PHILIPS

LED Luminaires

White paper

Evaluating performance of **LED based luminaires**

Evaluating performance of LED based luminaires

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 systems 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 IEC performance standards.

Philips Professional Lighting Solutions believes 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.

NOTE:
Guidance towards like-for-like comparison based on IEC performance standards is expected to be widely adopted in Europe.

Figure 1 – 3-step approach

1.1 Standardized quality criteria – bringing order to the confusion

As things stand at present, evaluating LED systems 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 large 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		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

When evaluating performance claims from different manufacturers:

a. Apply a standardized set of quality criteria for comparison;
b. 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. At present, 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 recently 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 standard	Performance standard
LED control gear	IEC 61347-2-13 Ed.2.0 Publication 2014	IEC 62384 Ed.1.1 Publication 2011
LED lamps	IEC 62560 Ed.1.0 Publication 2011	IEC 62612 Ed.1.0 Publication 2013
LED modules	IEC 62031 Ed. 1.1 Publication 2012	IEC 62717 Ed. 1.0 Publication 2014
LED luminaires	IEC 60598-1 Ed.8.0 Publication 2014	IEC 62722-2-1 Ed.1.0 Publication 2014

Figure 3 – Overview IEC standards LED based products

What Philips Lighting publishes on initial performance

To benefit from our standard development work in the IEC, initial performance specifications for all Philips Professional Lighting Solutions Europe LED based (general) lighting luminaires are measured in compliance with the appropriate IEC performance standards.

1. Initial rated input power (in W)
2. Initial rated luminous 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 ambient temperature of 25°C.

2.2 IEC ‘over time’ performance criteria

There are two relevant ‘over time’ performance values to be considered related to gradual and abrupt light output degradation of a LED based luminaire at rated life.

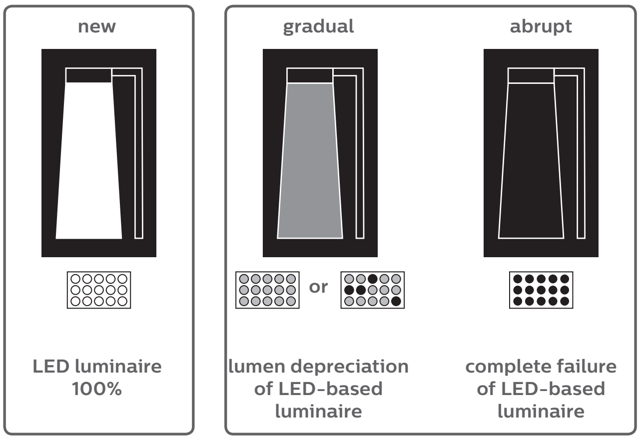


Figure 4 – Over time performance

Gradual light output degradation relates to the lumen maintenance of a luminaire over time. It tells you how much of the initial lumen output of the luminaire is maintained after a certain period of time. The lumen depreciation can be a combination of degradation of optical elements used, individual LEDs giving less light and individual LEDs giving no light at all.

Abrupt light output 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.

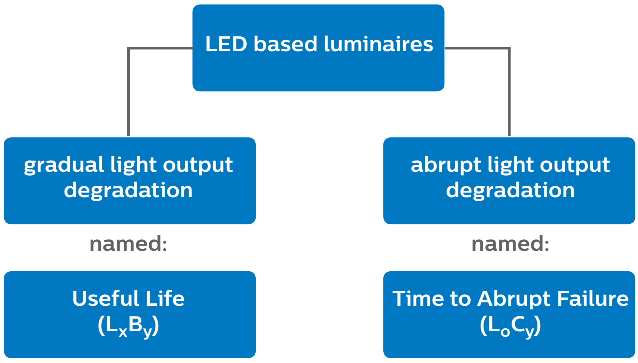


Figure 5 – IEC lifetime metric

2.2.1 Gradual light output degradation / Useful Life

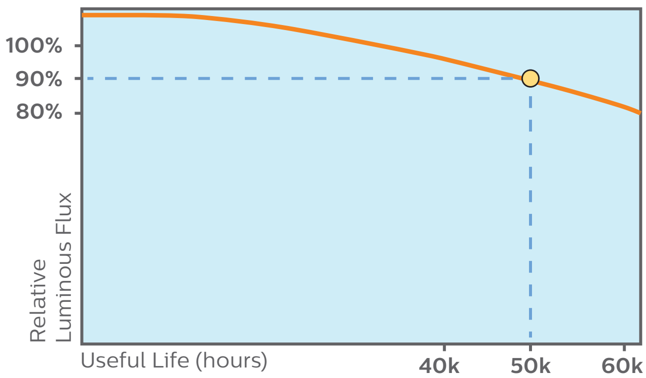
A gradual lowering of the light output and loss of efficiency

The gradual light output degradation of a population of LED based lighting products at a certain point in time is called Useful Life and is generally expressed as L_xB_y. Useful Life describes the lumen maintenance of a LED based luminaire over time.

