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Energy Efficient Lighting Guidance Document for New Construction and Retrofits: The State of North Carolina

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1. BACKGROUND

These guidelines were developed to assist designers of public projects in the selection of solid-state lighting (SSL) products and installation techniques that, when properly chosen and implemented, will provide long-term reliable service and performance. This document collects information based on field experience and conveys best practices that should be considered in any solid state lighting design. The document is intended to be a general guideline and is not a standard or specification. However, all applicable state building codes and standards must be followed.

SSL luminaires and lamps, based on light-emitting diode (LED) light sources, have made tremendous inroads in the marketplace over the past several years and have saved building owners significant amounts of money in reduced energy bills, lower maintenance requirements, and longer lifetime or useful life. This technology will be referred to as LED lighting throughout this document. The cost to purchase and install LED lighting has plummeted over the past few years, making it a viable choice for designers and building owners. The technology has matured and is a wise choice for many projects. However, as with any new technology, there are growing pains. Many owner representatives of State buildings would like to include LED lighting in their projects, but have been hesitant to do so until guidelines were available to help them in the selection and specification so they can avoid problems reported by others. The purpose of this document is to take field experiences and apply scientific study into why they worked as expected and why they sometimes did not. In their ongoing efforts to encourage State buildings in North Carolina to lead by example, the Department of Environmental Quality (DEQ) Utility Savings Initiative and the State Construction Office (SCO), in collaboration with RTI International have teamed up to develop these guidelines that designers and owners can use to help them make informed decisions when selecting LED products and system designs.

This document is organized with a discussion of the basic principles of good lighting design and the basic principles of good building designs regarding LED lighting in new construction followed by a section on LED lighting in retrofit projects. The topics of good lighting design and building design apply to both. New construction offers more flexibility in providing infrastructure (e.g., wiring, branch circuits) more amenable to LED luminaires, whereas retrofits utilize existing infrastructure and may not have the same flexibility in system design.

This document also provides information on LED luminaires that could be used in indoor and outdoor lighting. Performance expectations for energy efficient indoor and outdoor luminaires are given in Appendix C.

To support this discussion on LED lighting, an extensive glossary of LED lighting nomenclature is given in Appendix A and a list of the most common standards is given in Appendix B.

2. BASIC PRINCIPLES OF GOOD LIGHTING DESIGN

There are several basic principles of good lighting design that need to be considered in lighting projects for new construction and retrofits to existing lighting systems in order to achieve satisfactory performance. Among these are the need to consider the required light quality for the space including horizontal and vertical illuminance levels throughout, color of the light, the compatibility of the luminaires and the lighting control system, and the impact of glare and other factors. These principles of good lighting design should be considered in the context of the photometric and electrical characteristics of the LED lighting systems, which are likely to be different from a lighting system based on conventional lighting technologies.

2.1 Light Level and Illuminance

Less energy can be consumed if a lower lighting level or illuminance is feasible, but it is important to provide illuminance levels sufficient for the task and still meet code requirements. It is important to consider source light output measured in lumens (lm), illuminance (light levels) measured in lm/m2 (lux), or lm/sq. ft. (foot-candles), lighting uniformity, and lighting distribution (e.g., luminance and light distribution pattern (isotropic or directional)) when evaluating lighting quality.

Good lighting design practice requires the application of the lighting system in its intended environment including consideration of the needs and tasks of the occupants, the appropriate recommended IES illuminance levels for the space type/application, and the light distribution. In new construction and LED retrofits involving redesign of the lighting system, lighting calculations (e.g., AGi32 layouts) should be performed to make sure that the light level across the space meets the requirements. It is also recommended that luminaire samples be inspected by the responsible party to confirm the quality of the light and the perception of light intensity. The illuminance levels and uniformity needed for a space can be attained from published standards such as those from the Illuminating Engineering Society (IES) and specific standards of the owning agency. The illuminance (measured in lux or foot-candles) provided and intensity (measured in candela) of a light source or fixture can often be found in the manufacturer’s literature.

Lighting calculations are recommended for all spaces under consideration or at least all typical spaces such as classrooms, offices, and toilets and any special spaces. The Illuminating Engineering Society (IES) Handbook, Chapter 10, provides illuminance and lighting design recommendations for various spaces. The calculations should be performed using the basis of design fixture and include considerations for the light distribution pattern of the fixture and light loss factors such as dirt depreciation. For interior and outdoor applications it also very important that the calculations be provided to avoid high max to min uniformity ratios.

2.2 Correlated Color Temperature (CCT) and Color Rendering Index (CRI)

The lower the CCT value, the warmer the perceived color of the light. Likewise, the higher the CCT value, the cooler the perceived color of the light. Daylight (CCT often greater than 5000 K) and moonlight (CCT ~ 4100K) are considered cool light sources, whereas incandescent lamps are warm white (2700K). The designer needs to make sure that the light color is appropriately chosen for the application. A CCT value of 3000K–3500K may be suitable for general use in residential space and dorm rooms or a casual eating establishment, whereas a CCT value of 3500K–4000K may be suitable for use in offices and classrooms. A CCT of 4000K or higher would be suitable for parking garages and other outdoor applications.

CRI is a metric that measures how accurately the lighting source reproduces colors in an object (red, blues, yellows etc.). The test color samples used for determining CRI are specified by CIE and consist of eight standard pastel colors (R1–R8 values). The CRI is an average of the color rendering properties of the eight pastels. In addition, saturated colors such as red, yellow, green, and blue have been added to the color rendering evaluation matrix, and the measurement values for these saturated colors are represented as R9, R10, R11, and R12, respectively. These additional color metrics were added to quantify the ability of a light source to render saturated colors. Incandescent lighting has a very high CRI (typically around 100), whereas high pressure sodium has a very low CRI (typically less than 30). LED light sources generally have good CRI. A CRI value of 80 or higher should be specified for indoor lighting and 70 or higher specified for outdoor lighting...

In evaluating LED sources, it is also important to evaluate the R9 (i.e., saturated red color) metric since some LED light sources can be deficient in red emissions. As a general rule, an R9 value of 20 or higher is acceptable for most indoor lighting applications, while values greater than 0 can be acceptable in most outdoor lighting installations. In instances where high visual acuity is needed, a higher CRI and R9 value may be required.

2.3 Luminance and Luminous Intensity

Individual LED light sources tend to produce an intense white light, and the fixtures using LED sources should have lenses, diffusers, and reflectors to shield or diffuse the light and minimize glare.

Consider local codes and standards when designing outdoor lighting systems. This is especially important in outdoor applications where glare and light trespass can be a problem.

