CELMA

Federation of National Manufacturers Association for
Luminaires and Electrotechnical Components for
Luminaires in the European Union

CELMA Guide for OEM's and Producers of LED Based Luminaires

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TABLE OF CONTENT

INTRODUCTION

Design and production of LED based luminaries requires specific know-how and competences. Some of the relevant aspects to be taken into consideration by OEM's and producers of LED based luminaries are summarized in this document.

Selecting the right partner will help through the relevant questions and will help determine the right combination of company, market, application, lamp or luminaire.

1. First Fundamental Decision

For developing a LED based Luminaire it must be decided:

- Do you have sufficient experience and resources on your own
- Or will ou take the benefit of a partner with is an expert in the field of LEDs, associated components and electronics

2. Second Fundamental Decision

Do you want to?

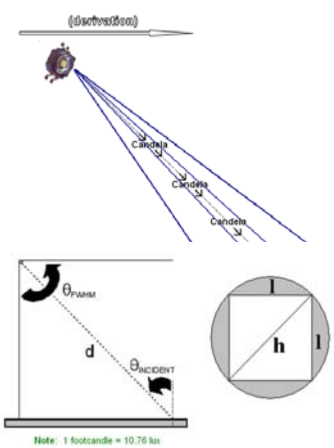
- Buy LED "light engines" and incorporate these into your existing or new lamps or luminaires
- Do you want to develop a luminaire consisting of LED modules with or without the assistance of third parties?

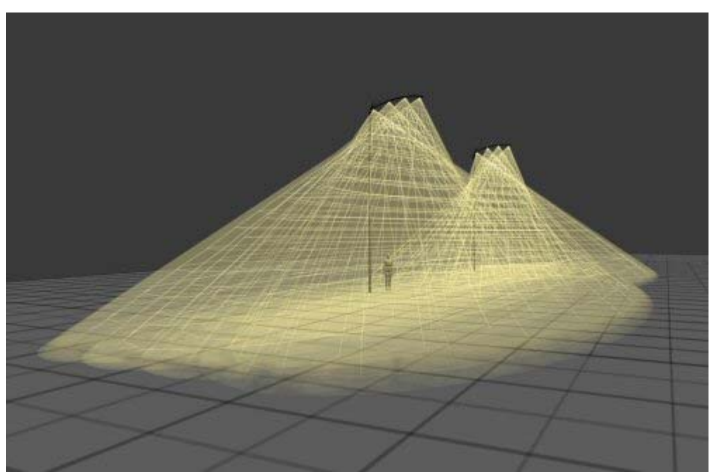
Your decision should be based on:

- Your core competency; is it electronic design or metal fabrication?
- Time to market
- Resources

3. Lighting Effect

Objective:
By ascertaining the light level which is needed, you will be able to determine the amount of LEDs you need and the combination of flux output the LEDs need to provide.





You should consider:

- LED flux output is normally quoted in Lumens (lm)
- Optical effects
  - A 90lm LED with no secondary optics, provides a very different lighting effect than the same LED with a 15° secondary optic
- Losses
  - Some LED manufacturers quote lumen values after "flash" test at the final stages of production. The Flash test is for a fraction of a second and with a temperature, often quoted as the Junction Temperature (Tj) of 25°C. For calculation of the light output of the luminaire, the flux at the expected Tj has to be used (available form the manufacturer's information).
  - Thermal Losses: As LEDs reach operating temperature, good thermal management (i.e. minimising thermal resistance, heat-sinking etc.) will have an impact on the thermal losses
  - Driver Losses: A well designed and optimised driver and power supply will increase the system efficiency.
  - Optical Losses: Secondary optics whether they are lenses, reflectors or diffusers have an efficiency value. Well designed and implemented optics minimise these losses and enhance a lamp or luminaire performance relative to the application

Drive current also has an influence at this stage as it increases the temperature of the LED which causes a further reduction of the efficacy (lm/W).

You should consider:

- Is efficiency (lm/W) your principal requirement? More LEDs driven at an optimised drive current (~350mA) to maximise the lamp or luminaire efficiency, may have an impact on the Bill of Materials (BoM)
- A smaller number of LEDs, driven at higher drive currents (~700mA), may actually reduce your BoM cost, but prove to be less efficient (lm/W)
- Your application should determine which route you follow

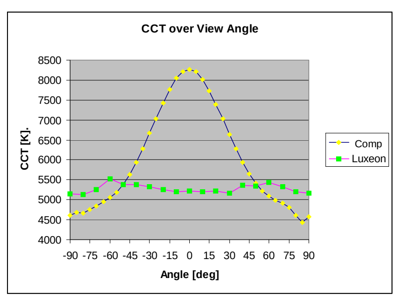
4. Colour Temperature (CCT)

Objective:

Selecting the colour temperature which is appropriate for your application, but is also supportable and available consistently through the supply chain and for the life of the product.

