Ten things you should know about LED
LED: Light source of the future

LED is without doubt the most talked-about issue in the lighting industry these days. What makes LED so interesting?

The LED technology is in rapid development, and LED has many applications. Because of the robustness of the diodes, LED is fast becoming the preferred light source in cold environments such as cold rooms and freezer rooms, and for demanding use, such as on board ships, rigs, and moving machinery. The longevity of the diodes makes them popular in inaccessible areas on top of windmills, telecommunication towers and chimney stacks, while the size makes them particularly suitable in really small spaces.

Other applications are emergency lighting, task lights, downlights, spotlights and other general lighting products, and as replacement for conventional light sources wherever possible.

At Glamox, we aim to produce LED luminaires with single LEDs, LED modules and LED drivers of the best possible quality. We always use the best quality components for our purposes, from the best manufacturers.

Ten things you should know about LED

On the following pages we are presenting ten aspects of LED technology that we believe are essential for the understanding of advantages and challenges related to the use of LED.

Glamox Technology Team

LED terminology

**LED**: Light Emitting Diode.

**LED MODULE**: An assembly of one or more LEDs on a printed circuit board.

**LED DRIVER**: The power control used to manage the light output of the LED module.

**TOTAL LUMINOUS FLUX**: The amount of light coming from a light source or luminaire.

**TOTAL POWER CONSUMPTION**: The power consumption of the whole luminaire or system, including losses.

**LM/W**: Lumen per watt. Lumen out of the light source or luminaire, divided by the total power consumption. Also known as efficacy.

**CCT**: Correlated Colour Temperature. Whether the light is perceived as warm, neutral or cool white.

**MACADAM'S ELLIPSE/STEPS**: A measure of colour tolerance.

**CRI**: Colour Rendering Index. A measure on how well a light source renders colours. Also known as Ra.

**L70**: The time elapsed to a LED emits 70% of its original light output. A typical lifetime is L70 minimum 50,000 hours.

**T<sub>amb</sub>**: Ambient temperature.
LED is a small and powerful light source that is changing the world of lighting.

A Light Emitting Diode (LED) is an electronic component that generates light in a semi-conductor material. Using the right materials, a diode may produce visible light of various wavelengths.

White light is created by either using a blue diode or “chip” and adding yellow phosphor on top of it or mixing light from one red, green and blue diode (RGB). The use of phosphor conversion is the most used method in the lighting industry, due to its high efficacy and flexible production method. The phosphor can be added directly onto each diode or as a remote phosphor plate on top of a mixing chamber. Both methods create a particular colour spectrum, or spectral power distribution for the LED depending on the phosphor layer.

LED is not a new invention and most of us are used to LED’s being red or green signal markers on your Hi-Fi or television set. These are so called – low-power LEDs. During the last couple of years “high power” LEDs, i.e. LEDs operating at powers of around 1 W, have reached a level of cost and performance that make them attractive to the general lighting industry.

Market studies forecast that in 2020, close to 50% of all new and replacement light source unit sales will be based on LEDs. Since LEDs are more expensive than conventional lighting, the value of the LED sales will be even higher.

The efficacy of the LED is measured in lumen per watt. The LED itself is expected to yield around 200 lm/W within the next decade. The LED luminaire, however, may reach an efficacy of above 160 lm/W due to system losses.

This figure shows the development in efficacy (lm/W) over time for conventional and LED light sources. Whereas fluorescent tubes are expected to reach a maximum of 120 lm/W, LEDs may reach above 200 lm/W in 2020. Note that luminaire efficacy is lower due to losses in the driver, optics, etc. (Source: Osram)
LEDs are more efficient than many conventional light sources.

One of the advantages of LED is that all the light is emitted in one direction. This entails fewer reflections inside the luminaire since we normally want the light to go downwards only. If we need a light distribution that goes both up and down, the LED is less suitable compared to e.g. a fluorescent lamp.