Glare can also be an issue in both indoor and outdoor lighting and needs to be considered in lighting designs to prevent discomfort glare which is a sensation of annoyance or pain caused by high luminances in the field of view. Glare occurs in two ways, either through luminances that are too high or luminance ratios that are too high (i.e., range of luminance in the visual environment is too large). Luminaire design is an important consideration when evaluating the potential for glare in a lighting design. Four factors of lighting design are known to lead to discomfort glare when not properly considered:

- Luminance of light source
- Size of the light source
- Position of the glare source in the field of view
- Luminance of the background

When considering the potential for glare, light produced by the luminaire as well as light reflected off of surfaces in the light path (e.g., polished marble) need to be evaluated. Additional information on glare avoidance can be found in the IES Lighting Handbook, 10th edition. Due to need to achieve illuminance and luminance levels and to maintain aesthetics, it would be advisable to view a sample fixture or a mock-up to determine if the intended application would be acceptable.

2.4 Up Light

Unlike sources from conventional lighting technologies, LED sources are typically directional light sources that produce light primarily in one direction. Omnidirectional light distribution patterns can be arranged through optical design at the lamp and luminaire level. For example, because of their small size, multiple LEDs can be arranged to point in different directions. By combining diffusers, reflectors and lens, virtually any lighting distribution can be achieved with a LED device with minimal impact on efficiency. Fluorescent, incandescent and other light sources such as metal halide are omnidirectional which means they emit light in many directions. Consequently, it is important to consider the light distribution pattern when selecting LED fixtures. Proper attention should be placed on the uplight and downlight components of the lighting pattern. For example, choosing a luminaire with no uplight component for use in high ceiling areas like a gym or a multi-story lobby may give the appearance of a dingy, poorly lit environment. In addition, such lighting designs may contribute to glare when looking up.

2.5 Control

Increased energy efficiency can be achieved through control of the lighting space using dimming, occupancy sensors, and daylight harvesting. To achieve optimal performance, the combination of fixtures, drivers, and controls must be carefully chosen to match the specific project requirements. Several considerations should be made when choosing a lighting system with controls:

1. The dimming range of the luminaire or lamp. Consideration of the expected dimming range of the lighting system is important. Some LED products are not capable of dimming over the full range of light outputs (i.e., 0–100%) due to design nor is this level of dimming needed in all applications.
2. The load capacity of each dimmer or control. The maximum number of luminaires or lamps attached to a controller is often limited by inrush and repetitive currents in the lighting system. This number is much less than that calculated based on steady-state loads. The minimum number of luminaires attached to a controller should also be considered for potential impact on flicker.
3. Type of control in lamp or luminaire. There are multiple control architectures currently in use with lighting systems including Forward Phase dimming, Reverse Phase dimming, Three-Wire dimming, 0–10 Volt, DMX, DALI, and other digital control systems. Not all control systems work with all products.
4. Standards and informational documents focused on lighting controls are available from The National Electrical Manufacturers Association, www.NEMA.org, and The Lighting Controls Association www.lightingcontrolsassociation.org.
5. Many companies are forming around controls for lighting system. A proper specification should be written to ensure quality equipment and installation.

Many LED light fixtures have good dimming capabilities, but compatibility with the chosen dimming system must be confirmed. Initial and operational costs for LED light systems can be less than fluorescent systems when dimming is the preferred method of control. This also can be useful in more complex installation where daylight harvesting or occupancy sensors are used in conjunction with LED fixture dimming.

Improper use of controls can lead to premature failure of the luminaire driver due to inrush or repetitive currents. The luminaire manufacturer should be consulted to ensure that the chosen control system works with the luminaire without impacting performance and life expectancy.

2.6 Exit and Emergency Lighting

The emergency lighting system shall comply with applicable requirements in NC Building code, NFPA 101 Life Safety Code, NFPA 70 National Electrical Code, NEMA standards, and UL testing standards with appropriate third party agency listing and labelling, such as UL 924.

a. LED Emergency Exit Luminaire (Sign)

   For unitary exit luminaires provide maintenance-free battery, automatic charger, self-diagnostic features (when available), and other features. Fixtures fed from a NEC 700 compliant generator circuit or any other emergency power source typically do not require an integral battery.

i. Battery

Sealed, maintenance-free battery type, with minimum of 90 minutes operating endurance. Provide with normal life expectancy of 10 years. Batteries shall be a high temperature type with an operating range of 0°C to 60°C and contain a resealable pressure vent, a sintered + positive terminal, and a - negative terminal.

ii. Charger

Fully automatic solid state type, full wave rectifying, with current limiting. Charger shall restore the battery to its full charge within 24 hours after a discharge of 90 minutes under full rated load. The unit shall be activated when the voltage drops below 80 percent. A low voltage, automatic disconnecting means shall be included if a battery is used, to disconnect the battery from the load and prevent damage from a deep discharge during extended power outage.

iii. Additional Features

Pilot light to indicate the unit is connected to AC power. The battery shall have high rate charge pilot light, unless self-diagnostic type. Tests switch to simulate the operation of the unit upon loss of A.C power by energizing the lamps from the battery. This simulation must also exercise the transfer relay.

iv. Warranty

Provide the entire unit with a minimum five years. The battery shall have an additional 2 years pro-rated warranty. Warranty will start from the date of project final acceptance. Include the warranty in the contract document.

v. Unit Test

Contractor should perform a test on each unit after it is permanently installed and charged for a minimum of 24 hours. Battery shall be tested for 90 minutes, in accordance with NEC 700. Any unit which fails the test must be repaired or replaced, and tested again. Copy of the test report shall be presented at final inspection and included in owner's Operation and Maintenance Manual. Include either starting voltage, ending voltage, and percent voltage drop or starting lumens, ending lumens, and percent lumens drop in the test report.

b. LED Emergency Egress Luminaires

Provide unitary emergency egress luminaires with maintenance-free battery, automatic charger, and two lighting heads. Luminaire shall be third-party listed as emergency lighting equipment, and meet or exceed the standards noted above and the following standards.

Provide battery voltage as recommended by luminaire manufacturer for LED light source.

Square wave inverters shall not be used with LED emergency egress lighting. Sinusoidal wave inverters are the preferred method.

i. LED Emergency Egress Luminaires for Normal lighting with Integral Emergency Batteries

ii. Additional Features

Pilot light to indicate the unit is connected to AC power. The battery shall have high rate charge pilot light, and self-diagnostic functions. A test switch to simulate the operation of the unit upon loss of AC power by energizing the lamps from the battery. This simulation must also exercise the transfer relay. Provide a switch accessible without removing covers or opening the fixture.

iii. Battery for Emergency Egress Luminaires

For unitary emergency lighting, provide maintenance free battery, with minimum of 90 minutes operating endurance and a normal life expectancy of 10 years. Batteries shall be a high temperature type with an operating range of 0°C to 60°C and contain a resealable pressure vent, a sintered + positive terminal, and a - negative terminal.

