Evaluating performance of

LED based luminaires

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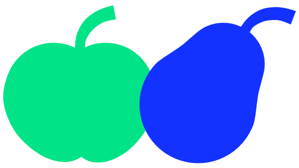
Avoid comparing apples and pears

In recent years there has been a significant increase in the use of LED based luminaires. Initially, there were no universal standards available to measure or compare the performance of LED based lighting products. This situation has been compounded by new and unproven entrants flooding into the market, some making dubious claims about their products' performance. There is a lot of confusion among customers about which LED products to choose.

In this regard, the main challenge for the professional market is to improve the way users of LED based luminaires, such as specifiers, lighting designers, technical engineers and policy makers, evaluate the performance claims of different LED luminaire manufacturers when preparing lighting projects or tender specifications. Today they often compare – unwittingly – apples with pears.



This white paper is intended to bring clarity and to enable evaluation of manufacturers' performance claims by explaining the different 'initial' and 'over time' performance criteria for LED based luminaires laid down in recent International Electrotechnical Commission (IEC) performance standards, in line with the IEC guidance paper issued by LightingEurope (January 2018, Evaluating performance of LED based luminaires).

We believe in a 3-step approach to create full transparency in the market:

1. Provide product performance specifications in compliance with appropriate IEC standards;
2. Create awareness amongst users of LED based luminaires on how quality criteria can help to compare and establish confidence;
3. Work towards independent third-party performance verification for LED based luminaires.

Figure 1: 3-step approach

1. Standardized quality criteria – bringing order to the confusion

As things stand at present, evaluating performance of LED products is complex. There are two main reasons for this:

a. Different manufacturers use different technical definitions to describe the performance of their products, thus making them difficult to compare.

b. The technical design of a product can make a tremendous difference in terms of performance. Even if two luminaires are based on exactly the same LEDs, their performance can be wildly different because of design choices made.

If we look, in the table below, at efficacy (expressed in lumens per Watt) for example, we can see that the design of the product can make a big difference to the system performance of the luminaire. The effectiveness of the heat management, the driver and the optics can all make or break the efficacy of the total LED based luminaire.

LED chip	Thermal design		Driver		Optics		Lumen Maintenance at 5000 hrs	Efficiency after 2 years
160 lm/W	95%	152 lm/W	90%	137 lm/W	85%	116 lm/W	98%	114 lm/W
160 lm/W	85%	136 lm/W	70%	95 lm/W	50%	48 lm/W	60%	29 lm/W

Figure 2: Impact design choices on performance.
The numbers indicated on the table are only illustrative.

Our recommended approach when evaluating performance claims from different manufacturers is the following:

1. Apply a standardized set of quality criteria for comparison;

2. Only evaluate products that have been measured in compliance with appropriate IEC standards.

This will allow you to judge comparison claims on an equal, like-for-like basis – apples with apples, so to speak, rather than apples with pears.

2. IEC performance criteria

Both 'initial' and 'over time' performance have to be evaluated in order to have confidence how LED based luminaires will perform and how long they will sustain their rated characteristics over their years of operation. Often, it can be difficult to know who to trust or what to believe.

Standardization of performance requirements is an important first step towards full transparency regarding the performance of LED based luminaires used in the professional market. Therefore, the IEC developed and published specific performance standards for LED based luminaires.

These standards describe how to measure 'initial' performance and provide a lifetime metric for 'over time' performance.

It should be noted that initial product specifications will typically be **measured,** whereas performance over time will be **calculated** using the IEC lifetime metric for LED based lighting products.

Product type	Safety standards	Performance standards
LED luminaires	**IEC 60598-1 Ed. 8.0** Publication 2014	**IEC 62722-2-1 Ed. 1.0** Publication 2014

Table 1: Overview IEC standards LED based luminaires

What we publish on initial performance

In line with the recommended approach and guidance given by IEC, initial performance specifications for all for all LED based professional lighting luminaires are measured in compliance with the appropriate IEC performance standards:

1. Initial rated input power (in W)
2. Initial rated luminous system flux (in lm)
3. Initial LED luminaire efficacy (in lm/W)
4. Luminous intensity distribution
5. Initial Correlated Color Temperature (CCT) in K
6. Initial rated Color Rendering Index (CRI)
7. Initial rated chromaticity co-ordinate value and expected tolerance (x,y) < x SDCM

Initial specifications of all LED based luminaires are specified at an performance ambient temperature Tq of 250C (depending application performance data at additional Tq can be published).