The performance of a LED is often measured in terms of lumen per watt or luminous efficacy. The efficiency of luminaires with fluorescent tubes is explained using the LOR or Light Output Ratio. The LOR indicates how efficient the optic is. For these luminaires, the installed power in watt is often used as a measure on the luminaire’s light output. LED luminaires, however, only use the total luminous flux.

The rated lumen value from a LED module may give an inaccurate picture of how many lumen you actually get from the luminaire. When you calculate the lumen output from a luminaire with fluorescent light sources you must take the rated lumen from the lamps and multiply with the Light Output Ratio (LOR) of the luminaire. One should pay special attention to the difference between the total luminous flux of the LED luminaire and the rated lumen output of the LED module itself.

**OUR SOLUTION:** When documenting a LED luminaire, we always list the total luminous flux of the luminaire.

For luminaires with fluorescent tubes, the wattage is often enough to understand their light output. With LED luminaires the total luminous flux is the correct measure. The same applies for luminous efficacy. Lumen per watt is the measure for the efficacy of a LED luminaire, whereas LOR is often used for luminaires with fluorescent tubes.

Conventional light sources cast a lot of light backwards, which may be lost in the optics design of a luminaire. The LED, on the other hand, emits all light in one direction.
LEDs last longer and do not need to be replaced as often as many conventional light sources.

One of the benefits of the LED is its long lifetime. Because it has no movable parts or filaments that may break, LED’s can have long lifetimes. That makes them particularly well suited where installation heights are large or when the luminaires are not easily accessible for lamp replacements.

We normally define the lifetime of a LED as the time expected for it to drop to 70 % of its initial light output. This measure is called L70. A typical L70 lifetime is 50,000 hours. For Glamox the stated lifetime is related to L70 at the stated ambient temperature ($T_{\text{amb}}$) of the luminaire.

In a lighting installation, a fluorescent lamp would be replaced 2-3 times before 50,000 hours operation time is reached. Fluorescent lamps will lose 10 - 25 % of their light output before they are replaced. The LED, however, does not need to be replaced, but its light output will drop 30% over its lifetime.

Sometimes, the LED driver lifetime is the bottle neck of the system design. If e.g. the driver lifetime is limited to 50,000 hours at the rated ambient temperature, and the LED module lifetime is longer at the same temperature, the lifetime of the complete luminaire is exhausted at 50,000 hours, unless the driver may be replaced. An easy replacement may not always be the case with built-in drivers or installation in places that are difficult to access.

**OUR SOLUTION:** We list the real lifetime of selected LED product families, i.e. how many hours it really takes before 70% light output is reached. We do this at the rated maximum temperature, which may be as high as 45 degrees C in some cases. This data is available on request.
LED lifetime is determined by the temperature inside the diode.

Inside the LED the temperature may get very high. This causes the LED to gradually emit less and less light. The higher the internal temperature, the faster the lumen degradation.

At high internal temperatures, the blue chip and phosphor layer degenerates and the LED will eventually lose light. This happens gradually and the LED will slowly fade away. The internal temperature depends on the ambient temperature. The higher temperature of the LED’s surroundings, the higher internal temperature.

A story often heard is when increasing the ambient temperature by 10 degrees, the lifetime is halved. For some Glamox luminaires, however, when increasing the ambient temperature by 10 degrees, the lifetime decreases by only 10,000 hours. This does not apply for all LED luminaires, hence luminaire specific data is available on request.

Another thing that influences lumen maintenance is the current running through the diode. The higher current, the higher temperature inside and the shorter lifetime. Proper heat management is therefore the key to control LED lifetime. In luminaires, the LED is cooled by a heat sink and the size and design of this determines the lifetime of the LED.

**OUR SOLUTION:** We provide real lifetime curves at different $T_{\text{amb}}$. They are available on request.

The light output from a LED is gradually reduced with time. Higher temperature on the LED chip (the so-called junction temperature) speeds up the degradation.
Installed lumen pack as a result of LLMF = 0.7 and 0.85. A light planner always plans for 100% light output at the end of the installation’s lifetime in order to have enough light at end of life. Maintenance factors are used to account for the degradation in lumen output and other factors and the initial light output is therefore much higher.