You should consider:

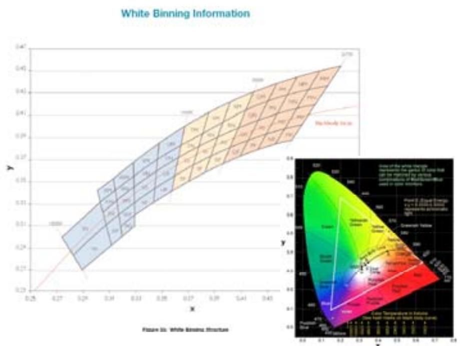
- What lumen output do you require, this may have an impact on the CCT range you select, for example some very warm white LEDs (~2700K) may sacrifice lumens in order to achieve the desired CCT
- Can your LED supplier, provide consistent support for LEDs in the CCT range or Bin that you have selected?
- And can these volumes be supported across the life of the lamp or luminaire?
- Colour Rendering Index (CRI) requirements, can also have an impact on your CCT selection. In some LED manufacturers case, the warmer the white, the higher the CRI, but you should check individual manufacturers data
- Colour consistency over viewing angle.
- You should know the CCT depending on the viewing angle how this and how this would affect your in your application. You should also consider that adding a secondary optic, may well exaggerate the CCT difference. You should consider the human eye's sensitivity, which is different at different CCT points



- Knowledge about the manufacturing
- processes of White LEDs will help to
- understand how to optimise the system.

There are two ways of producing high intensity white-light using LEDs. One is to use individual LEDs that emit primary colours e.g. red, green, and blue, and then mix the colours in ratio's to produce white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light. Additional effects can be created by mixing white (phosphor converted) LEDs with primary colour LEDs

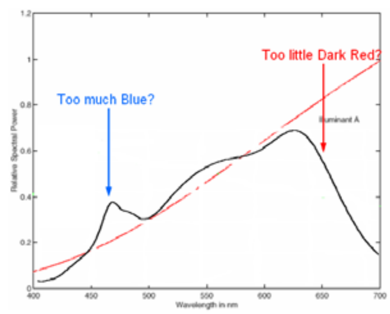
Production variations do still
of CCT points on the black body curve
precise and LED manufacturers provide
LEDs that fall into colour bins, above
and below the black body curve



Much of the development work by various LED manufacturers is focused in the area of improving CCT targeting. You should expect to see ongoing improvements in this important area

You should also consider:

- Does your application need white light of a stable colour temperature
- Or do you demand a tuneable colour temperature to create different effects

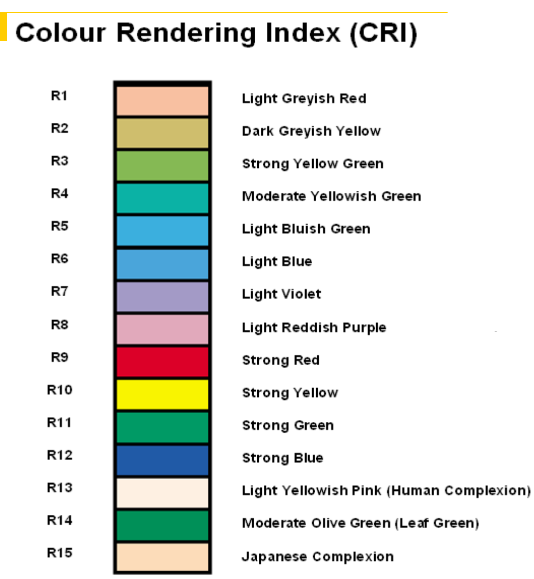


5. Colour Rendering Index (CRI)

Objective:
Meeting the CRI requirements of your lamp or luminaire design, by selecting the right LED or combination of LEDs

You should consider:

- White LEDs come with a fixed CRI.
- Mixing LED (solid colours and white) can have an impact on the CRI, as well as total lumen output and LPW efficiency
- Does your proposed design lend itself to single LEDs or can you combine different colour LEDs (whether they be white or solid colour LEDs)?



