LED – THE FUTURE OF LIGHTING

We know the whole spectrum

FAGERHULT

"LED's greatest advantage is also its greatest challenge. Balancing efficiency with ergonomics. Combining good economy and lighting comfort. And we're there now."

Leif Norrby, Product Development Director, Fagerhult

It's a bright new world. LED has revolutionised the lighting landscape; a high light flows ensure superb efficiency and economy, with a life span of tens of thousands of hours. From what was previously the domain of decorative accent lighting, LED technology has evolved into a practical, general lighting option. To truly embrace the benefits of LED, and to address the challenges they pose, requires completely new luminaires, rather than just changing the light source. Fagerhult are developing luminaires specifically for LEDs, creating viable solutions across the whole spectrum of a lighting project. Drawing on over half a century of lighting know-how and innovation, this approach has focused on softening the intensity of the light to create a harmony between efficiency and comfort.

What's the point of efficient lighting if no one is there?

In the early days of T5 fluorescent tubes it was apparent that high levels of light require new reflector solutions to maximise the efficiency of the light source, while reducing glare. T5 offered an increased luminance from 14,000 cd/m² to 17,000 cd/m². With LED, this has rise to 300,000 cd/m². LEDs produce an intense light which can be harsh on the eye unless managed correctly. And what is the point of saving money on lighting if no one can stand to be in that room? Fagerhult's innovative glare-reduction technology circumnavigates these issues, taking full advantage of the efficiency whilst ensuring user comfort.

New concepts in luminaire design

Free from the shackles of the specific shape or size of the light source dictating design, luminaires can become smaller, slimmer and more unpredictable. Fagerhult's Freedom luminaire takes this concept to the extreme. Combinations of linear or circular housing can be used in numerous configurations, offering the designer the opportunity to draw their own lines in light.

No one would dream of putting a fluorescent tube in a candleholder

And, by the same token, it is not possible to get the best out of LEDs if the luminaire was not designed for that technology. It requires the right design, ballast and cooling, to guarantee the level of efficiency and life span that makes the investment worthwhile.

The whole spectrum is what matters

From recessed modular fittings and downlights, through to accent lighting and interior design, Fagerhult offers a wide range of LED solutions suitable for various applications.

LED. A brief introduction

It provides light, but is not a light source in the traditional sense. It can reproduce all the colours in the light spectrum, it works best in groups and, in just a few years, has revolutionised the lighting industry. This is LED.

Short for light-emitting diode, an LED is a semiconductor that radiates light when subjected to electrical impulses – a phenomenon called electroluminescence. An LED runs on direct current (DC) and often requires a separate electrical ballast – a 'driver'. The ballast converts the mains voltage to an optimal level for the LED.

The light is generated when the electrons strive to achieve balance. An LED consists of two sections: one with an excess of electrons (n-conducting) and one with a shortage of electrons (p-conducting). The boundary between these two areas is called the p-n junction or depletion layer, and this is where it all happens. When direct current is connected to the diode, the excess and shortage balance out to create light.

The wavelength of the light emitted, and thus its colour, depends on the materials the LED is made of. The main colours are red, orange and green, and a variety of shades

The light is generated when the electrons strive to achieve balance. When the current is connected to the diode, the excess and shortage balance out, creating light.

of blue. The most common way to create a white light is to apply a phosphor-based coating to a blue diode. The phosphor converts the blue light to white light in a range of colour temperatures. The quality of the white light is affected both by the choice of LED and by the properties of the phosphor.

LEDs are very small; the active light-emitting surface is no bigger than 1–2 mm². A single diode can rarely produce enough light for a given lighting situation. For the unit to work, it must be mounted on a circuit board, with multiple LEDs combing in a cluster to form a LED module (not to be confused with retrofitted light sources). LED modules come in many varieties with specially adapted light flow and design to suit specific types of luminaires. Often professional services are required to install and replace LED modules, but some models are easy to manage even for end-users.

LED. Application areas

LED technology is the future of lighting and will develop in parallel with traditional light sources. LED is still in an early stage of development; we can expect a future in which LED is the natural choice for many more applications than today.

Indoor

In public environments, such as offices and schools, LED technology has previously only been used for more decorative-style lighting – accent lighting or colour-shifting effects. In these contexts, LED has replaced previous low-voltage halogen light sources. Now LED technology has achieved sufficient quality, energy efficiency and life span to surpass traditional solutions for general lighting as well. LED luminaires can replace both downlights and previous T5 applications in places such as corridors, offices, entry halls and conference facilities. New reflector and anti-glare technology allow the luminaires to make use of the huge light flows offered by LED while still making it comfortable for people to be in the room. Examples include Fagerhult's downlight series Pleiad G3 and the recessed general lighting system Multilume Flat. In addition to general and accent lighting, LED technology also has a place in specific environments. LED is often the preferable light source for works of art, museum artefacts or food products, as the light does not contain UV or IR radiation that can cause degradation.

LED luminaires are an ideal replacement for both downlights and T5 solutions.

Regardless of environment, LED is superior in contexts where you want to save on labour and expenses associated with maintenance.In contrast to traditional light sources, LEDs achieve full brightness immediately and, in fact, the life span of the diode is increased by frequent switching on and off.

Retail

The LED technology of today already has many benefits which can help create enhanced dynamic in-store lighting concepts, with the trends and possibilities set to continue to develop in the future.

LED solutions are superior for simulating natural light through artificial windows and on walls.

Adjustable, white LED light, which changes the colour temperature between warm and cold (2700 K–6500 K), are already a commonly used solution. Ideal for fittings rooms where clothes can be viewed in different lighting situations, LEDs can be positioned behind the mirror as a more discreet alternative to the fluorescent tubes previously used in this concept. Similarly, the small size of the LED light source makes it very useful to integrate into shelves and displays, as well as for illuminating products in small spaces.

Adjustable white LED light is also an asset in the shop itself, allowing staff to adjust the colour temperature to the season. Warm white light creates a welcoming atmosphere in winter, while cold white light creates a cooler impression in summer. And when it comes to simulating natural daylight within artificial windows and walls, this light source is also superior. The moving fluctuations are far more natural that what any other light source could present.