With a lumen maintenance factor of 0.7, lighting installations risk over dimensioning.

Since the definition of LED lifetime is related to L70, the lamp lumen maintenance factor (LLMF) is therefore 0.7. This light loss is countered by adding extra light in the lighting installation’s initial phase.

The other factors that contribute to the light installation’s maintenance factor (MF) are the light survival factor (LSF), the room surface maintenance factor (RSMF) and the luminaire maintenance factor (LMF). The product of these factors will bring the maintenance factor (MF) down to somewhere between 0.5 – 0.8 depending on application and type of luminaire. Installations with T8 luminaires with a LLMF of 0.75 will have a slightly higher maintenance factor than LED installations with a LLMF of 0.7.

Because of the LLMF of 0.7 for the LED, the lighting installation needs to be over dimensioned by a factor of 43% (1 divided by 0.7). This may lead to a higher energy consumption and a more expensive installation. Instead, light planners should pay special attention to lifetime curves and intelligent control systems.

Some of our luminaires have longer lifetimes than L70 50,000 hours. Therefore, the LLMF is higher, the lighting installation’s maintenance factor is higher and the energy waste is less. For example, with a LLMF of 0.85 instead of 0.7, the over-dimensioning is reduced from 43% to 18%.

OUR SOLUTION: For a selection of our LED luminaires, lifetime related to other lumen maintenance factors than L70 can be given on request. We also list the lumen maintenance at 50,000 hours, if this differs from L70.
LEDs come in all colour temperatures, but white LEDs are not always white.

Because LEDs do not have a full colour spectrum, we must pay special attention to their colour quality and colour rendering capabilities. Otherwise, a lighting installation with visible colour differences may be the outcome.

When LEDs are produced, the production outcome is LEDs with many different colours or colour temperatures. CIE’s 1931 colour diagram is used to create a binning structure, i.e. groups of diodes that share the same colour characteristics. The LED suppliers offer different bins to luminaire manufacturers. The fewer bins the higher cost.

Some binning systems relate to the human eye’s colour sensitivity via a model called MacAdam ellipses. The ellipses are mapped onto the binning structure in the colour diagram and their size corresponds to the LED’s colour tolerance. The size is measured in steps. The more steps, the bigger tolerance and the easier it is to spot a difference in colour. Generally, a 3-step ellipse is considered a good colour tolerance.

OUR SOLUTION: Most of our LED luminaires have a colour tolerance of 3 MacAdam steps or better.

Colour temperature indicates whether a light source is perceived as warm, neutral or cool white. LEDs may be produced in all colour temperatures, which are characterised by the dominating wavelengths. The colour temperature of a LED is defined by the blue and yellow peaks in the spectrum.

MacAdam ellipses vary in size (number of steps) according to the colour variance of the LEDs inside the ellipses. The bigger the ellipse, the more variance (less uniformity).
The colour rendering capability of a LED is influenced by its colour spectrum.

As LEDs do not have a full colour spectrum, proper colour rendering from LED luminaires may be a challenge. However, LEDs are available with very high colour rendering capabilities.

Light sources render colours differently depending on the colour of the light already present in the light emitted from the source. For example, if the light emitted does not contain any red light or wavelengths, red colours will look grey under this light. We measure this effect by the colour rendering index, CRI or Ra. $R_a$ is the average value of the light source’s ability to render eight standard colours on a scale from 1 to 100, where 100 is the best. For indoor applications, an $R_a$ of 80 is considered good.

LEDs may contain less red wavelengths that can cause poor rendering of red colours. It is possible to avoid this by using special materials when producing the diodes. LEDs may therefore have $R_a$ indices of up to 95. Nevertheless, one must pay special attention to the LEDs CRI or $R_a$ values.

**OUR SOLUTION:** All our LED products comply with the applicable norms for colour rendering.
Because LEDs are perceived as brighter than conventional light sources, you may design installations with lower lux levels.

