardization efforts within and between the involved industry sectors. But these challenges are surely within the capabilities of the innovative companies driving this revolution.

UL has already taken the first step, certifying basic PoE lighting equipment and establishing requirements within the applicable lighting product standard. If history serves as a guide, the next few years will see increased competition in both basic equipment and in the peripherals and application software that will expand the reach and functionality of PoE lighting technology. These innovations will serve as the basis for further revisions of the NEC and applicable product standards in order to clarify requirements and minimize confusion, with innovation driving regulation and regulation channeling further innovation.

For more information about UL's standards applicable to PoE lighting technology, go to www.ulstandards.ul.com. For details on UL's certification of PoE lighting equipment, contact Michael Shulman at Michael.Shulman@ul.com. For other inquiries related to UL's lighting solutions please contact lightinginfo@ul.com and visit www.ul.com/lighting today.