Sometimes a lighting concept may need a little something extra and coloured effect lighting can be just the thing. Using RGB LEDs can create a dynamic and effective lighting concept with feeling. Different colours trigger different emotions; green signals well-being and has a calming effect; yellow creates energy, blue cools and red signals passion. LED opens the door to new ways of creating mood and impressions for different occasions. A control system lets you adjust, dim and change the colour of the lighting.

The directivity and optical efficiency of LED, in combination with lenses and reflectors, make it an ideal technology for spotlights. Often better than a traditional solution, it is relatively simple to achieve the desired lit effect using less power. LEDs with a cold white light are even more effective and are the preferable solution where this type of lighting is suitable, for example in a refrigerated display case.

Outdoor

In general, LED technology is the optimal alternative for outdoor lighting. These luminaires are subject to the vagaries of weather, temperature, vibrations and human interference. Often the systems are designed so that special equipment is needed to conduct maintenance and replace broken components. The reduced maintenance characteristic of LED technology is both a practical and economic solution. Another advantage of LED lighting in outdoor environments is that cold temperatures actually have a positive effect on the diodes, enhancing light flow and life span. This, when compared with a light source with an aluminium housing, offers an extremely durable, reliable, maintenance-free luminaires that require a minimal amount of electricity in relation to the amount of light they generate.

Cooler outdoor temperatures have a positive effect on LEDs, enhancing light flow and life spans.

Advantage LED. Differences compared to traditional light sources

The way LEDs emit light when stimulated with electricity differs from traditional light sources, in which the light is a by-product of the filament being heated or of a gas discharge. Unlike traditional light sources, an LED contains no mercury, making it a better choice in terms of the environment and recycling. Altogether, LED technology provides many advantages in terms of function and design.

Because LEDs do not emit ultraviolet (UV) or infrared (IR) radiation, the technology is extra well-suited for lighting in sensitive environments. Museums and exhibitions of art and artefacts, as well as grocery retailing with food displays, are just a few examples.

In contrast to traditional light sources, LEDs achieve full brightness immediately and, in fact, the life span of the diode is increased by frequent switching on and off. Equally the light flow increases at lower ambient temperatures, so luminaires with LED technology are the ideal choice for refrigerator or freezer rooms and outdoors.

LEDs do not contain any moving or fragile parts. Therefore, a properly designed LED luminaire is well-equipped to handle vibrations and other mechanical stress.

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When you install LED tubes in an existing system, you take over the re-sponsibility for the entire luminaire.

Retrofitting. Is it enough to simply replace the light source?

Energy efficient, reliable and long-lasting. In many ways LED technology is superior to traditional light sources. But to really make the most of the technology, you need luminaires that were developed especially for LEDs.

There are many types of retrofit LED light sources on the market which can be used to replace traditional sources, for instance cold halogen lamps (HRGI) of up to 50 W and other types of halogen lamps. Some of these models also offer brightness adjustment. This type of light sources can be used in locations where light flow, light quality and efficiency are lower, for example in a home environment. From a short-term capital outlay perspective it may appear more profitable to simply replace the light source within the existing luminaire to LED, however there are factors which need to be taken into consideration.

No product standard

In areas which place a high importance on light output and quality, retro-fitted LEDs are not always suitable. There are LED tubes on the market that are designed to replace T8 fluorescent tubes (26 mm) and run on conventional lighting ballasts. As the scheme was originally designed for a traditional light source- switching to LED may conflict with the original lighting design.

There are currently no product standards for this type of LED tube, nor are they covered by the standards for the LEDs. Some variants have been found to have structural flaws that make them dangerous, prompting the Swedish National Electric Safety Board to force suppliers to withdraw them from the market. An important consideration when retro-fitting LED light sources is that responsibility for the entire luminaire passes over to the person who replaces it as the existing fixture has been tampered with.

An LED luminaire can have a very long life span – assuming that it is well-designed and has high-quality components.

LED. The economical alternative

As electricity prices rise, low power consumption becomes increasingly important. LED is superior to all other alternatives on the market in terms of energy efficiency and life span. But how much can we really ask?

Comparing LED with traditional solutions can easily turn into a matter of apples and oranges. The properties measured in the laboratory of an LED manufacturer cannot be directly linked to how an LED module performs in a luminaire. To get a good idea of the light's capacity, the LED needs to be placed in its specific lighting context.

Light output equals light flow

The energy efficiency of luminaires with traditional light sources is described in terms of light output ratio (LOR). The LOR is measured by comparing the light flow (also known as luminous flux) from a freely glowing reference light source with the measured luminous flux from the luminaire. But the energy efficiency of an LED luminaire cannot be defined by light output, because LED modules do not have a standardised nominal luminous flux as fluorescent tubes do. The reason for this is that the whole luminaire, including the LED and the electrical ballast, is counted as a reference, with the result that the light output is always 100 %. Instead, the efficiency of an LED luminaire is defined as the ratio of the total measured luminous flux (lm) to the radiant flux including ballast (lm/W).

Coloured light at no additional cost

One of the advantages of LED is that the technology can produce coloured light without using a filter, which saves a lot of energy. For instance, with a traditional spotlight adding a colour filter can reduce the light flow by up to 90 %. With an LED, the colour of the light is determined by the material it is made of.

Suited for many types of luminaires

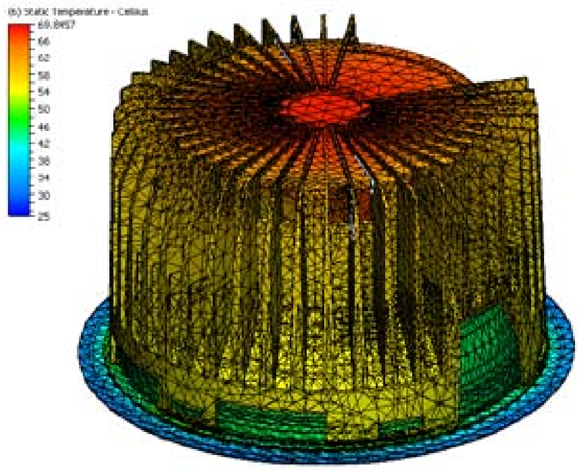
While the rapidly improving luminance from white LEDs opens up exciting possibilities in luminaire design, it's important to distinguish between the data for individual LEDs and those for a complete luminaire solution. The data provided by manufacturers of LEDs or LED modules nearly always refer to the maximum luminance of a cold LED. They take no consideration of losses due to higher temperatures, the power consumption of the electrical ballast or losses in reflectors or lenses. The luminance of a poorly designed LED luminaire, or one running on a poor-quality ballast, may be less than half the nominal value of the LED.