“What we see we cannot measure – and what we cannot see we cannot”. In both indoor and outdoor lighting, the perceived lux levels from LED luminaires may differ from the actual light measurements.

For example, a light calculation for LED flood lights, based on conventional lux requirements, may result in too higher perceived light levels at low background luminance levels.

Why does this occur?
The standard way of calculating and measuring lux levels is based on light levels during the day. Luxmeters are tuned to filter out the visible part of radiant energy in accordance to the CIE’s spectral luminous efficiency curve for photopic or daylight vision. However, during conditions with less light, such as during dusk or dawn – or mesopic light conditions, the human eye is more sensitive to blue light. The consequence may be that your lighting installation gets more light than needed, because lux meters do not register this “extra light” at shorter wavelengths. This is not a new phenomenon, since discrepancies between e.g. high pressure sodium lamps and other conventional lamps already exist. For high luminance levels, the photopic spectral luminous efficiency curve is correct.

How can this be solved?
Scientists* have proposed a method to better resemble the human eye’s perception of light. The method represents well the eye’s responses at low luminance levels.

The method involves conversion factors that are used by multiplying the lumen output or lux level of the listed light source with the given factor, to get the perceived light level in your installation. The factors are used by dividing the required lux level of your lighting installation with the factor corresponding to the light source used. E.g. a 100 lux requirement on an outdoor LED installation may be divided with 1.7 to get 60 lux. The installation should be dimensioned accordingly.

A biological explanation of the phenomena
In daytime and during high luminance levels, the colour sensitive cone receptors on the eye’s retina come into play and we call this the photopic vision. Luxmeters are therefore tuned to measure photopic lumens. The more light sensitive rods give our night or scotopic vision. At light levels in between daylight and nightlight, the mesopic vision comes into play, a mix between the photopic and scotopic vision.

**DISCLAIMER:** This recommendation of pupil lumen conversion factors is based on available research and Glamox experience. We bear no responsibility to any claims of poor light quality (e.g. too low or too high lux levels) when using these recommendations.

*Berman, Lawrence Berkley Laboratory, 1991: Energy Efficiency Consequences of Scotopic Sensitivity

**OUR SOLUTION:** We provide advice on how to account for conversion factors when designing lighting installations.

### Conversion factors for light sources with difference colour temperatures

<table>
<thead>
<tr>
<th>Light source/luminaire</th>
<th>Colour temperature (CCT)</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure sodium (HPS)</td>
<td>2000 K</td>
<td>0.7</td>
</tr>
<tr>
<td>Metal halide (MH)</td>
<td>5500 K</td>
<td>1.4</td>
</tr>
<tr>
<td>FL/FX 60 LED (Glamox luminaire)</td>
<td>5000 K</td>
<td>1.7</td>
</tr>
<tr>
<td>Fluorescent tubes</td>
<td>3000 K</td>
<td>1.0</td>
</tr>
<tr>
<td>Fluorescent tubes</td>
<td>5000 K</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Installation with 100 lux, achieved by 12 x 400 W HPS flood lights**

**Installation with 41 lux (100 lux divided by 2.4 (1.7/0.7), which is the ratio between the conversion factors of HPS and cool white LEDs) achieved by 10 x FX60 160 W LED flood lights.** The two installations will seem equally bright to the observer.
Test with 400 W High Pressure Sodium lamps in flood lights. Average illuminance level: 286 lux.

Test with 160 W LED luminaires. Average illuminance level: 95 lux. The installation seems equally bright or brighter to the human eye. Both pictures were taken with identical parameters: Exposure time 1/2 sec; F-number: 8; ISO speed: 400.

The human eye consists of different types of photo receptors. Cones are colour sensitive to blue, red and green colours. Rods are sensitive to low light levels.

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Rods are sensitive to low light levels.
The LED driver is the “cruise control” of the LED luminaire. Without a proper driver, the LED may get too hot or unstable.

What makes a LED driver different from conventional power supplies is that a LED driver responds to the varying needs of the LED, by supplying a constant amount of power to the LED as its electrical properties change with temperature.