For normal lighting fixtures with integral batteries, provide maintenance free batteries with minimum 90 minutes operating endurance, normal life expectancy of 5 years, and listed for use with the associated fixture. Provide minimum 5 year full warranty with an additional 2 more years prorated warranty.

iv. Charger

Provide fully automatic solid state type, full wave rectifying, with current limiting. Charger shall restore the battery to its full charge within 24 hours after a discharge of 90 minutes under full rated load. The unit shall be activated when the voltage drops below 80%. A low voltage disconnect switch shall be included if a battery is used, to disconnect the battery from the load and prevent damage from a deep discharge during extended power outage.

v. Warranty

The entire unit shall be warranted for minimum five years. The battery must have a 3 year warranty with an additional 3 more years pro-rated warranty. Warranty shall start from the date of project final acceptance. Warranty shall be included in the contract documents.

vi. Unit Test

Contractor shall perform a test on each unit after it is permanently installed and charged for a minimum of 24 hours. Battery shall be tested for 90 minutes, in accordance with NEC 700. Any unit which fails the test must be repaired or replaced, and tested again. Copy of the test report shall be available at final inspection and shall be included in owner's operation and maintenance manual. Include either starting voltage, ending voltage, and percent voltage drop or starting lumens, ending lumens, and percent lumens drop in the test report.

2.7 Third Party Listings and Certifications

Due to the fact that the LEDs are a constantly changing technology make sure that any luminaires, lamps, components, retrofit kits, and drivers have proper third party listing such as UL or Intertek (ETL mark).

2.8 Outdoor Lighting

It is especially important in outdoor lighting to make sure that all fixtures or drivers have adequate surge protection to avoid failure of fixture due to lightning strikes or other surges. Also make sure fixtures are properly grounded and are able to function in dirty power circumstances (e.g., overvoltage, undervoltage, high harmonics).

Overvoltage can arise from a variety of sources including natural phenomenon. The reasons for overvoltage include:

- Lighting electromagnetic pulse (LEMP) caused by either a direct lightning strike, an indirect lightning strike caused by lightning currents, or an indirect lightning strike caused by Earth connection or electromagnetic induction;
- Switching electromagnetic pulse (SEMP) caused by switching in the grid, Earth faults or short circuits, or triggering fuses;
- Electrostatic discharge

When designing an outdoor lighting system, considerations should be given for proper protection. However, it is often not possible to mitigate all lightning-induced transients. To provide some level of protection, outdoor lighting should be rated for surges of at least 10 KV. Indoor lighting system components should be rated for surges of at least 2.5 KV. For both indoor and outdoor lighting, consideration should be given to the need for additional surge protection with harmonic mitigation at the power panel serving the lights. In addition, evaluating surge protection of a LED luminaire, the method in which the level of surge protection was determine needs to be considered. Ideally, surge protection of a device is evaluated in accordance with standard test methods such as IEEE/ANSI C62.41.2.

3. BASIC PRINCIPLES OF BUILDING DESIGNS

The majority of the lighting systems are used in conjunction with a building or other structure (e.g., parking decks) to provide either interior or exterior illumination. It is important to consider the impact of an LED lighting system on the building infrastructure (e.g., wiring, circuit breakers, controls, emergency power) to ensure that the two are compatible. For new construction, these factors should be considered at the design stage in order to provide the proper infrastructure to support advanced lighting systems throughout the life of the building. For LED retrofits, proper considerations such be given to ability of the existing building infrastructure to work properly with the chosen LED retrofit approach.

3.1 Wiring Methods

Proper wiring methods must be used in all new construction including dedicated full-sized (i.e., 100%) neutrals all the way from the lighting and appliance branch circuit panel board to the device. This requirement is a consequence of the use of higher efficiency solid-state electronics including devices such as LED drivers, variable frequency drivers, elevator controllers, and computers. All wiring methods must comply with the National Electrical Code (NFPA-70).

3.2 Special Considerations for the Distribution System

A dedicated lighting panel is recommended especially in instances when lighting is the majority of the load. Examples of installations that meet this requirement include but are not limited to schools, offices, parking garages, greenhouses. Often these buildings will have roughly 40% of the electricity consumption due to lighting, roughly 40% due to HVAC systems, and roughly 20% to wall plug loads. This approach will allow the installation of additional surge protection, if desired or needed.

Avoid other non-linear loads such as UPSs, VFDs, elevator controllers, computer intensive plug loads, and other solid-state electronic devices on the same branch circuit panel as the LED lighting system.

1. It is suggested that lighting panels be separated from large non-linear loads using appropriate methods such as isolation transformers, large diameter wire, and through distance.
2. It is also suggested that consideration be given to the stiffness or softness of the electrical systems. For examples utilities typically provide a stiff electrical system that can tolerate stress, such as inrush currents and voltage transients, without a significant voltage drop. In contrast, soft electrical systems, such as photovoltaic cells, other renewable power sources, and UPSs, do not tolerate stress as well which can produce increased transients.
3. In specific circumstances such as hospitals, computation centers, elevators, or where there is a high concentration of plug loads, harmonic filters and harmonic mitigating

transformers may be needed to reduce transients. In addition, multi-pole (i.e., 12-pole or higher) VFDs could be used in these instances.

3.3 Voltage Drop

Since voltage drop is proportional to wire length and size, longer wire lengths will produce higher voltage drops at a given size. Therefore, consideration should be given to wire length and size to reduce issues with non-linear loads such as LED drivers, VFDs, and elevator controllers.

3.4 Inrush Current and Circuit Loading

NEMA 410 allows for short duration (i.e., less than several milliseconds) inrush currents that are significantly higher (i.e., 40-fold or higher) than steady state currents. This allowable inrush current impacts the degree to which branch circuits can be loaded. It also can have an impact on breaker contacts, breaker panels, and branch circuit designs. As a result of this potentially high inrush current, many of our successful project have used branch circuit loading of 50% or less.

In addition, controls, sensors, and photocells used on LED devices must be rated to withstand the potential levels of inrush current.

3.5 Emergency Power for LED Systems

The designers shall consider that LED luminaires usually require an electrical driver to operate, multiple luminaires connected to a single driver may leave an area below acceptable lighting levels on failure of that single driver.

4. LED RETROFITS

4.1 Background

LED-based lighting has emerged as a potentially cost effective and low maintenance alternative to tradition lighting technologies (e.g., incandescent, fluorescent) in many instances. LED retrofits can be a convenient and cost-effective approach to provide the benefits of LED lighting without a complete overhaul of the building infrastructure. This chapter covers the application of LED lighting as retrofits to an existing lighting system and considers four major classifications of LED lighting retrofits:

a. Lamp replacement—a direct replacement of an existing conventional lamp or source (e.g., incandescent, fluorescent) with an equivalent lamp utilizing on LED light sources. Many LED replacement lamps have an electronic driver integrated into the lamp housing, while a few LED replacement lamps, such as LED-based linear fluorescent retrofit lamps, can be used with the existing ballast in the luminaire.

   Care should be taken to differentiate between source luminous flux (i.e., from the lamp) and delivered luminous flux from the luminaires. While photometric reports containing lumens produced and light distribution pattern for the lamp may be available, similar reports are not generally available when the LED lamp replacement is used in an existing luminaire. This performance may be significantly different.