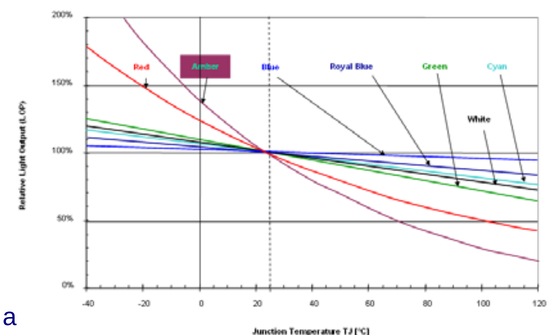
- Examine the manufacturer's data sheet carefully. Is the quoted CRI figure; an average across all the Ra values, just some of the Ra values or a specific Ra value. What does your particular application demand?

6. Ambient Environment & Temperature Considerations

Objective:
The ambient environment and particularly the temperature should be an important consideration and considered in respect of the LED junction temperature (Tj)

You should consider:

- The light output of LEDs declines at higher temperatures. As a guide AlInGaP technology technology (red, amber) looses more losses more light at higher operating temperatures than InGaN technology (blue, green and white)



- Colour point (solid and white) can shift a specifically amber LEDs exhibit some significant colour shift
- LED manufacturers quote values in their data sheets relating to maximum junction temperatures (Tj), this is usually in respect of reliability and lumen maintenance
- Some LED manufacturers define certain LED characteristics according to an ambient temperature in their data sheets. These ambient temperatures are often correlated to the junction temperature of the LED. This ambient temperature does not describe the temperature of the ambience around the luminaire. It is typically the air temperature surrounding the module. For easy measurement of the temperature a reference point tc is defined by the manufacturer of the LED module.
- Junction temperature, thermal design and heat sinking, may have an impact on the aesthetic design as well as the BoM cost, of your lamp or luminaire

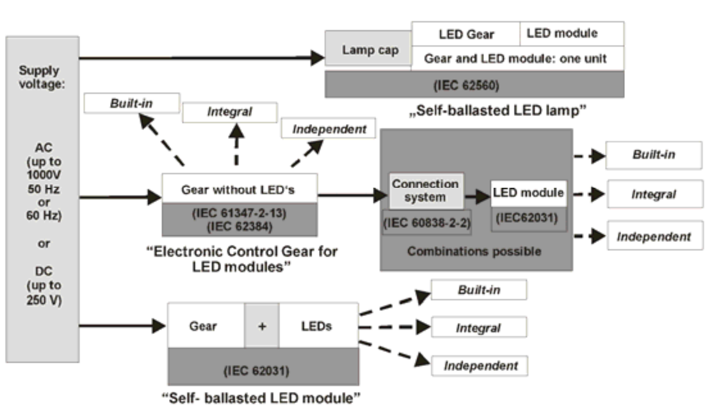
Your particular application and design may or may not require you to take very particular care of the temperature considerations. For example an exterior luminaire installed in the Middle East, where ambient temperatures could be significantly high, may be designed in a very different way to that of a luminaire used at lower temperatures as in the north of Europe.

7. Standards

Objective:
CELMA has published a separate guide relating to the standards appropriate to designing and building LED lamps and Luminaires.

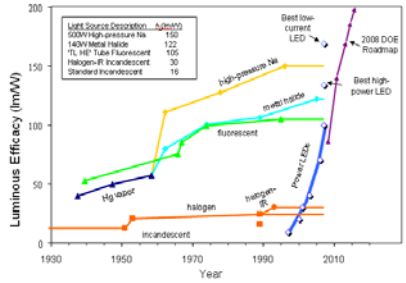
An overview of this can be seen below;

Overview of systems composed of LED modules and control gear



Conclusion:
Please consult on [CELMA website]() the full CELMA guide, titled LED related standards

8. Efficacy



- Emerging ~ 100 lm/W phosphor white power LEDs
- Expect ~ 150 lm/W power LED performance within the next 3-5 years

Objective:
LED technology and specifically phosphor converted white LEDs have made significant improvements in light output and efficiacy (lm/W). Much R&D effort is focused in this area, with much of the effort being focused on improving Quantum Efficiency (Internal and External). Some LED manufacturers are also working in areas that include; reducing forward voltage (Vf), which has a direct impact on power consumption and also reducing the “droop effect” associated with higher drive currents. Additional areas for R&D effort include phosphor technology