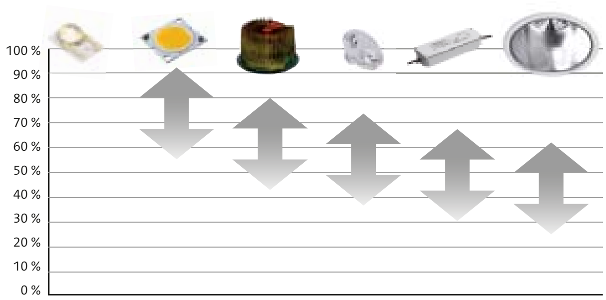
With modern technology, an LED luminaire developed specifically for a given purpose can replace several luminaire types with traditional light sources – from downlights with low-voltage and halogen light sources to general lighting with T5 fluorescent tubes. The LED solution retains or improves the energy efficiency – but the goal should also be to maintain control over visual comfort and direction. This is particularly important in connection with work-related facilities that are extra sensitive to glare, for example offices.

At least 50,000 hours

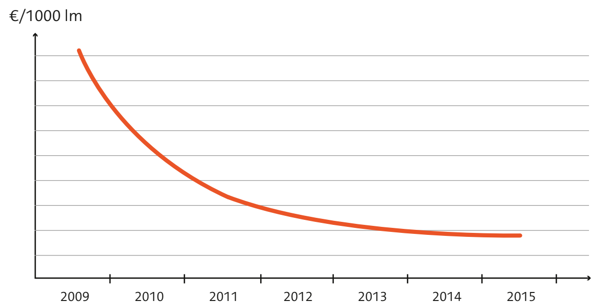
An LED luminaire can have a very long life span – assuming that it is well-designed and has high-quality components. An LED very rarely breaks although, as with any electronic products, there is a normal failure rate. Rather than breaking, an LED generates reduced light flow over time. Life expectancy is defined as when the light from the lamp goes down to 70 % of the initial value. The Life span is expressed as L_{70}, followed by the number of hours. The standard life span of most LED luminaires is L_{70} 50,000 hours, but there are deviations both upwards and downwards. The expected life span is affected by several factors:

- Choice of LED (manufacturer and type)
- How hard the chosen LED is run (that is, how high a current it runs on)
- Luminaire design (considering the temperature of the LED or LED module)
- Choice of ballast (driver)
- The environment where the product is installed
- Other materials used in the design





Schematic sketch of losses. This illustration shows the process from the individual LED, through heat losses in the modules (where the diodes heat each other up), to light losses in lenses, reflectors and ballasts, to the light that actually radiates from the luminaire. Depending on the design, each loss can be of greater or lesser magnitude.



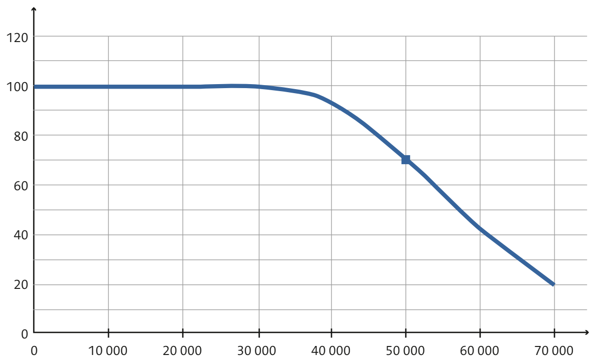
With the development of new technology and increasing efficiency, the prices of LED components have been steadily dropping for some time, but this is expected to stabilise. This graph shows what has happened so far and the projected cost p/ lm of an LED module.

Once the L_{70} life span is reached, the LED still continues to produce light for a long time but with a further reduction in light flow. Therefore, to maintain the required levels, the module or entire fitting should be replaced at this point. After a projected 15–20 years of operating time it may well be worth changing the entire system as newer, more efficient technology will be available.

Maintenance-free

Outside of standard cleaning, LED luminaires are pretty much maintenance free throughout their lifecycle. As such, larger organisations can save considerable amounts by not having to keep stock of equipment and associated man-power in replacing the light sources.

One of the advantages of LED is that the technology can produce coloured light without using a filter, which saves a lot of energy.



How to calculate expected life span: After 50,000 hours, about 70 % of the light flow remains (L_{70} 50,000 h).

The environmental effect of reduced power consumption is significant – in particular when the electricity comes from power sources that are not environmentally optimised.

LED. The environmental alternative

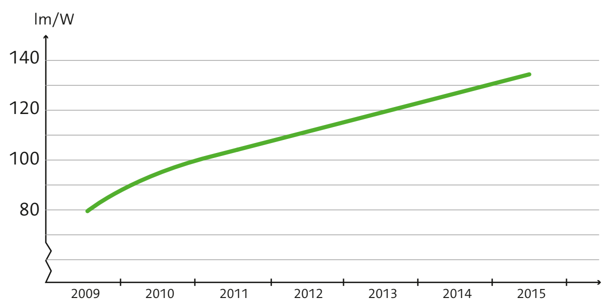
From an environmental stance the energy efficiency and long life span are the two key benefits of LED. At the end of its life an LED module is recycled in the same way as other electronics. Although unlike traditional light sources, such as fluorescent tubes, LED modules contain no mercury, which simplifies waste management and reduces the risk of emissions.

Superior efficiency

As with all lighting, the greatest impact on the environment is related to the energy used during its use. The large amount of light produced, compared to the energy consumed, makes LED solutions very efficient, this is particular important when the electricity used to power then comes from sources that are not environmentally optimised, such as coal. There are a selection of products that produce more than 200 lumen per watt in laboratory environments, however, these LEDs are not yet ready for a commercial launch.

Less waste

The life span of an LED module greatly exceeds that of a traditional light source. This leads to reduced consumption of raw materials, less throwing away and less strain on the recycling system. However, the environmental impact of an LED luminaire in terms of energy efficiency and life span is always dependent on how the luminaire is designed and what context it is intended to be used in. Thus, it is important to do calculations on each individual project and not blindly trust laboratory tests.