   An additional factor to consider for LED lamp replacement retrofits is whether the lamp is approved for use in enclosed fixtures. LEDs dissipate heat primarily through conduction pathways that often involve the luminaire housing. If the temperature of the LED lamp rises too high (due to improper heat sinking or use in an enclosed fixture), premature failure may result.

b. Replacement kits for luminaires—consists of kits intended to replace key components of a luminaire such as lamps, drivers, connectors, lenses, reflectors, and wiring. Not every kit has all of these components. In general, the existing luminaire housing is retained when a LED retrofit kit is installed. The photometric performance (e.g., illuminance, luminance, and light distribution pattern) of the luminaire after installation of the replacement kit may be different from that of the original luminaire and should be evaluated.

c. Complete luminaire replacement—involves a 1:1 replacement of an entire luminaire and all of its components with a luminaire that has an LED light source. The photometric characteristics (including illuminance, luminance, and light distribution pattern) of the LED luminaire replacement need to be compared to that of the original fixture.

d. Lighting system redesign—involves a re-design of the illuminance in a space often using lighting simulation software (e.g., AGi32). A lighting system redesign can be performed in conjunction with complete replacement of the luminaire to accommodate a change in light distribution pattern and illuminance levels from new LED luminaires. The final layout of the luminaires in the retrofit will depend on required illuminance levels and not the existing locations of the luminaires being replaced. Unless a light system redesign is performed, the retrofit may not meet minimal lighting standards.

All of these will be collectively referred to as "LED retrofits" throughout this document. Each type of LED retrofit will be referred to individually when special attention needs to be given due to the characteristics of that type of retrofit.

Whenever a LED retrofit project is planned, it is critical that the organization installing the retrofit work closely with the owner of the building or lighting system to make sure that the end system meets applicable standards and achieves project goals.

4.2 Costs/Budget

All retrofit projects need to be consistent with the scope of the work project and consistent with the Life Cycle Costs Analysis (LCCA), when required. Because of the longer life of LED lighting, maintenance costs should be included in the life-cycle costs analysis especially in applications where equipment and worker safety can have a cost impact. The cost-benefit analysis of LED lighting could be impacted by situations such as:

- Requirement for scaffolding
- Locations over pools

4.3 Atriums, High Bays, and Auditoriums with Fixed Seating Desired Lighting Quality

The criteria for good light design are presented in Chapter 2, "Basic Principles of Lighting Design," of this document. These criteria are applicable to LED retrofits as well.

4.4 Condition of Existing Fixtures

If the existing light fixture housing is to be used (i.e., lamp replacement or replacement kit), a thorough inspection should be conducted on each light fixture to make sure that it is compatible with the intended LED lighting retrofit. Among the items to be considered are:

- Physical Size—It is important to confirm the physical properties and dimensions of the lamp and luminaire when performing a retrofit. Failure to perform this analysis may result in unexpected costs to the project. For example, some LED lamps have different dimensions than the traditional lamp technologies that they are replacing and may not fit into the same lamp sockets or luminaire housings without an extender.
- Housing—If an existing luminaire housing is to be retained in a retrofit, ensure that the condition of the housing is sufficient for continued use. In addition, the housing should be capable of dissipating the heat generated by the LED source and driver.
- Lenses—if the luminaire lens is to be retained, make sure that it is cleaned, or replaced if cracked or discolored. Yellowed or degraded lenses may change the light output from a luminaire.
- Ballast/drivers—if a retrofit LED lamp is being installed that will use the existing ballast or driver in the luminaire, make sure the retrofit lamp is compatible. The manufacturer should be consulted to confirm compatibility.

- Input voltages—The acceptable input voltage of the LED retrofit lamp or kit should be compatible with the input voltages being supplied.
- Sockets—when planning a LED retrofit lamp upgrade, check to ensure that there is sufficient clearance around the housing for the lamp to fit into the socket. Some LED retrofit lamps have heat sinks around their base that increase their size relative to a conventional lamp. Sockets may have to be replaced in some existing fluorescent fixtures with Instastart™ lamps that used shunted sockets which are not compatible with new LED replacement lamps. Further, reconfiguring the original luminaire to allow line conversion of sockets will require unique maintenance challenges that need to be considered over the remaining life of the fixture.
- Manufacturer—when installing a retrofit kit in an existing luminaire, check with the luminaire manufacturer to see if an approved retrofit kit is available for that product.
- Whip length and location of knock out boxes—If a new LED retrofit luminaire is being installed as part of a 1:1 complete luminaire replacement, check that the location of the knock out boxes on the luminaires are sufficient for the existing whip length. Otherwise, additional costs may be incurred for new whips.
- Third Part Listing—per NC General Statute and NEC—410.6 third party listing of electrical equipment is required. Care should be taken to verify that any modification to the existing fixture maintains the third party approval.

4.5 Controls

The compatibility of any LED retrofit with control systems needs to be confirmed before selection of the specific retrofit approach. The manufacturer of either the LED retrofit or the control should be able to provide information on compatibility. This analysis should include all lighting controls such as:

- Photocells
- Daylight harvesting controls
- Dimming
- Occupancy/Vacancy
- Building or room control systems

The criteria for good lighting control design are presented in Chapter 2, "Basic Principles of Good Lighting Design," of this document. These criteria are applicable to LED retrofits as well.

4.6 Existing Infrastructure and Building Conditions

Retrofit LED devices are used with the existing building infrastructure in an attempt to minimize modifications. Since LED lighting devices can have different electrical and physical properties, relative to conventional lighting technologies, it is important to understand the impact of the chosen retrofit approach on the existing building systems to avoid unexpected cost or field performance and reliability issues.

- Electrical—As discussed in Chapter 3 of this document, LEDs represent a non-linear load to the branch circuit and may require an upgrade in wiring depending on branch circuit loading, power quality (i.e., harmonics), and level of surge protection. Two areas that deserve special consideration for LED retrofits are:
  - Shared or reduced size neutrals on the existing electrical system may represent a significant problem for the project; and
  - Significant unloading of the electrical circuits may create other problems in the building.