You should consider:

- The comments in section 3.0.0.
- That the luminaire design, the secondary optics (see 14.0.0), the driver as well as the junction temperature have an important impact on the efficacy of the luminaire system.
- With your application in mind, what is the target for minimum LED efficacy (lm/W)?
- Supportability and ongoing support of particular Flux (lumen output) LEDs
- Optimising the drive current and number of LEDs in your lamp or luminaire, may have an impact on the overall BoM cost appropriate to your application

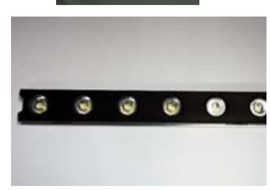
9. Integration into luminaire design

Objective:
As a light source, LEDs do give the designer the freedom to design significantly different luminaires.

You should consider:

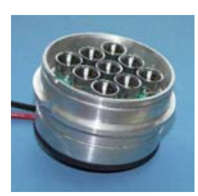
Can the luminaire be used as the heat-sink?

- What is the lighting effect required? (also see 3.)
- Do you need special encapsulation against harsh ambient conditions (IP class)?



- High power LEDs usually come in two formats
  - Point source, often 1mm²
  - LED die clusters

  Each has its own optical characteristics, which can be incorporated into a design and or secondary optics



Designers should also consider:

- Time to market
- Resources
- Core skills
- Using a ready made light engine
- Or develop their own light engine

Conclusion:
LED light sources do give you the flexibility to be different!

10. Reliability & Lifetime Requirements of Lamp or Luminaire

Objective:

LED manufacturers provide reliability and lifetime data in relation to the LED Junction Temperature (TJ), tc temperature and driving current.
The L70, the operating time until the LED flux is depreciating to 70 % of its initial flux has become a common definition of the LED lifetime.

You should consider:

- The ambient temperature, this has an effect on the overall lamp or luminaire temperature
- The thermal resistance of your design, impacts on the lamp or luminaires ability to sink heat away from the LED junction
- Does your selected LED supplier provide data in a Bx format for mortality and Lx format for lumen maintence?
- Challenge the data, is this data related to theoretical or real life testing?
- Has the LED manufacturer used a robust mathematical model to extract the lifetime data?
- At what junction temperature and drive current is the reliability data derived?
- What is the sample batch of the reliability data?
- Can you compromise your heat-sink design and optimise your BoM costs, to meet the life time requirements of your particular application?
- What is the impact on your business and any potential field failures of lamp or luminaire?
- Can your LED supplier provide you with ppm or FIT (Failure In Time) failure rate data? Is this to the demanding automotive level of <10ppm

Conclusion:

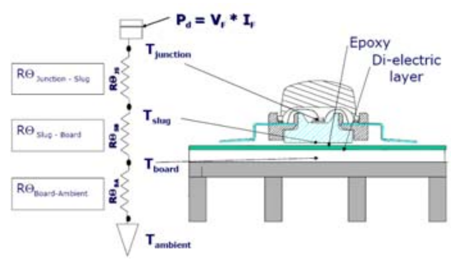
An appropriate partner will guide you through their reliability data. Some possible partners can provide models that show; drive current, Tj and reliability curves, that are appropriate for your particular set of circumstances.

11. Thermal Management

Objective:

The conversion rate of electrons to photons in an LED is expressed as a Quantum Efficiency. Excellent LEDs today achieve a quantum efficiency of 45%. The excess energy in the form of heat is therefore required to be soaked away from the LED junction. LED manufacturers are focusing R&D effort on the Internal Quantum Efficiency (IQE) and External Quantum Efficiency (EQE) of LEDs in an effort to improve the efficacy (lm/W) of LEDs. The best LEDs today are approaching 100lm/W, but you should consider that there are the other losses associated and illustrated in 3.

The overall objective of a correctly designed lamp or luminaire, is to maintain the Tj at a value, certainly less than the manufacturers recommended value and appropriate with the application and life expectancy of the lamp or luminaire



You should consider:

- What is the life expectancy of your product?
- The life time of the LED depends on the junction temperature Tj. The max Tj max must not be exceeded in order not to destroy the LED. As a reference point a tc point is defined on the LED module.
- What is the maximum tc value quoted by the LED manufacturer? (You will have to differentiate between the tc value related to a particular lifetime and the absolute maximum tc, which must not be exceeded in order not to destroy the LED.