Useful Life is expressed as L_xB_y and means length of time during which y% of a population of operating LED based luminaires of the same type fail to provide at least x% of the initial luminous flux. 'L_x' describes the lumen maintenance: L_{80} means that the luminaires of this specific type still give 80% of their initial light output.

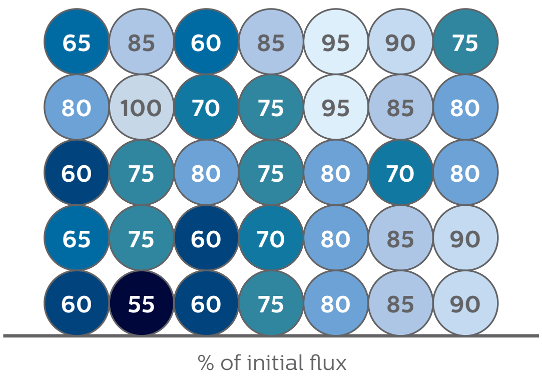
'B_y' describes for what percentage of the population that is true. The example $L_{80}B_{50}$ reflects the age (in hours) at which 50% of the population have failed parametrically. Parametrically in this case means a LED based luminaire producing less light than 80% of its initial flux but still operating.

If we take a closer look at a typical curve showing how light output decreases with time, we can read off the point in time where the light output has decreased to a certain value:

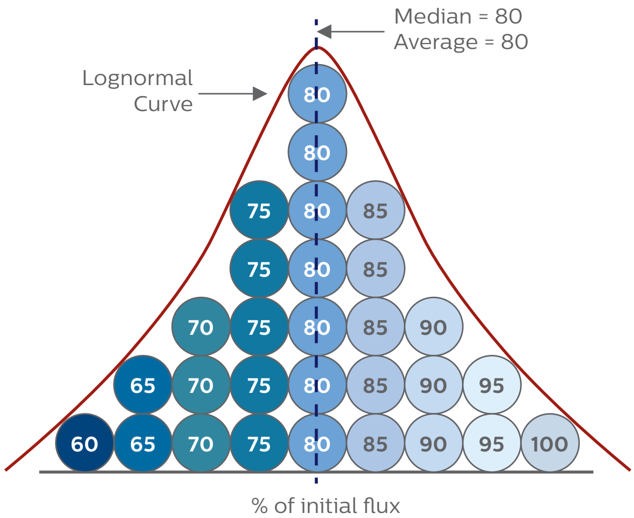


However, to understand the Useful Life of the respective LED based luminaires, we need to investigate what is actually happening at that point.

What we do is measure a whole batch of products and obtain a range of values:



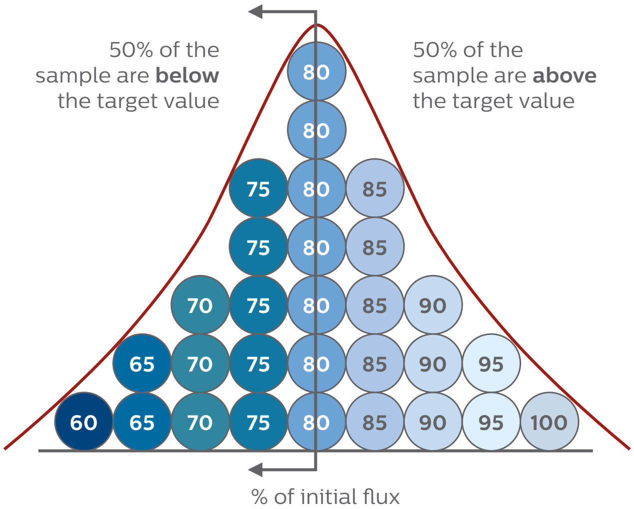
When we average all the products we have measured we create a point on our depreciation curve. In fact, some of the products will be above that average and some below. They will not all be the same value. So let's rearrange our data in a more meaningful way:



Now we have arranged all our data so we can see how many of the products are below and how many are above the average. It is useful to look at the median, which is the point on the graph where we have the same number of points above the median as below it.