2.1 IEC 'over time' performance criteria

There are two relevant 'over time' performance values to be considered related to the degradation of a LED based luminaire at rated life.

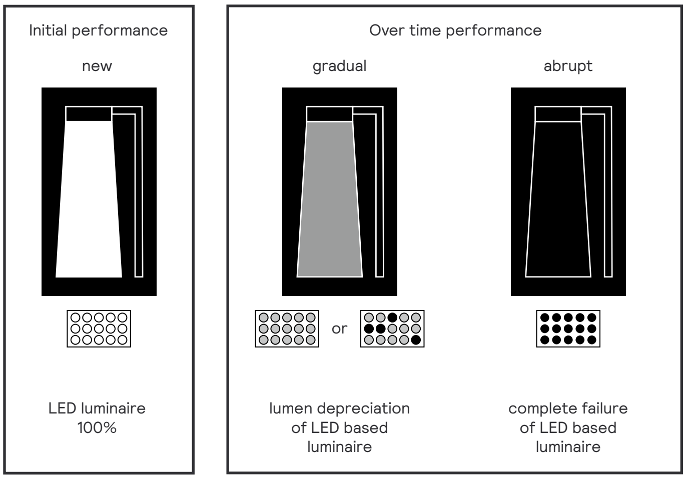


Figure 3: Initial and Over time performance

Gradual luminous flux degradation relates to the lumen maintenance of a luminaire over time. It describes how much of the initial luminous flux output of the light sources in the luminaire is available after a certain period of time. Luminous flux output depreciation can be a combination of individual LEDs giving less light and individual LEDs giving no light at all. (Note: For the assessment of degradation in optical components over time there are no standards available yet)

Abrupt luminous flux degradation describes the situation where the LED based luminaire no longer gives any light at all because the system, or a critical component therein, has failed.

The IEC lifetime metric for LED based luminaires specifies Useful Life and Time to Abrupt Failure.

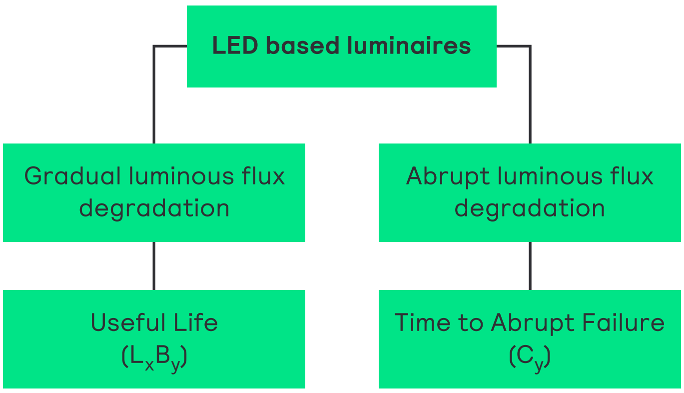


Figure 4: IEC old lifetime metric

2.2.1 Useful Life and Median Useful Life

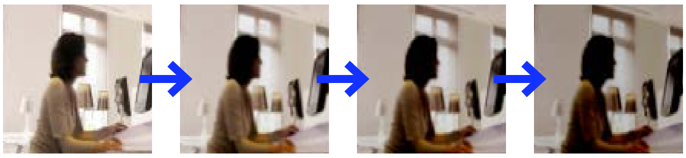


Figure 5: A gradual lowering of the light output and loss of efficiency

At any given time, the gradual light output degradation of a population of LED based luminaires is called Useful Life; generally expressed as L_xB_y. The population includes operating LED based luminaires only; non-operative products are excluded.

Useful Life expresses the age at which a given percentile of LED based luminaires (y) cannot meet the lumen maintenance factor x. Light output lower than the required luminous flux maintenance factor x is called flux degraded, because they produce less light but still operate.

To compare lifetime data unambiguously, IEC introduced Median Useful Life (L_x). Median Useful Life is the time at which 50% (B_{50}) of a population of LED based luminaires are flux degraded. For example, Median Useful Life L_{90} is understood as the length of time during which 50% (B_{50}) of a population of operating LED based luminaires of the same type have flux degraded to less than 90% (L_{90}) of their initial, luminous flux but are still operating.