  In addition, if using LED luminaires to replace the emergency lighting system, consideration needs to be given to the impact of inrush current on the generator and or battery system. The project may need rewiring to eliminate shared or reduced size neutrals to maintain reliability of the emergency power system.
- Asbestos—Prior to replacement of any luminaire or control system above the ceiling level, a determination needs to be performed on whether hazardous materials are present and would require mitigation. If so, this may limit the retrofit options to those which do not disturb the ceiling.
- Ceiling types—Certain ceiling types (e.g., hard ceilings, Z-spline ceilings, drop ceilings, etc.) may require additional labor to restore or replace the ceiling which should be included in the project costing.
- Painting and patching—LED retrofit luminaires that are different sizes from the original fixture may require painting and patching to restore appearance of ceilings and walls to acceptable levels.
- Insulation above ceilings—if new LED retrofit luminaires are installed, they should be rated for use with insulation, if present.
- Emergency systems and exit lighting—If any part of the LED retrofit lighting system is replacing part of the building's emergency or exit lighting system, care should be taken to make sure that the existing emergency lighting system is not compromised. In addition, the compatibility of any new LED retrofit with existing emergency lighting system should be considered to ensure proper function of the emergency lighting system.
- HVAC and heat load effects—LED lamps and luminaires dissipate heat primarily through conduction instead of direction radiation into open space, as many lighting technologies do. Consequently, LED-based lighting sources present a different heat load to the building HVAC system that needs to be considered.
- Other items to be considered when evaluating different LED retrofit options:
  - Air handling luminaires
  - Plenum rated fixtures
  - Fire rated ceilings
  - Be aware of existing code and owner requirements for such things as light fixture, raceway, and ceiling supports and fire tenting

4.7 Outdoor and Exterior Lighting LED Retrofits

When installing a LED retrofit kit to an existing luminaire or a new LED luminaire as a retrofit in an outdoor environment, special care should be taken to ensure that the lighting quality is not altered in an undesirable fashion. This step is necessary because changing the luminaire or installing a LED lamp or LED replacement kit can have a significant impact on the light distribution pattern from the luminaire including altering the mix of downlight and uplight produced by the luminaire. Considerations of the downlight component also need to be evaluated for the mix of forward light and back light of the retrofit are appropriate for the application. It would be useful to have an evaluation that includes an examination of the LED luminaire or LED replacement kit installed in a representative luminaire and if possible in the actual use environment. Other items to be considered in evaluating the impact of installing a LED replacement kit in an existing luminaire or installing a new LED luminaire as a retrofit include:

- Spacing and light distribution—since the light distribution pattern of the LED retrofit may be different from the original luminaire, some areas may not receive the same illumination levels or may be over-lit or under-lit after installation of the retrofit.
- Glare—improperly designed LED sources can be a source of glare, so attention should be given to whether the LED retrofit will increase the level of glare.
- Light trespass—LED retrofits in outdoor environments need to consider the impact of light trespass when evaluating different options.
- Sky glow—due to their more directional nature, LED retrofits can lower the amount of sky glow compared to conventional technologies.
- Backlight, Uplight, and Glare (BUG) rating—This rating could be examined to ensure that light trespass, sky glow, and glare levels are acceptable.
- Durability—When installing a LED retrofit, it is important to ensure that the durability of the outdoor fixture is not changed. In particular, data on the performance of the retrofit including salt spray testing, the temperature rating (especially the upper and lower temperature ratings), and the ingress protection (IP) rating of the retrofit should be examined.
- Surge protection—the surge protection available in the existing lighting system (building) should be evaluated to ensure that it is adequate for the chosen LED retrofit approach. A minimum surge protection rating of 10kV is required for outdoor lighting fixtures.
- Vibration rating—in some applications (e.g., parking garages) it may be necessary to evaluate the vibration rating of the fixture.
- Photocell and controls—when installing a LED retrofit in an existing luminaire, the compatibility of the photocell and other controls with the LED retrofit should be confirmed. In addition, improper photocell operation, particularly during the day in hot conditions, could shorten the life of the LED retrofit.

Installing a LED replacement kit in an existing luminaire will change the luminaire efficiency (i.e., the ratio of the light delivered by the luminaire to that light produced by the source (i.e., lamp)). Consequently, the actual illuminance levels in the area to be lit need to be considered before and after the LED retrofit and used as the basis for evaluating any LED retrofit. If the luminous flux produced by the source (i.e., high pressure sodium lamp) is used as the basis for this analysis, unexpected lighting issues may arise due to the more directional nature and higher luminaire efficiency of LED sources. When performing a verification of the illuminance levels, it is important that the light meter be calibrated for a white light source such as LEDs instead of a source such as HPS with more limited spectral features.

4.8 Other Items to Consider for LED retrofits

- Warranty of the LED retrofit
- The wiring of the installation
- Grounding
- Whether LED retrofit kits are available for the existing luminaire product
- Cost—Payback, LCCA

Renovation or construction of more than 20K ft^2, needs an LCCA. If it falls under North Carolina General Statute, you need to determine the baseline luminaire.

5. FIXTURE-LEVEL INFORMATION

Multiple LED luminaires are available on the market in common sizes. Examples of specifications for interior and exterior LED luminaires and components are given in Appendix C. The designer should contact manufacturers and develop a specification that is appropriate for the application. The examples in Appendix C can be used as a resource.

Appendix A
Nomenclature and Common Terms

Lighting technology has a well-defined nomenclature that has been established through the Illuminating Engineering Society of North America (IES) and other standards organizations. Several significant publications are available to provide accurate definition of importance lighting terms. These include:

IES, *ANSI/IES RP-16-10: Nomenclature and Definitions for Illuminating Engineering*, 2010, New York, New York.

D.L. DiLaura, K.W. Houser, R.G. Mistrick, and G.R. Steffy, *The Lighting Handbook, 10th Edition.* Illuminating Engineering Society, New York, New York, 2011.

International Lighting Vocabulary, electronic edition (e-ILV). CIE, Available at http://eilv.cie.co.at/.

Additional resources such as the Energy Star Luminaire Specification version 2.0 also contain a list of useful terms. This document is available for download at http://www.energystar.gov/sites/default/files/Luminaires%20V2%200%20Final.pdf.

Additionally, the Design Lights Consortium publishes category definitions available at: https://www.designlights.org/content/QPL/ProductSubmit/CategoryDefinitions

Common Terms

These terms are commonly used in lighting technologies and standard definitions are provided here for convenience. The normative references provided above should be consulted if necessary.

ANSI—American National Standards Institute

ASHRAE- The American Society of Heating Refrigerating and Air-Conditioning Engineers.

ASTM—American Society for Testing and Materials

Back light—Illumination from behind (and usually above) a subject to produce a highlight along its edge and consequent separate between the subject and it background. (IES RP-16-10).

Beam angle—angle between the two directions for which the intensity if 50 percent of the maximum intensity as measured in a plane through the nominal beam centerline. For beams that do not possess rotational symmetry, the beam angle is generally given for two planes at 90°, typically the maximum and minimum angles. Note that in certain fields of application, beam angle was formerly measured to ten percent of maximum intensity. (IES RP-16-10).

Candela—SI unit of luminous intensity. One candela is one lumen per steradian (lm/sr). (IES RP-16-10)

CIE—Commission Internationale de l'Eclairage (French). International Commission on Illumination (English).

Color Rendering Index (CRI)—measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature. (IES RP-16-10).

Color Tunable Luminaire—a luminaire that adjust the color of light emission either automatically or based upon user inputs.

Correlated Color Temperature (CCT)—the absolute temperature of a black body radiator whose chromaticity most nearly resembles that of the light source (IES RP-16-10).