- What is the thermal resistance of the system, from the LED through to the heat-sink?
- Do you have the resources to trial heat-sink material and different designs?
- Can you use a software package to model your heat-sink and application conditions?
- Do you have the appropriate equipment in order to x-ray your solder joints and thermal path?
- What materials can or could be used in your PCB and heat-sink design?
- Can these be optimised to meet BoM constraints?

Conclusion:
This is recognised as the most critical area of lamp or luminaire design. There are potential partners who have the experience and the software models in order to aid this part of the design and provide you with the solution that is appropriate for your application.

12. Electrical insulation between circuits and metal accessible parts

On the market there are different types of LED control gear available. The driver may provide insulation between input and output circuits and, depending on this insulation level, it is necessary to design the correct insulation between the LED circuits and accessible metal parts (heat-sink or metal enclosure). The control gear standard (EN 61347-2-13) is under revision, but it is possible to have the following classification:

- Auto-wound control gear or control gears with capacitor or resistor divider. In this case no insulation is provided between the supply and the output circuit. The luminaire manufacturer shall design the insulations considering LED circuits as it is directly connected to the supply and therefore provide the insulations required for the rated supply voltage, independently to the value of voltage within or between LEDs.
- Separating control gears. In this case the insulation provided by the control gear is only “basic” insulation. This classification, even if it is allowed by the standard, is not commonly used because it does not give effective advantages. The insulation between the LED circuit and accessible metal parts shall be, also in this case, designed for the rated supply voltage
- Isolating control gears. The insulation provided between input and output is double or reinforced insulation. The voltage delivered is above SELV limits (50V a.c. or 120V d,c) and it is identified by the marking U_{out} on the control gear. In this case the insulation between the LED circuit and the outer case depends on the class of the luminaire and shall be:
    - Class I luminaire: Metal parts of class I luminaires which are accessible in normal use must be earthed. The insulation between LED circuit and accessible metal parts shall fulfill the requirements for basic insulation (e.g. creepage and clearance distances, electric strength test, insulating resistance), based on the output voltage of the converter (U_{out}).
    - Class II luminaire: LED modules must be protected additionally in class II luminaires. Creepage distances and clearance to accessible metal parts must fulfill the requirements for double or reinforced insulation (based on the output voltage of the converter U_{out}), the electric strength test from the output wiring of the converter to accessible metal parts shall fulfill the requirements for double and reinforced insulation (based on the output voltage of the converter U_{out}).

- “SELV” or “SELV Equivalent” control gears. They are the most used type of control gear because they give advances in the luminaire construction. They are marked with the sentence ”SELV” or “SELV Equivalent” or by the symbol for safety isolating transformer (see below). The insulation provided by the control gear is a “double or reinforced insulation” and the voltage provided is below the dangerous limits. In this case the luminaire manufacturer may design the insulation only according to the maximum voltage in the output circuit. It means practically a single layer of insulation with reduced thickness and with reduced requirements of creepage and clearance distances.

Symbol for safety isolating transformer

Reduced thickness of insulation gives advantages also for the thermal management on LED. It is known that electrical insulating material are also thermal insulating material; the use of less insulation allow the heat to be transferred easily from the LED junction (part connected to the electrical circuit to be insulated) to the heat sink or to the metal case of the luminaire (accessible part which may be touchable).

Summary:
The luminaire design depends on the type of converters. SELV converters with a SELV output voltage allow an installation according to class III requirements with very limited requirements for the insulation. If the voltage is below 25V AC or 60V DC, it is possible to have access to the circuit in many types of luminaires.
Non SELV isolating converters or converters with Uout > 25V AC or 60V DC require LED modules to be designed for a higher voltage, the luminaire has to take this higher voltage in consideration as well.

Special attention should be taken to the temperature of the LED module as the additional insulation may require a larger heat sink to compensate the higher thermal resistance.