In addition to the median value (B_{50}), B_{10} or other values exist in the market. Although B_y is a defined performance characteristic, the IEC 62722-2-1 standard does not include any technical explanation for how this parameter should be verified or applied. Moreover, lighting application design standards give no guidance either. Closer technical evaluation is therefore necessary.

It can be expected that around a distribution of products there will be a proportion above and a proportion below the rated performance value. The graph below shows an example of the normal distribution for a L_{90} rated product, illustrating the difference of a B_{10} or B_{50} value.

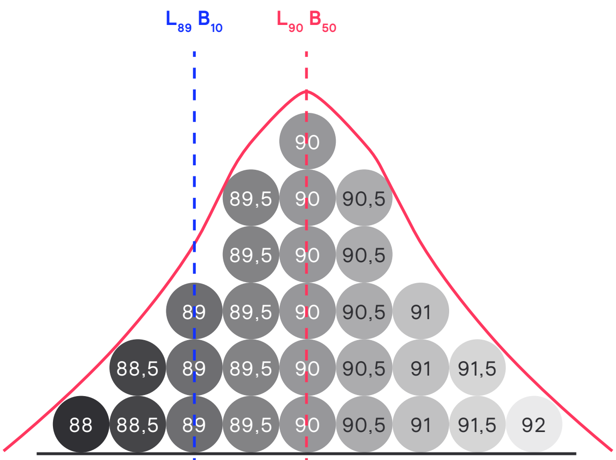


Figure 6: Example of normal distribution for a L_{90} rated product

Detailed analysis from various manufacturers in LightingEurope of product data from LED based luminaires shows that, when projecting installation life up to 100,000 hours, the difference in flux degradation between B_{10} and B_{50} is about 1%.

What this means in practice, for the L_{90} example at 100,000 hours, is that an initial luminous flux of 10,000 lumen will be 9,000 lumen in the case of B_{50}. If the same luminaire is rated as B_{10}, the corresponding value would be 8910 lumen. Bearing in mind that the rated light output data of both LED and traditional light sources are subject to typical tolerances of up to 10%, this practical differential can be regarded as negligible.

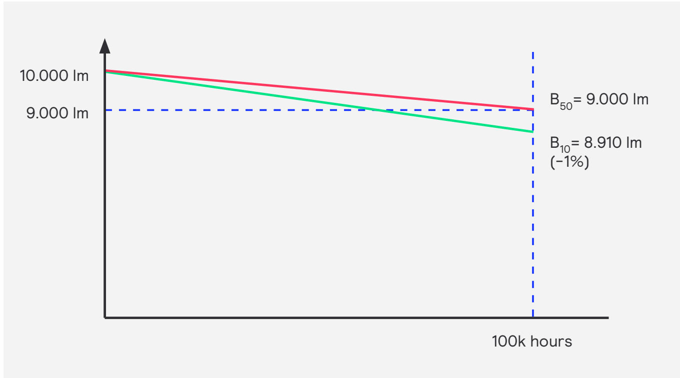


Figure 7: Product data analysis of an example of a LED based luminaire

As B_{10} and B_{50} are so close together, the spread due to depreciation is low and the median (B_{50}) value accurately represents the lumen deprecation behavior of several products at the projected lifetime (in this example 100,000 hours). The measurement process for B_{50} is standardized and more widely accepted than any other B_y.

Statistically the median (B_{50}) value represents with a sufficient degree of accuracy the lumen deprecation behavior of a population of LED based luminaires at the projected lifetime. For this reason, LightingEurope recommends promoting and expressing Median Useful Life as L_x without B_{50} notification.

We endorse the guidance from LightingEurope and will publish the lifetime specifications in accordance with this.

2.2.2 Time to Abrupt Failure and Abrupt Failure Value

Figure 8: An abrupt decline in light output due to breakdown or failure of the product or any of the components in the system

An important parameter to be considered with regards to expected long life is system reliability. A LED based luminaire will last as long as the component used with the shortest life. Several critical components of a LED based luminaire influence system reliability.