This graph shows how LED efficiency is expected to advance by 2015. The average annual increase in efficiency is about 10 %.

Light quality

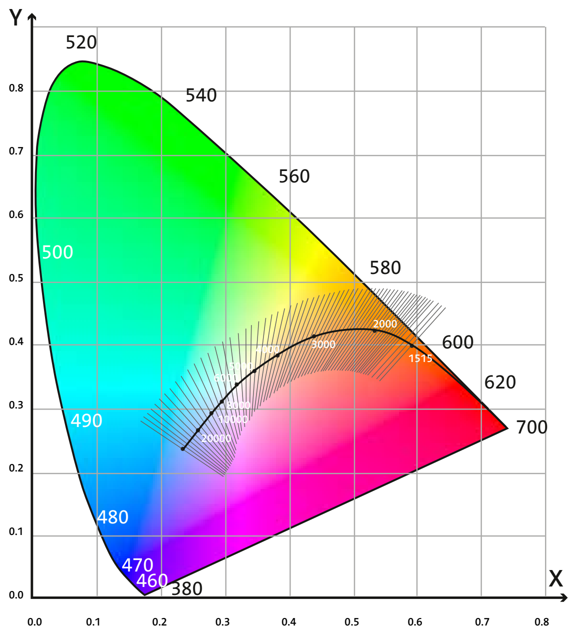
Many factors affect the light quality of LED. Colour temperature, colour rendition and colour quality affect both how the light works and how it is perceived. Although the technological properties of LED's and traditional light sources are not directly comparable, the user's demands for how the light from a good luminaire should behave, remains unchanged.

It is important not to focus too heavily on the replacement value when considering both colour temperature and colour quality. Also look into how the quality changes during the product's expected life span.

Colour temperature

The colour temperature of a light source is given in Kelvin (K). Originally, Kelvin was a measure of the colour of a heated (and therefore glowing) black body. For lamps with a filament, this measure is easy to apply, as the colour temperature in Kelvin is the same as the actual temperature of the filament. For light sources with no filament – such as fluorescent tubes, gas discharge lamps and LEDs – we must calculate a correlated colour temperature (CCT) in Kelvin. The instruments and measures available today were developed for traditional light sources and not specifically for LED, so the International Commission on Illumination (CIE) has begun to develop new methods of measuring. Colour temperature may vary from one manufacturer to another even if they report the same measurement. In addition, the colour temperature of an LED can change over time, which means that the value after several thousand hours of use will not be the same as that for a new product.

When LEDs are produced, their colour temperatures and luminous flux vary widely, making it preferable to choose from a limited assortment. Manufacturers sort their products into 'bins' according to their performance. The fewer bins your LEDs are selected from, the more stable the quality of the product. The closer the selection the more the supply decreases and the cost increases, therefore luminaire manufacturers tend to accept diodes from nearby bins as well.

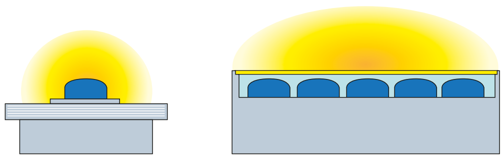


This illustration shows how to calculate a correlated colour temperature: The filled-in curve shows the colour temperature in actual Kelvin degrees. The chromaticity of the light source is measured on one of the isothermal lines and the correlated colour temperature is the point where the line crosses the curve.

Variations in white light

Usually white light is created by applying a phosphor-based coating to a blue diode, either directly on the diode or on a separate plate over it. This coating converts some of the blue light to white light of various colour temperatures – a process that is reminiscent of how a standard fluorescent tube works. The quality of the light is determined both by the specification of the blue LED and by how carefully the phosphor is matched to the selected diode.

White diodes come in a wide range of colour temperatures, from warm white to very cold (2700–8000 K). Because a blue LED is the basis of the white light, efficiency is



How to create white light from a blue diode, or in the case on the right, from a cluster of diodes. On one individual LED, the phosphor covers the diode; in a module, the phosphor is placed on a plate that covers all the diodes in the module.

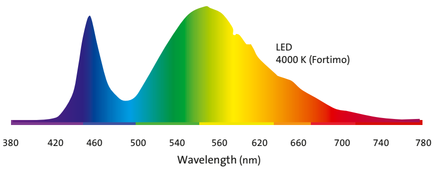
greater for colder colour temperatures. To obtain a warmer colour temperature, the phosphor must convert a larger proportion of the original blue light.

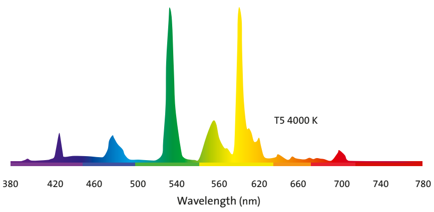
Colour rendition

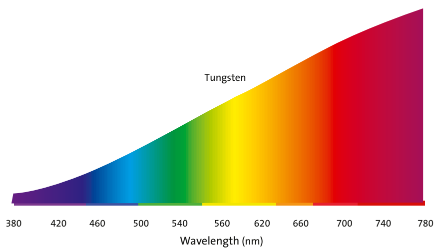
Colour rendition in LEDs is not exactly the same as in traditional light sources, but it is still described as Ra/CRI. The Ra scale is from 1 to 100 and measures the capacity of the light source to render colours. Depending on your choice of LED, the degree of colour rendition (Ra) normally varies from 60 to 95. A high Ra often produces a somewhat lower luminance.

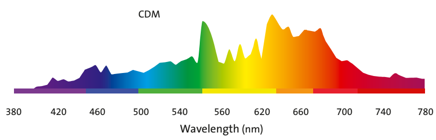
Normally, colour rendition is measured using the CIE method on a scale of eight colours (see illustration). The Colour Rendering Index (CRI) is given as an average value (Ra), so it is possible for a light source to be good at rendering seven colours but not as good at the eighth. A complementary scale is called CRI 1–14, which contains six more colours. As the illustration shows, this LED cannot render the bright red colour, number nine, in an optimal way. In consequence, the average CRI 1–14 value is lower than the average for CRI 1–8. Regardless of the average value, we can see that the LED does not give an ideal rendering of the red scale.