CSA—Canadian Standards Association.

DALI—Digitally addressable lighting interface.

Direct Lighting—lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be of infinite extent, is 90 % to 100 %. (ILV 17-319).

Directional Luminaire—a luminaire that provides direct lighting.

DLC—DesignLights Consortium.

DMX—Digital multiplexer.

Down Light or Downlight (luminaire)—a small direct lighting unit that directs the light downward and can be recessed, surface mounted, or suspended (IES RP-16-10).

Electronic Ballast—a device which operates at a supply frequency of 50 or 60 Hz and operates the lamp at frequencies greater than 10 kHz. (ANSI standard C82.13-2002).

Enclosed fixture or enclosed luminaire –a device for providing illumination to a space in which free air flow is restricted due to the presence of a cover, globe, or lens. Many enclosed luminaires will raise the temperature of LED lamps, due to restricted air flow which limits cooling, which could shorten their lifetime.

External driver—an electrical driver that is a separate module from other parts of the luminaire and is typically attached to the luminaire housing.

Foot candle—a unit of illuminance. One footcandle is one lumen per square foot (lm/ft^2). (IES RP-16-10).

Glare—the sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted to causing annoyance, discomfort, or loss in visual performance or visibility. (IES RP-16-10).

HVAC—Heating ventilation and air conditioning

IALD—International Association of Lighting Designers Founded in 1969 and based in Chicago, IL, USA, the International Association of Lighting Designers (IALD) is an internationally recognized professional organization dedicated to the profession of architectural lighting design and with a vision to create a better world through leadership and excellence in lighting design and the cultivation of the universal acknowledgement and appreciation of the Power of Light in human life. www.iald.org

IEC—International Electrotechnical Commission

IES—Illuminating Engineering Society

Illuminance—the areal density of the luminous flux incident at a point on a surface.

Indirect Lighting—lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be of infinite extent, is 0% to 10%. (ILV 17-575).

Input power— power consumption in watts of a ballast or driver and a light source system operating in a normal mode, as determined in accordance with the test procedure (ANSI Standard 82.2-2002).

Inrush current—Input current of short duration during initial start-up that is much greater than the operating or steady state current. (NEMA 410-2011).

Inseparable LED Luminaire—A luminaire featuring solid state lighting components (i.e. LEDs and driver components) which cannot be easily removed or replaced by the end user, thus requiring replacement of the entire luminaire. Removal of solid state lighting components would require (for instance) the cutting of wires, use of a soldering iron, or damage to or destruction of the luminaire. This definition does not encompass luminaires which feature LED light engines or GU24 based integrated LED lamps which are user replaceable / upgradeable without the cutting of wires or the use of solder, or the specific residential luminaire types designated "directional" in the scope of this document. (Energy Star)

Integrated LED Lamp—an integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, ANSI standard base and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a corresponding ANSI standard lamp-holder (socket). (IES RP-16-10)

LCCA—Life cycle cost analysis

LED (Lighting Emitting Diode)—a pn junction semiconductor device that emits incoherent optical radiation when forward biased. The optical emission may be in the ultraviolet, visible, or infrared wavelength regions. (IES RP-16-10).

LED Driver—a device comprised of a power source and LED control circuitry designed to operate a LED package (component), or an LED array (module) or an LED lamp. (IES RP-16-10).

LED Lamp, Integrated—an integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, ANSI standard base and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a corresponding ANSI standard lamp-holder (socket). (IES RP-16-10).

LED Lamp, Non-integrated—an assembly comprised of LED arrays (modules) or LED packages (components) and ANSI standard base. The device is intended to connect to the LED driver of an LED luminaire through an ANSI standard lamp-holder (socket). The device cannot be connected directly to the branch circuit. (IES RP-16-10).

LED Light Engine—an integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed and does not use an ANSI standard base. (IES RP-16-10).

LED Luminaire—a complete lighting unit consisting of LED-based light emitting elements and a matched driver together with parts to distribute light, to position and protect the light emitting elements, and to connect the unit to a branch circuit. The LED-based light emitting elements may take the form of LED packages (components), LED arrays (modules), LED Light Engine, or LED lamps. The LED luminaire is intended to connect directly to a branch circuit. (IES RP-16-10).

Light Trespass—involves the effect where light strays from the intended purpose and becomes an annoyance or nuisance. An example of light trespass is a streetlight with a high backlight component which provides a higher than desired level of illuminance to nearby houses.

Linear Load—a linear load is one where the impedance of the load is a constant. When voltage is applied to a linear load the magnitude of the resulting current waveform, although possibly shifted in time, is directly proportional to the applied voltage.

Luminance—the quotient of the luminous flux at an element of the surface surround the point, and propagated in directions defined by an elementary cone containing the given direction by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plane perpendicular to the given direction. The luminous flux may be leaving, passing throughout, and/or arriving at the surface. Formerly, *photometric brightness*. (IES RP-16-10).

Luminous Efficacy of a Source of Light—the quotient of the total luminous flux emitted divided by the total power input. It is expressed in lumens per Watt (lm/W). It is often shortened to luminous efficacy

Luminous flux—the time rate of flow of radiant energy, evaluated in terms of a standardized visual response. Unless otherwise indicated, the luminous flux is defined for photopic vision. (RP-16-10).

Lumen maintenance—the luminous flux output remaining (typically expressed as a percentage of the initial output) at any selected elapsed operating time. Lumen maintenance is the converse of lumen depreciation. (adapted from IES LM-80-08).

Lumens—Si unit of luminous flux.

Lumens per Watt (lm/W)—the units commonly used to express luminous efficacy.

Lux (lm/m^2)—the SI unit of illuminance. One lux is one lumen per square meter. (IES RP-16-10).

Max to Min Uniformity Ratio—a design criteria to assure that light is distributed evenly across the entire field. A max/min uniformity ratio of 2:1 means that the brightest point is no more than double any other point.

Nadir—the angle pointing directly downward from a luminaire or zero degrees.

NEMA—National Electrical Manufacturers Association

NFPA—National Fire Protection Association

Non-Directional Luminaire—luminaire types which are not designated directional.

Non-Linear Load—a non-linear load is one where the impedance of the load changes with the magnitude of the applied voltage and/or the current through the load. When voltage is applied to a non-linear load the resulting current waveform may be significantly different in form from the waveform of the applied voltage.

Photo Control or Light-Activated Switch—a photoelectric switch that controls lighting by the level of daylight illuminance. (IES RP-16-10).

Power Factor—the power input in watts divided by the product of input voltage and input current of a fluorescent lamp ballast or LED driver, as measured under test conditions.

Power Source—a transformer, power supply, battery, or other device capable of providing current, voltage, or power within its design limits. This device contains no additional control capabilities. (IES RP-16-10)

Power Supply—an electronic device capable of providing and controlling current, voltage, or power within design limits. (IES RP-16-10)

Sky glow—effect of brightening of the night sky that involves scattering of lighting toward an observer from components in the atmosphere.