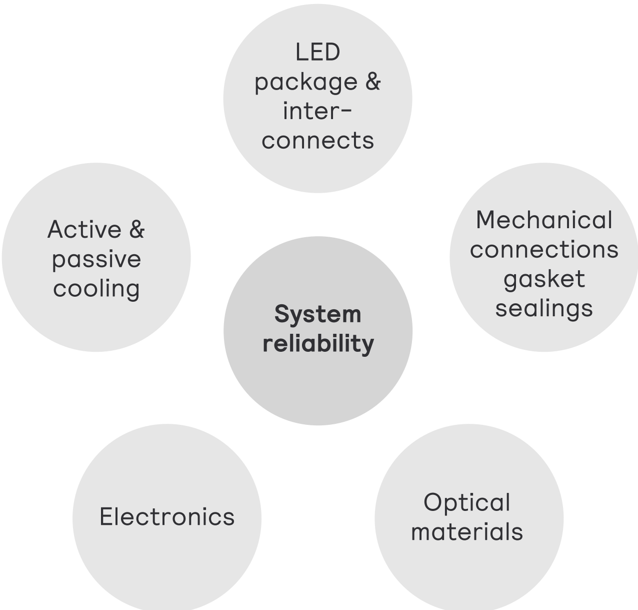


Figure 9: Critical components LED based luminaire

Degradation of optical material may cause luminous flux to reduce rather than abruptly degrade. Failure of one of the remaining principal components generally leads to complete failure of the LED based luminaire. This is not taken into account in the rated Median Useful Life. Consequently, abrupt failures should be considered separately during lighting engineering and planning. This is why the IEC lifetime metric also specifies time to abrupt failure, as this takes into account failure modes of principal components in the LED based luminaire design.

The abrupt light output degradation of a population of LED luminaires at a certain time is called Time to Abrupt Failure and is generally expressed as C_y. It expresses the age at which a given percentage (y) of LED based luminaires have failed abruptly.

To simplify the evaluation of manufacturers' performance data, IEC introduced the Abrupt Failure Value (AFV) of a population of LED based luminaires. Abrupt Failure Value is the percentage of LED based luminaires failing to operate at Median Useful Life (L_x). For example, an AFV of 10% indicates that 10% of the population of initially operating LED based luminaires fail to produce any luminous flux at Median Useful Life.

The current IEC standards do not describe completely what failure modes of principal components to include in the Abrupt Failure Value (AFV) calculations. Since most of the abrupt failures in practice occur in relation to the LED control gear, LightingEurope recommends specifying the expected control gear failure rate of the device as the AFV indicated for the Median Useful Life of the LED based luminaire.

We endorse this recommendation and will publish the Abrupt control gear failure values accordingly.

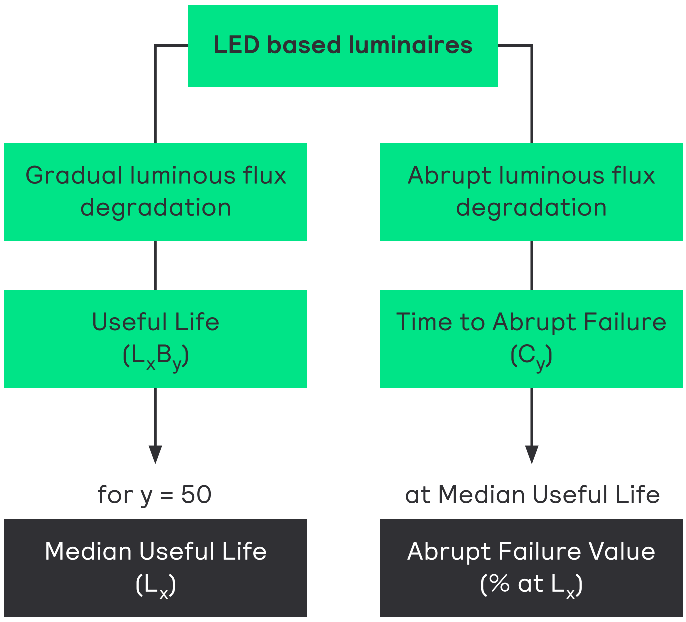


Figure 10: IEC new lifetime metric

2.2.3 Why lifetime is not always a critical factor

In actual practice, lifetime data for LED based luminaires is often a race for the highest number of hours for the Median Useful Life $L_{80}B_{50}$. We have to be aware that in the professional market, requirements are specific to the lighting solution within the application and a lighting design needs to be performed. The input is often the average installation life, which suggests that the highest number of hours is not a relevant discriminator when selecting a LED based luminaire.