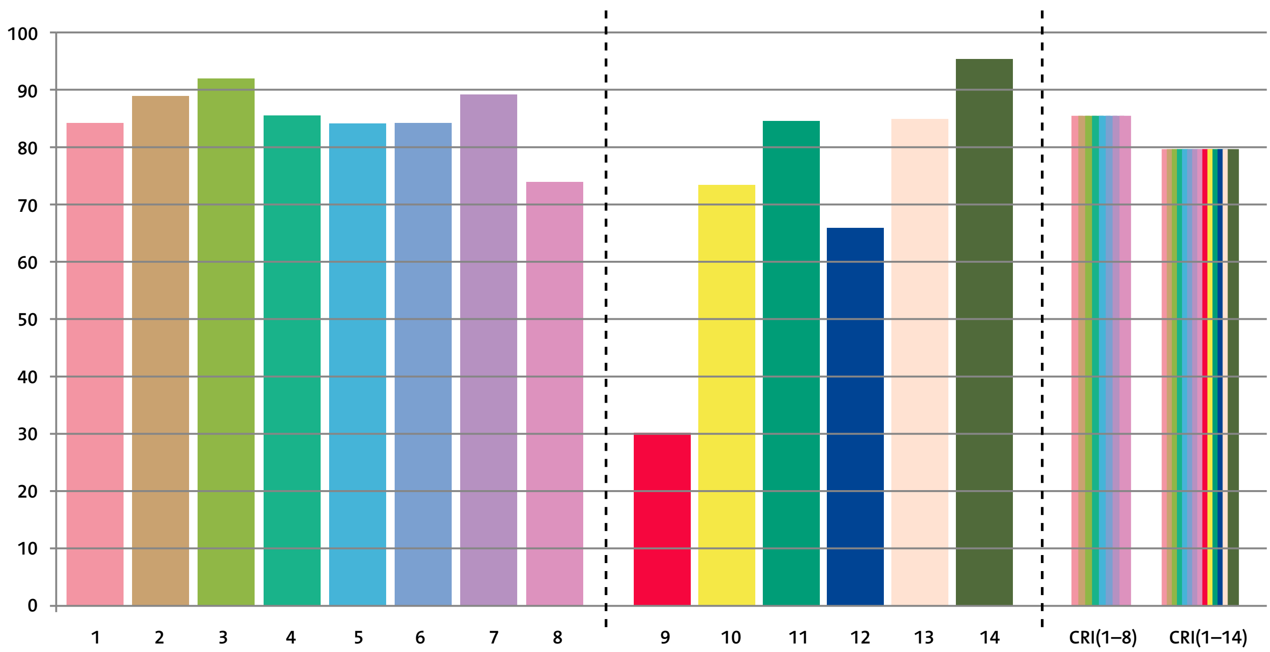
Colour rendition can vary among LEDs from different manufacturers, but is linked to the spectral distribution of the LED. Therefore, an analysis of the spectral distribution can give us more information about the LED's ability to reproduce colours. It is also worth noting that colour rendition can differ between a new LED and one that has been in use for several thousand hours.











Chromaticity

The chromaticity of an LED product – that is, degree of deviation of its colour temperature – is defined in MacAdam ellipses in Standard Deviation of Colour Matching (SDCM) as per the CIE 1964 standard. The MacAdam system originates from the United States and ranks colour quality on a scale of 0 to 10.

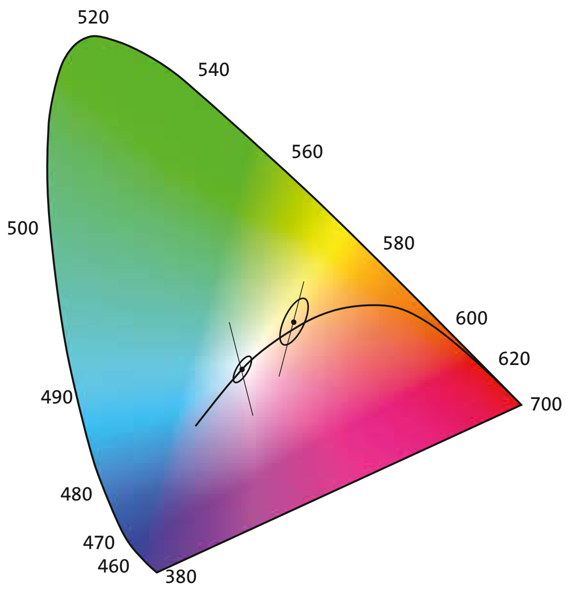
Between 0 and 4 is it difficult to see differences in colour, but further up the scale it can have an obvious and negative disparities. The problems are greatest when lighting a white surface, or placing a LED strip very close to a white wall. The requirements for most other Indoor environments are usually around MacAdam 3–5 SDCM. By comparison, a T5 fluorescent tube from the major manufacturers is about MacAdam 4. For exterior applications, a rating of MacAdam 7 SDCM is perfectly OK.

One of the key considerations is how the colour quality of a product changes throughout its lifespan. Some LED's can maintain a very high colour quality for the first thousand hours but then deteriorate rapidly. The design of the luminaire is another critical factor, where insufficient cooling, or the LED being run too hard, can both have a negative impact.

Methods of documentation

Despite the lack of all inclusive standards, the European organisation for luminaire manufacturers, CELMA, has proposed a number of parameters and methods of measurements for the documentation of LED luminaires. While it can be viewed as a temporary stop-gap pending the establishments of international standards, these parameters will, in all likelihood, be included in future IEC and CEN standards.

The main purpose of uniformed reporting to allow an accurate and fair comparison between different manufacturers and solutions, while highlighting the pertinent information which should be collected from manufacturers outside of CELMA.



Large variation in colour quality results in a larger ellipse and a higher MacAdam value. The size of the ellipse is calculated using a formula.

Poor-quality LEDs can lead to irritating differences. The problems are greatest when lighting a white surface.

The design of an LED luminaire intended for working environments is a careful balancing act between comfort and economy.

Visual comfort

The great challenge with LEDs is to keep glare within reasonable levels. It is not unusual that diodes and LED modules have a luminance (light intensity) of over 300,000 cd/m². In contrast, a standard T5 fluorescent tube has a luminance of 17,000 cd/m².