13. Driving your Power LED

Objective:
Fundamentally, you have a choice of using “off the shelf” drivers (ballasts) or designing your own driver solution

You should consider:

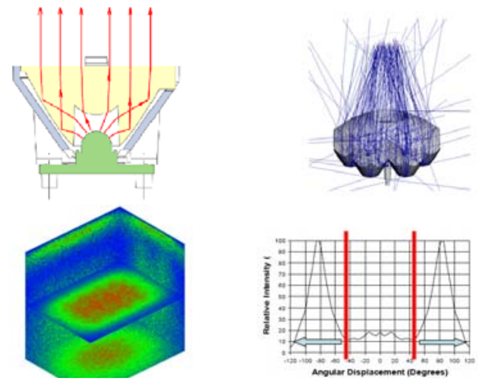
- What is the driver topology and is this appropriate to the application?
- Do you need to dim the LEDs?
- Are you driving a single colour or mixing different colours?
- What are the efficiency requirements of your solution?
- Are there any space constraints that should be considered in the design?
- What is the input voltage?
- Generally, the efficiency of dual voltage drivers of say 110/230v AC input, will be lower than a dedicated single voltage driver. Is a dual voltage driver required?
- How many LEDs will you want to drive? Is the driver optimised for the number of LEDs
- Does the driver solution allow thermal feedback so that over temperature sensing reduces the drive current and reduces the possibility of damaging LEDs?
- Do you want to integrate the driver into your luminaire or do you need an external driver unit (for maintenance or thermal reasons?
- The driver has an important impact on the lifetime of a luminaire. Hence take care for a good thermal management and scrutinize the lifetime data you receive from your supplier.

Conclusion:
There are organisations, which you may choose as a partner or partners, that provide the; finished drivers or the reference driver designs

Selecting the right partner, will help you through these questions and help you determine which is the right driver design for your; company, market, application, lamp or luminaire.

14. Secondary Optics

Objective:
High power LEDs usually come in two formats; point source, often 1mm² LED or die clusters. Each has its own optical characteristics, which can be incorporated into a design and or secondary optics



You have a number of fundamental decisions to make:

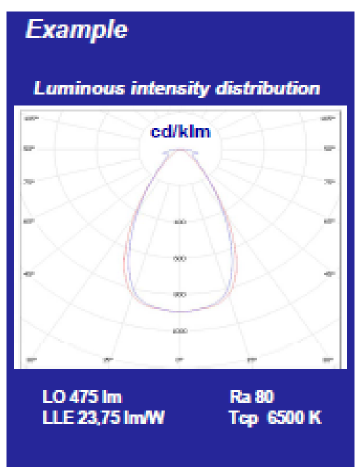
- Don't use any secondary optics
- Use off-the-shelf secondary lenses
- Use off-the-shelf secondary reflectors
- Use a diffuser or light guide
- Design your own or have your own custom optical system

You should consider:

- What effect are you trying to create?
- Do you need a secondary optic?
- Can you incorporate an optical feature into any other part of your product design?
- What are the optical losses associated with the secondary optics?
- Are the secondary optics production and assembly friendly?
- Will your BoM budget allow a secondary optic?
- Can your LED supplier provide you with the necessary ray-set data so that you can design your own optical systems?

Conclusion:
There are organisations, which you may choose as a partner or partners that provide secondary optics or custom design solutions.

15. Presentation of photometric data for LED luminaires



This CELMA Guide deals with the measurement and presentation of essential photometric data for LED luminaires until the standards EN13032 Part 1 and 2 are revised.

Details about the measurements:

- The performance measured from LED luminaires with its own control gears powering all lamps used in the luminaire
- Total LED luminaire light output and light distribution measured under stabilized conditions
- Total LED luminaire power measured under stabilized conditions

Essential LED luminaire data:

- Luminaire light output (LO): total flux of the luminaire measured under practical specified conditions with its own lamp and equipment
- Luminaire power (Pi): the total rated power (in watts) of a specific luminaire should be obtained in accordance with EN 15193 in Annex B
- Luminaire lumens (light output) efficacy (LLE): total luminaire light output, (LO) divided by the total luminaire power, (Pi)
- Normalised intensity table: the tabulated luminous intensity values normalised to the total luminaire output from the luminaire shall be given in $cd.klm^{-1}$ or in cd
- Normalised luminance table: the values in the luminance table shall be normalised to total lumen output from the luminaire and shall be given in $cd.m^{-2}.klm^{-1}$ or in $cd.m^{-2}$
- Shielding angle
- Glare Rating (UGR/GR) is to be considered

Essential LED Lamp and Luminaire data:

- Correlated colour temperature (T_{CP}), K
- General Colour Rendering Index (CRI), Ra
- Lifetime Lxx, Fxx (h)
- Lamp Lumen Maintenance Factor (LLMF)
- Lamp Survival Factor (LSF)
- Operating temperature on the module (T_C)