To investigate this further, the average installation life for different indoor and outdoor applications has been calculated, based on the annual operating hours and the average time to refurbishment for a product in a specific application. It should be noted that these values may not be realistic in every situation.
An example would be the use of automatic lighting controls or application requiring 24/7 illumination.

Indoor applications	Default annual operating hours (EN15193)	Average time to refurbishment	Average installation life
	t_O	years	hours
Offices	2500	20	50,000
Education	2000	25	50,000
Hospitals	5000	10	50,000
Hotels	5000	10	50,000
Restaurants	2500	10	25,000
Sports	4000	25	100,000
Retail	5000	10	50,000
Manufacturing	4000	25	100,000

Table 2: Possible examples of average installation life for different indoor applications

Outdoor applications	Default annual operating hours (EN13201-5)	Average time to refurbishment	Average installation life
	t_O	years	hours
Street	4000	25	100,000
Tunnel (entrance)	4000	25	100,000
Tunnel (interior)	8760	12	100,000
Sport (recreational)	1250	20	25,000
Area	4000	25	100,000

Table 3: Possible examples of average installation life for different outdoor applications

To conclude, for products used in most indoor applications, the average installation life will not exceed 50,000 hours. For products used in most outdoor applications, the average installation life will not exceed 100,000 hours.

Moreover, we believe that "number of hours" should not be a dominant discriminator when selecting LED based luminaires for professional applications. For the lighting design, the maintained luminous flux at the average installation life for a specific application is much more relevant and may support energy saving through the reduction in over-design to account for losses through life.

In accordance with the LightingEurope guidance paper, we recommend not to specify or declare lifetime claims exceeding 100,000 hours, unless it is clearly required by specific lighting applications and verified by an appropriate life test period.

We will publish the L_x values related to both indoor and outdoor applications where the product may be used (see Table 2 and Table 3 respectively).

2.2.4 In summary – performance over time

Luminaire life is always a combination of gradual and abrupt light degradation. Note that luminaire life claims must always be specified together with a specific ambient temperature, number of burning hours and associated switching cycles.

As mentioned above, the design of the LED based luminaire can have a significant impact on the luminaire performance, including its lifetime.

It is therefore important to realize that data provided by LED or LED board suppliers cannot simply be translated one-to-one as LED based luminaire performance data. Therefore, we need to be wary of claims such as “these luminaires use the same LEDs so therefore their (over-time) performance is the same”.

It is also important to remember that over time performance values are predictions rather than measurements.

As the Useful Life and Time to Abrupt Failure of LED based luminaires are so long, it is not possible for manufacturers to measure these before launching new products. Instead, they use shorter measurements and extrapolate those to arrive at predictions.

Since there is not yet any standard in place that describes how these predictions or extrapolations should be done, the quality of these predictions varies wildly. The IEC only describes a lifetime metric for LED based products at this point: which parameters should be stated in terms of Useful Life and Time to Abrupt Failure, but not how to calculate these.

We have developed a best-in-class tool to calculate Useful Life and Time to Abrupt Failure for LED based luminaires. Calculations are based on real-life endurance test data of LED boards, accelerated testing of critical components and a deep understanding of which design parameters are critical to extend luminaire lifetime.

Our over time performance claims for LED based luminaires take into account individual LED module performance mea-surements, thermal design parameters, optical degradation parameters and possible failure modes of all critical components in the LED based luminaire design.

What we publish on performance over time

The ‘over time’ performance specifications of Signify luminaires are calculated using the IEC lifetime metric for LED based lighting products and in accordance with the LightingEurope guidance paper on “Evaluating performance of LED based luminaires”. Over time life claims are specified at a performance ambient temperature Tq of 25°C.

For **indoor** LED based luminaires we will publish two IEC-compliant quality criteria:

1. Lumen maintenance at median useful life:
   - for all products at 50k hours
   - for Industry products in addition also at 100k hours
2. Control gear abrupt failure rate (%) at median useful life

For **outdoor** LED based luminaires we will publish two IEC-compliant quality criteria:

1. Lumen maintenance at median useful life:
   - for most products at 100k hours
   - depending application (e.g. sports) for some products a lower number of hours (35k, 50k or 75k hours) is published
2. Control gear abrupt failure rate (%) at median useful life.

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