Luminaire developed for working environments are a careful balancing act between comfort and economy. From a financial stance, creating a naked LED module with a cooling unit and external driver would deliver the highest lumens to watts ratio. However, this solution would be completely impractical. The greater the efficiency the great the glare, a factor which should be considered in both the development and selection of luminaires.

In commercial environments the light from an LED or LED module has to be controlled by reflectors, lenses, or some other form of diffusing material. Lenses are usually directly linked to different manufacturers and the type of LED. The choice of reflector material or lens used is crucial to maintaining the luminaire’s efficiency while keeping the luminance sufficiently low.

Electrical ballast and operating temperature

The ballast is the heart that drives an LED. Different luminaires uses different ballasts and if the ballast is unsuitable, or improperly connected, it can damage or even ruin the LED luminaires connected to it.

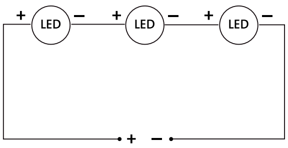
LEDs and LED modules require special electrical ballasts, or drivers, which converts 230 V of mains voltage to suitable values to operate the component. Most of these are also designed as Safety Extra Low Voltage (SELV) systems, which means that the LED and other components do not need touch protection.

The disadvantage of SELV systems is somewhat lower efficiency due to losses in the protective separation. Luminaires without SELV are only designed to shelter the LED modules and wires from touch and therefore require a tool to access the components.

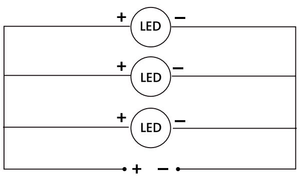
Current or voltage

LEDs can be powered in two ways: with constant current or constant voltage. Constant current means that the diodes run on a constant 350, 500, 700 or 1050 mA of current and are serially connected to the ballast. The voltage in the circuit depends on the number of diodes: the forward voltage of each diode is added to the next in the series. A downlight with three LEDs intended to run on a constant-current ballast will have a secondary voltage of about 9 V DC (3x3 V). If several luminaires are serially connected to a single ballast, the voltage is multiplied by the number of luminaires.

SELV technology limits the number of diodes that can be serially connected because too many will lead to excessive secondary voltage. In addition, it is unlikely that the ballast has the capacity for such a high voltage or power.



In a constant-current system, the LEDs are serially connected to ballasts.



In a constant-voltage system, the LEDs are parallel connected to ballasts.

SELV limitations in EN 60598-1 (luminaire standard): For IP 20 luminaires the limit is 60 V DC, and for luminaires with a higher protection class than IP 20 the limit is 30 V DC. This is assuming that the diodes are accessible to touch. If they are shielded, the permitted voltage is 120 V DC, but the certification of the luminaire and the recommended ballast must be considered.

Constant current is usually used for LED products with a large number of diodes, such as LED strip lights and products that produce a glowing line. The LEDs are connected parallel to ballasts. The constant voltage is usually 8, 10, 12, 24 or 48 V DC. Several LED products can be connected parallel to a single ballast, as long as the ballast has the capacity. The voltage drop in the wires is estimated to be the same as in traditional extra-low-voltage installations

Use the right ballast

Regardless of the type of power source, it is important that the ballast is suited to the specific type of LED luminaire. The polarity is also important because this is direct current (DC). If the ballast is unsuitable or improperly connected, it can damage or even ruin the LED luminaires connected to it.

It is important that the ballast is designed for and approved to operate LEDs. Although some LEDs can run on conventional transformers, such transformers can lack certain kinds of safety features, such as short-circuit protection, which can lead to injuries.

Operating temperature

Traditional light sources always radiate heat. While an LED itself doesn't it is still a problem. Unlike traditional light sources, which are cooled by ambient air, the LED must be cooled by the material behind it. Heat has the greatest negative impact on an LED's life span, luminance and efficiency. This is why Fagerhult makes sure when developing LED luminaires that the temperature of the components remains within the manufacturer's specifications and meets the requirements in our own policy.

Fagerhult's LED policy

Fagerhult uses only LED's, or LED modules, from recognised manufacturers and pay close attention towards ensuing they are powered for optimal lifespan and efficiency.

To help safeguard against the negative issues related to excessive heat all components within the Fagerhult range remain within the manufacturers stated levels. An additional safety margin is added when measuring the control temperature (t_c) and when calculating the temperature of the LED (t_j). This policy has been applied to other electronics, such as high-frequency ballasts and emergency lighting, for many years and has helped ensure the stated expected life span is always achieved by a good margin. The design is optimised by using software that stimulates temperatures and a heat camera to test calculations on the luminaire prototypes. During inspections and testing, the luminaire is always installed in the way it is intended to be used by the end customer. By including these processes at the early stage of the design, this additional margin can be included without increasing the cost of the luminaire.

Control

High-quality LED lighting can be regulated by a range of control systems. In addition light intensity, timers, daylight harvesting and proximity control, LED offers completely new options for controlling the colour of the light.

The regulation of LED light is managed using ballasts with pulse-width modulation (PWM). The connected load is run by a technology consisting of a square wave with varying frequency. The load is switched on and off with a high frequency, which gives the impression that the light level changes. PWM ballasts are available with various types of control interfaces, such as DALI, DSI, DMX 512 and switchDIM. Separate PWM units are also available, which can serve as connections between constant voltage and the load.

Colour shifting RGB/DMX

Colour shifting in red, green and blue is generally referred to as RGB control. About 65,000 colours can be obtained by mixing and combining these three colours at various strengths. Creating a specific colour requires some type of control unit or interface to a program that communicates via DALI or DMX 512. The control unit might be a lighting desk – which is unusual in many applications – a router or some kind of control panel.

People often make an association between DMX, RGB and LED. A simple description of DMX is a control unit that controls all electrical loads. DMX 512 is a standard protocol that was initially developed to control lighting and dimmers in theatrical environments via a lighting desk. It has a high rate of transfer, which requires high-quality installations, wiring and connections. However, with the development of new light sources and the desire for colour in various applications, DMX control has come into use in many other environments.

DMX is advancing

DMX is also available in a recently updated version, RDM, which allows you to address loads via the DMX wiring, as long as the loads and software are correctly selected. The most common way to address DMX is with a DIP switch setting on each unit. (RDM is currently employed in such products as Fagerhult's Pleiad LED Wallwasher with Lexel.)