Solid-State Lighting (SSL)—the term—solid state refers to the fact that the light is emitted from a solid object—a block of semiconductor—rather than from a vacuum or gas tube, as in the case of an incandescent and fluorescent lighting. There are two types of solid-state light emitters: inorganic light-emitting diodes (LEDs) or organic light-emitting diodes (OLEDs). (Sandia National Laboratories)

Total Harmonic Distortion (THD)—is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

UL—Underwriters Laboratory

UPS—Uninterrupted power source or uninterrupted power supply

VFD—Variable frequency drive

Appendix B
List of Reference Standards

Lighting product certification and qualification programs such as Energy Star and DLC employ a number of standards in their evaluation process, and a list of standards that are often used in this process is given below. This list is a subset of the "Methods of Measurement and Reference Documents" that are part of the Energy Star certification process. Standards that are not explicitly required by Energy Star are noted in the table.

Organization	Identifier	Description
ANSI/NEMA/ ANSLG	C78.377-	Specifications for the Chromaticity of Solid State Lighting Products
ANSI/ANSLG	C82.16 (anticipated)	Light Emitting Diode Drivers—Methods of Measurement
ANSI[a]	C82.15 (anticipated)	Robustness Testing for LED Drivers (need official title)
ANSI	C82.77-10	Harmonic Emission Limits—Related Power Quality Requirements for Lighting Equipment
ANSI/IEEE	C62.41.1	IEEE Guide on the Surge Environment in Low-Voltage (1,000 V and Less) AC Power Circuits
ANSI/IEEE	C62.41.2	IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1,000V and Less) AC Power Circuits
ANSI/UL	1310	Standard for Safety of Class 2 Power Units
ANSI/UL	1598	Standard for Safety of Luminaires
ANSI/UL	1598C	Light-Emitting Diode (LED) Retrofit Luminaire Conversion Kits
ANSI/UL	8750	Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products
ASHRAE	90.1	Energy Standard for Buildings Except for Low-Rise Residential Buildings
CIE	Pub. No. 13.3	Method of Measuring and Specifying Color Rendering of Light Sources
CIE	Pub. No. 15	Colorimetry
FCC	CFR Title 47 Part 15	Radio Frequency Devices
IEC	62301 ED.2.0 B:2011	Household electrical appliances—Measurement of standby power
IEC	62321 Ed. 1.0	Electrotechnical Products—Determination Of Levels Of Six Regulated Substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers)
IEEE	PAR1789	IEEE Recommending Practices for Modulating Current in High Brightness LEDs for Mitigating Health Risks to Viewers

(continued)

Organization	Identifier	Description
IES	LM-79-08	Electrical and Photometric Measurements of Solid-State Lighting Products
IES	LM-80	Measuring Lumen Maintenance of LED Light Sources
IES	LM-82	Method for the Characterization of LED Light Engines and Integrated LED Lamps for Electrical and Photometric Properties as a Function of Temperature
IES	LM-84	Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires
IES	RP-16	Nomenclature and Definitions for Illuminating Engineering
IES	TM-21	Projecting Long Term Lumen Maintenance of LED Sources
IES	TM-28	Projecting Long-Term Luminous Flux Maintenance of LED Lamps and Luminaries
IES[a]	TM-30	IES Method for Evaluating Light Source Color Rendition
NEMA	LSD 45	Recommendations for Solid State Lighting Sub-Assembly Interfaces for Luminaires
NEMA	SSL 7A	Phase Cut Dimming for Solid State Lighting: Basic Compatibility
NEMA[a]	410	Performance Testing for Lighting Controls and Switching Devices with Electronic Drivers and Discharge Ballasts
NFPA[a]	70	National Electrical Code (NEC)
NFPA[a]	101	Life Safety Code
NCSEC[a]	Energy Conservation Code	NC Energy Conservation Code
NCSBC	Building Code	NC State Building Code

[a] Not required as part of the Energy Star qualification process.

Appendix C
Examples of Expected Performance from LED Lighting Systems

Interior LED Fixture Example Specification

I. Application and types

a. Recessed Troffers Grid, Modular and Z Spline

b. Linear

II. Construction/Finish

a. No visible welding, no plane-protruding screws, latches, springs, hooks, rivets or plastic supports viewed from the occupied (room) side are allowed.

b. Air-handling capability (optional)

c. Recessed, Type IC (intended for insulation contact) (optional)

d. Earthquake clips (optional)

III. Maintenance

Include the following requirement if field replaceable modules are desired:

a. Power supplies/drivers/ballasts, LED arrays, boards or light engines shall be easily field replaceable using common hand tools (e.g., screwdrivers, pliers, etc.) and without uninstalling the luminaire

IV. Electrical and Photometric Requirements

1. Electrical

a. Operating voltage: 24 Vdc, 120 Vac at 60 Hz, 277 Vac at 60Hz, or universal voltage (120, 220/240, 277 Vac at 50/60 Hz)

b. Power factor: ≥ 0.90 (at full luminaire output and across specified voltage range)

c. Total harmonic distortion: ≤ 20% (at full luminaire output and across specified voltage range)

d. Transient and surge protection: ANSI C62.41-2002 Category A surge protection standards up to and including 2.5 kV for interior fixtures.

e. Sound: Class A not to exceed a measured value of 24dB

f. Maximum standby power: 1W

g. Warranty: 10 year non-prorated on complete fixture including driver.

h. LED arrays in the product(s) will be considered defective in material or workmanship if a total of 10% or more of the individual light-emitting diodes in the product(s) fail to illuminate during normal operation after installation.

i. Driver Robustness

LED Power Supply/Driver

i). Driver efficiency (at full load):

ii). ≥ 85% for drivers capable of ≥ 50 watts

iii). ≥ 80% for drivers capable of < 50 watts

iv). Federal Communications Commission (FCC) compliance: FCC 47 Part 15 Non-Consumer limits for EMI/RFI emissions

j. Temperature Rating

Each luminaire shall be designed to operate at an average operating temperature of 25°C.

The operating temperature range shall be 0°C to 25°C.

k. Thermal management

The thermal management (of the heat generated by the LEDs) shall be of sufficient capacity to assure proper operation of the luminaire over the expected useful life.

The LEDs manufacturer's maximum junction temperature for the expected life shall not be exceeded at the average operating ambient temperature.

The LED manufacturer's maximum junction temperature for the catastrophic failure shall not be exceeded at the maximum operating ambient temperature.