One of the advantages with LED is the short response time. It switches on and dims immediately and can dim from 0,1 to 100%, whereas fluorescent tubes dim from 3 to 100%. Sodium lamps have a smaller dimming range, or do not dim at all. Because of the short response time, LEDs are suitable in stairwells, warehouses and parking garages together with presence detectors.

Another advantage when driving LEDs is the efficiency when producing coloured light. Coloured light is often made from mixing light from red, green and blue light sources by dimming them individually. Some coloured fluorescent tubes are very inefficient, which is not the case for LED.

A LED driver is an electronic circuit which serves as an energy source for LEDs. The driver changes AC voltage to DC while optimizing the driving current for LEDs. Luminaires with dimming possibility or sensors require more complex drivers.

A common driver type is constant current for LEDs in serial connection. This driver type is well suited for dimming. A second type is constant voltage for LEDs in parallel connection. This type is ideal for large number of LEDs, e.g. in LED strips. It is important to check the rated current or voltage, the rated output power of the driver and the efficiency (the ratio between output and input power in per cent).

Today LED-drivers are available for almost all types of control signals. The driver is often dedicated to one type of control signal whether it is DALI, DSI, 1-10V (dimming only) or DMX. It is important is to check what type of control signal is needed for your luminaire.

OUR SOLUTION: We only use LED drivers from recognized suppliers and we make sure that the driver lifetime matches the expected lifetime of the luminaire.

The luminous flux from LEDs depends directly on the forward current (I). Since LED emits light depending on forward current, the LED light source intensity is controlled by changing the current value. However, changing the forward current value may lead to a shift in colour temperature or CRI, if not managed properly.
Total cost of ownership may be lower for LED installations.

The introduction of LED has led to a rush among owners, architects and specifiers to use the new technology in new and modernised installations. However, to use LEDs should be done with care. Not all applications are suitable for a LED installation. For example, the higher cost price of a LED luminaire compared to one using a conventional light source may not be recouped during the installation’s life time. Therefore, a total cost of ownership approach is crucial, analysing investment in luminaires, energy costs, lamp change costs, cleaning costs and others. Also, sensors should be taken into account, since they will reduce energy costs and increase luminaire lifetime further. In most cases, a LED solution’s annual costs including capital costs would be lower than that of a conventional solution.

OUR SOLUTION: We advise our customers to carefully evaluate the payback time of installations with LED versus fluorescent tubes by using our investment calculator available on our web site.

The figure explains the principle of total cost of ownership. The initial investment of the LED installation may be higher than that of a traditional lighting installation, but the LEDs lower energy consumption and maintenance cost may provide a lower total cost over the lifetime of the installation.

In this example, an installation with LED downlights is compared to an installation with compact fluorescent light sources. The conventional solution has lower total costs the first two years. After two years, the LED solution is more cost efficient.
Product guide
A selection of our LED luminaires

**Technical outdoor/indoor:**
1445, MIR LED, TL60

**Navigation lights:**
Series 65 / Series 65 Arctic

**Task lights:**
Ovelo, Ninety, L-1 LED

**Explosion proof:**
MAX ICE

**Emergency lighting:**
E80

**Pressure watertight:**
0673 LED
Flood lights:
FL 60, FX 60

Downlights:
DL 60

Escape route lights:
E85

Perimeter and obstacle lights:
HL55-P/-O

Cold area:
1771

Scan the QR code with your smart phone to access the full LED product guide on our web site.
Light influences people

Glamox is an industrial group that develops, manufactures and distributes professional lighting solutions for the global market. The Glamox Group is a leading supplier to the world’s marine and offshore markets, and a significant supplier to the professional building market in Europe. We own a range of quality lighting brands including Glamox, Aqua Signal, Luxo, Høvik lys and Norselight.

Quality and expertise
Our products and solutions are developed and tested by our engineers at our own research and testing facilities, and manufactured and certified in accordance with all relevant quality and environmental standards. They are based on the latest technology and expertise – and generations of experience.

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