DMX compared to DALI

There are more differences than similarities between DMX and DALI. DALI was developed with a focus on energy-efficient fluorescent-tube lighting in public environments where people work and visit. It has been a very popular alternative considering its limitations, but its simplicity was the key. Multiple control units can control all or part of the electrical loads. In the not-too-distant future, the current DALI standard will be expanded with DALI Colour Control Command.

Comparison of DALI/DMX

Control protocol	DALI	DMX
Speed	Slow	Fast
Number of addresses	64	512
Multiple units at same address	No [1)]	Yes
Automatic addressing	Yes	No [2)]
Centralised control	No	Yes
Decentralised control	Yes	No
Cord length	300 m	300 m
Cord requirement	No	Yes, Cat5
Terminating resistor	No	Yes

1) Converters for 1–10 V are common.
2) RDM luminaires can be addressed via software.

Greater efficiency, lower prices and better applications of the technology will contribute to steadily growing demand for LED.

LED – a glimpse of the future

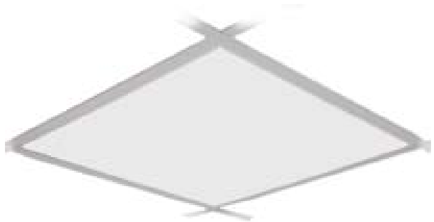
Advances in the LED field are astounding. Efficiency has doubled in just a few years, while costs have dropped dramatically. But what happens next?

This development is likely to continue, even if the rate may slow. It is not unreasonable to expect that LED systems that produce 100 lm/W today may be up over 150 lm/W in a year or two. As volumes increase, costs will drop, although how much is uncertain.

However, it is clear that greater efficiency, lower prices and better applications of the technology will contribute to steadily growing demand for LED luminaires for public environments. It is not unreasonable to assume that LED lighting will dominate sales in ten years or so.

One phase in Fagerhult's further development of this technology is research into how people perceive LED lighting. Indications that LED light is perceived as brighter than traditional light sources at the same power levels lead to thoughts about opportunities for even more energy savings. The company is also working to develop even more applications for general and workspace lighting, which can replace luminaires with T5 fluorescent tubes. A joint standardisation project called Zhaga is under way in the lighting industry. The aim is to develop common product standards for physical dimensions and connections to electrical, photometric and thermal product standards. The project is mainly about making it easier to replace LED modules and electrical ballasts. The first standardised modules are expected to be available in 2011.

Multilume Flat



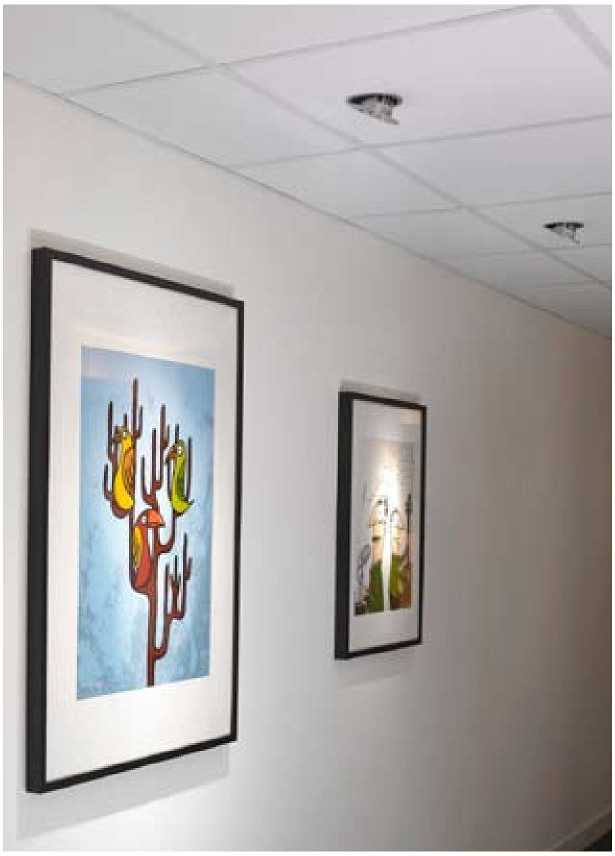
The Multilume Flat is amongst the first LED luminaire that is more efficient than a T5 luminaire; producing more than 80 lumens per watt, with the same light ergonomics. Its slim aluminium profile, with a low recessed depth, offers many advantages in the construction process. Multilume Flat was developed for daylight and proximity control and can be fitted with two different anti-glare devices - micro-prismatic or opal.

Pleiad G3

Pleiad G3 is a series of LED downlights designed especially for general lighting. Thanks to an innovative reflector, it combines the efficiency and high light flows of LED technology with exceptional glare reduction and light treatment. Available in a variety of designs and complemented with a large range of accessories, there is a solution for all types of spaces and applications.

Pleiad Power LED

Pleiad Power LED is a small, efficient downlight that brings power economy and energy efficiency into one complete package. The luminaire is designed for entrances, meeting halls and showrooms and other applications which require varied a generous, general light.



Pleion

Pleion is a series of downlights equipped with advanced lens technology, specially formulated for the LED light source. The lenses allow a wide range of beam angles, with minimal glare making it suitable for all types of environments where you want to create variation in the lighting or accentuate objects. The ability to angle the luminaire contributes to its inherent flexibility.

Pleiad LED Wallwasher

Pleiad LED Wallwasher makes optimal use of LED technology. A new reflector design makes it possible to avoid a dark line where the wall and ceiling meet. An even, soft spread light fills the whole wall, creating new opportunities for striking and varied light planning. The series also includes complementary downlights that follow the same square design aesthetic.

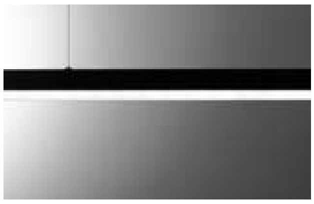
Easy LED

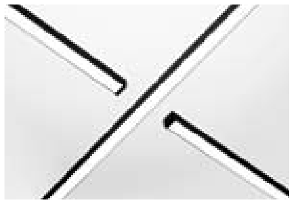
The Easy LED is an energy-efficient, flexible alternative to traditional recessed downlights with a halogen light source. Its size, design and function make it ideal for representative environments, such as hotels and offices, where the lights are often on for long hours.