The driver manufacturer's maximum case temperature shall not be exceeded at the maximum operating temperature. Thermal management shall be passive by design. The use of fans or other mechanical cooling devices shall not be allowed.

l. Flicker criteria

Consider IESNA standards for flicker and IEEE PAR1789 Recommended Practice to limit flicker to acceptable levels. Flicker needs to be considered at both the luminaire level when fully powered and when dimmed.

m. EMI/RFI

The luminaire and associated on-board circuitry must meet Class A emission limits referred in Federal Communications Commission (FCC) Title 47, Subpart B, Section 15 Non-Consumer requirements for EMI/RFI Emissions.

n. Inrush Current

Consult NEMA 410, especially Table 2.

o. Manufacturer Criteria

Manufacturers shall be firms regularly engaged in the manufacture of recessed lighting fixtures of types and ratings required, who have a service organization in the continental US, and whose products have been satisfactorily used in similar service for not less than 5 years. The manufacture of the fixtures shall comply with the provisions of all applicable code and standards. All fixtures shall be tested before shipping.

2. Photometric & Colorimetric Performance

a. Photometric

i). Minimum initial delivered luminaire lumens

a). Identify each type of fixture and the expected delivered luminaire lumens.

ii). Minimum Luminaire Efficacy (LE) or Luminaire Efficacy Rating (LER) :

Energy Star and DLC certified products are a source of potentially acceptable luminous efficacy levels. –

b. Colorimetric

i). Correlated Color Temperature (CCT): Only allowed CCTs are 2700K, 3000K, 3500K, 4000/4100K, 4500K and 5000K

ii). Acceptable tolerances as provided in ANSI C78.377-2015 (LED)

iii). Color Rendering Index (CRI) [R_a] ≥ 80 with a positive R_9 value

iv). Color shift of no less than Δu'v' < 0.007 during the warranty period

Exterior LED Fixture Example Specification

I. Application

a. Street and Walkway Luminaires

b. Exterior Wall Luminaires

c. Parking Garage Luminaires

d. Perimeter and Security Lighting

3. Correctional and Institution Lighting

In correctional institutions, it is imperative that a large block of LED lights come on instantaneously. The system design has to take this into consideration when designing the electrical power source, and the number of circuits supplying the perimeter lights. When the perimeter security lights are backed up by standby generators, the generator selection has to take into consideration the LED lighting load and the potential inrush current on the generator starting. The back-up generator system shall take into consideration the impact of SSl lighting on other loads on the same generator system, and consider separating the LED lights via a separate transfer switch. Additional intertie protective relaying shall be provided for the Standby generator and the Utility service to avoid potential total black out situations. Ensure that the fence is grounded properly. Each lighting pole shall be grounded and connected to the fence grounding loop. In case of electronic intrusion detection at the perimeter fence, conduct analysis to rule out possible interference between the two electronic systems.

- Starting inrush limited to 40 times normal.
- Multiple drivers to drive multiple LEDs, to ensure continuous operation.
- Glare rating below 40; to be proven by vendor's photometric calculations
- Corrosion resistant housing and wet location rating

II. Construction/Finish

a. Construction/Finish/Appearance Shall be selected by the user for the specific application desired. In particular, the environmental exposure should be considered when selecting the construction and finish. For example, luminaires used in a coastal setting should be resistant to salt water corrosion.

b. Lenses shall be UV Stabilized or UV Resistant if exposed to sunlight.

c. All outdoor fixtures shall be suitable for damp or wet location. Luminaires intended for use in wet locations should also have at least an IP65 rating as defined by IEC 60598.

III. Maintenance

a. Fixtures with replaceable and upgradable components are preferred. Power supplies/drivers/ballasts, LED arrays, boards or light engines shall be easily field replaceable using common hand tools (e.g., screwdrivers, pliers, etc.) and without uninstalling the luminaire

IV. Electrical and Photometric Requirements

1. Electrical

a. Operating voltage: 24, 48, 60, 380 Vdc, 120 , 208, 240, 277, 480Vac at 60Hz, or universal voltage (120, 208, 220/240, 277, 480 Vac at 60 or 50/60 Hz). Fixture voltage should match the application voltage.

b. Power factor: ≥ 0.90 (at full luminaire output and across specified voltage range)

c. Total harmonic distortion: ≤ 20% (at full luminaire output and across specified voltage range)

d. Transient and surge protection: ANSI C62.41-2002 Category A surge protection should be a minimum of 10kV for exterior fixtures utilizing devices compliant with UL 1449. In many cases, higher surge protection may be appropriate and should be evaluated per NFPA standard 780.

e. Sound: Class A not to exceed a measured value of 24dBa

f. Maximum standby power: 1W

g. Warranty: 10 year non-prorated on complete fixture including driver.

h. LED arrays in the product(s) will be considered defective in material or workmanship if a total of 10% or more of the individual light-emitting diodes in the product(s) fail to illuminate during normal operation after installation.

i. Temperature Rating

The ambient operating temperature range shall be -40°C to 40°C. Carefully evaluate certain circumstances where this condition may be considered.

j. Thermal management

The thermal management (of the heat generated by the LEDs) shall be of sufficient capacity to assure proper operation of the luminaire over the expected useful life.

The LEDs manufacturer's maximum junction temperature for the expected life shall not be exceeded at the average operating ambient temperature.

The LED manufacturer's maximum junction temperature for the catastrophic failure shall not be exceeded at the maximum operating ambient temperature.

The driver manufacturer's maximum case temperature shall not be exceeded at the maximum operating temperature. Thermal management shall be passive by design. The use of fans or other mechanical cooling devices shall not be allowed.

k. Flicker criteria

Consider IESNA standards for flicker and IEEE PAR1789 Recommended Practice to limit flicker to acceptable levels. Flicker needs to be considered at both the luminaire level when fully powered and when dimmed.

l. EMI/RFI

Fixture shall meet FCC Part 15 standards for conducted and radiated emissions.

m. Inrush Current

Consult NEMA 410, especially Table 2

n. Manufacturer Criteria

Manufacturers shall be firms regularly engaged in the manufacture of recessed lighting fixtures of types and ratings required, who have a service organization in the continental US, and whose products have been satisfactory use in similar service for not less than 5 years. The manufacture of the fixtures shall comply with the provisions of all applicable code and standards. All fixtures shall be tested before shipping.

o. Control Criteria

All installed outdoor lighting shall be controlled by a photocontrol or outdoor astronomical time switch control that automatically turns OFF the outdoor lighting when daylight is available.

2. Photometric & Colorimetric Performance

a. Photometric

Pole luminaires shall meet IES full cutoff criteria and shall be available in multiple distribution patterns including Type II, Type III, Type IV and Type V.

The lumen output of the fixture shall not decrease more than 20% over the defined operational lifetime of the fixture.

Pole and parking garage luminaires shall preferably employ design features that reduce observer glare

Minimum Luminaire Efficacy (LE) or Luminaire Efficacy Rating (LER):

1. Lumen Output <5000 lm: 60 lm/W
2. Lumen Output 5000 lm – 10000 lm: 70 lm/W
3. Lumen Output >10000 lm: 75 lm/W

b. Colorimetric

Color temperature range shall be in the 4,000–5,100 Kelvin. Fixtures shall have a minimum color rendering index of 70 CRI.