The Easy LED comes in a fixed version and a version that can be tilted 30° and twisted 355°, allowing you to accentuate walls and objects. Both come in white and alu-grey and are rated to IP 44, which means they can also be installed in bathrooms.

Freedom

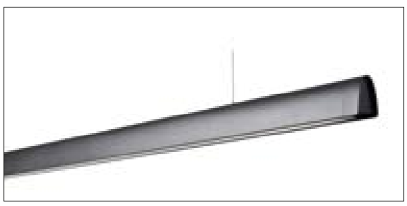
Freedom is an innovative LED luminaire that makes it possible to create free forms suspended in the air, on the ceiling and on the wall. With the help of two modules, one straight and one curved, the luminaire can be built up to follow the shape of the room or a creative concept. Offering architects, interior designers and lighting designer's full freedom of expression.





Gaudi

With Gaudi new technology meets timeless elegance. A suspended luminaire inspired by classical architectural principles and developed based on LED technology. Gaudi has tailored optics for the latest generation of LEDs that distribute a balanced effective light with an appealing colour temperature. The luminaire is available in two models: Gaudi Linear and Gaudi Circular.



Fasett

Fasett is a wall mounted luminaire with a contemporary design, specifically developed for LED. By positioning the diodes close together on the module no dots appear on the diffuser, while still providing a well-directed, even, comfortable light. The components are encapsulated, which makes the Fasett an excellent choice for busy facilities.

Beetle

Beetle is a wall-mounted luminaire developed for LED technology. Its design concept features classic, rounded shapes, allowing a well-reflected and comfortable glare-free light. Encapsulated components make Beetle a robust, maintenance-free solution for environments where many people are active. The fixture is also fitted with adjustable ballasts for ease of control.

G5

G5 is a luminaire for task lighting on a desk or other working areas. LED technology makes it an extremely energy-efficient alternative to traditional halogen solutions. This approach has contributed towards a enhanced ability to adjust the direction of the light, focusing on the desktop with minimal upward spill. The design of the fixture takes advantage of all the benefits of the technology, combining small dimensions with clean lines. Cost-effective everyday luxury!

Zoft LED

A wall fixture with a classic design, Zoft LED embraces the long life and maintenance-free advantages of LED technology. The luminaire has excellent glare reduction and an even distribution of light, ideal for applications such as stairwells. The frame is white and the dome is matte, opal glass – or acrylic for additional durability. Zoft LED is additionally fitted with adjustable ballasts for extra ease of control.

Densus LED

LED technology requires good cooling for optimal performance, which makes it extra useful in cold or well-ventilated areas. LEDs also lights up quickly, even at low temperatures. Densus LED is a sturdy lighting solution for cool spaces, such as refrigeration and freezer rooms, loading docks and other environments where the luminaire is switched on and off many times a day.

LED Handrail

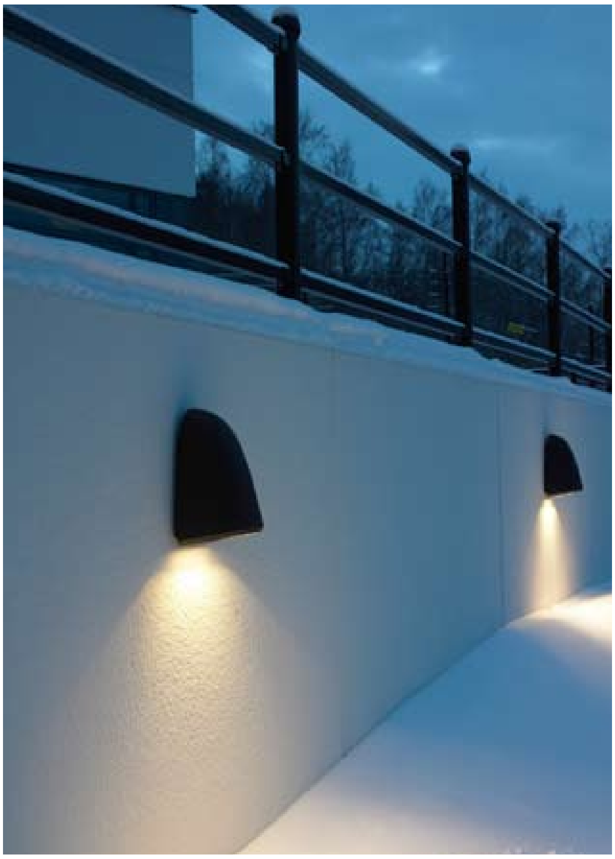
LED Handrail is a brand new way to integrate light into architecture – in or outdoors. The sleek aluminium handrail creates a cohesive, bright line that enhances the design of the space, whether it is a hall, a courtyard or a park. The wide choice of options ensures there is a solution for virtually any design concept. Easy to integrate into any environment, energy efficient and maintenance-free!

Rondo LED

Rondo LED is a further evolution of Fagerhult's classic Rondo series, designed to make the very most of LED technology. The directed light combined with new reflector technology ensures very high light output with the same excellent glare control. Rondo LED is a complete series including post, wall and ceiling fixtures that can be recessed or surface mounted.

Triton

Triton is a sturdy basic luminaire with optics specially designed for LED technology. Soft, pure lines and models for bollard and wall mounting make Triton an easy-to-place series in all types of environments. Maintenance-free and energy-efficient, this luminaire is a door-opener for those who want to try out the benefits of LED technology.



Azur LED

The Azur LED was specially designed for LED and is characterised by advanced reflector technology. The Azur LED post is an indirect-lighting solution that makes optimal use of the directed light of LEDs. All uplight is captured by the upper reflector and distributed back through the opal surface of the dome. The result is an effective, wide-spreading, very comfortable light that is well controlled, all light going where it does the most good. The Azur LED is available in a post and a wall version, and fits together well with earlier models in the Azur family.

Fagerhult develops, manufactures and markets professional lighting systems for public environments such as offices, schools, industries and hospitals. Our operations are run with a constant focus on design, function, flexibility and energy saving solutions.

Fagerhult Lighting Ltd, Fagerhult United Arab Emirates and Project Lighting Ltd are part of the Fagerhult Group, one of Europe's leading lighting groups with operations in more than 15 different countries. AB Fagerhult is listed on the NASDAQ OMX Nordic Exchange in Stockholm.

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