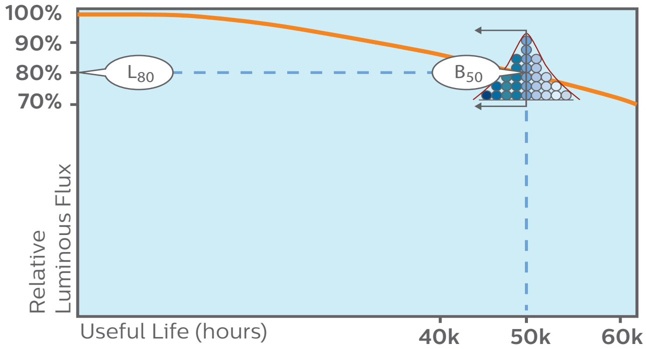
With LEDs the distribution is logarithmic for LED lumen decay. With such a distribution, the median is close to the average. This is significant as we will use the Average for our design calculations and the Median for predicting life beyond measurements.

In this example the median is 80 and we have as many points above the median as below it. We say that the life is the time to which the average is 80% of the initial average value.



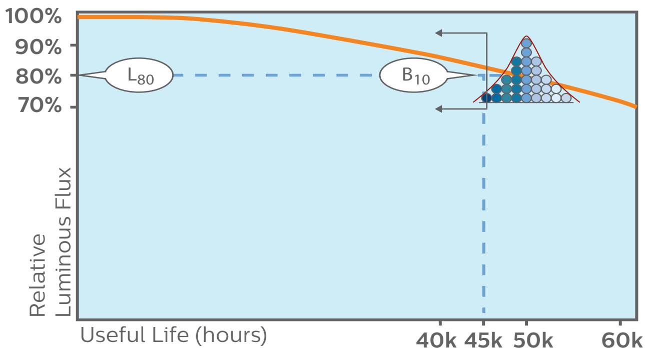
Light output lower than the target value (in this case 80) is called a 'parametric failure' because the product produces less light but still operates.

If we now place this data back on our graph then we see that the average is at 80% and we have 50% parametric failures and 50% still operating above our rated value of 80%.

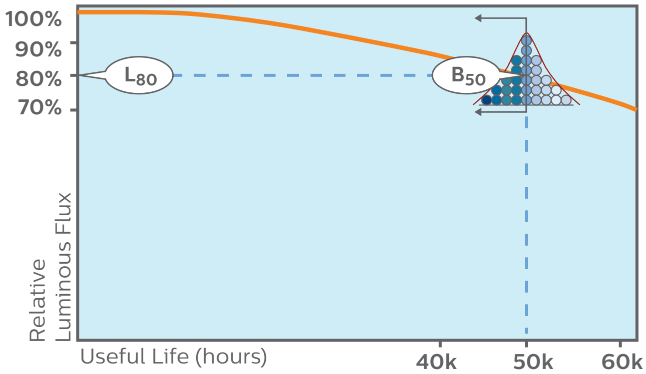


In the IEC this is defined as the Useful Life, and we use the Lx term to quantify the average value and the By to tell us how many are above the average and how many below. In this example we would say that the Useful Life ($L_{80}B_{50}$) = 50,000 hours. Useful Life therefore has to contain both the 'L' and the 'B' component.

We may decide that having 50% of our sample below the average is too much and we would want to consider a smaller percentage. If we want, say, 10% of our batch below the average then the time to achieve this will be less.
In this example we would say that the Useful Life ($L_{80}B_{10}$) = 45,000 hours.



However, for general applications we would normally take y to be 50:



In this specific case the average and the median values will be the same, so we define the Rated Median Useful Life L_x. In this case we don't need to use the 'B' term as with median y is always 50.
Rated Median Useful Life, or Rated Lifetime in the new IEC general definition, is the value marked on product datasheets, leaflets or website.

2.2.2 Abrupt light output degradation / Time to Abrupt Failure

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

Besides lumen maintenance (Useful Life), there are other factors to consider when evaluating performance over life.

LED based luminaires and modules are sophisticated products consisting of many components. An important parameter that should be considered with expected long life is system reliability. A LED based luminaire will last as long as the component used with the shortest life. There are several critical components of a LED based luminaire that influence the system reliability

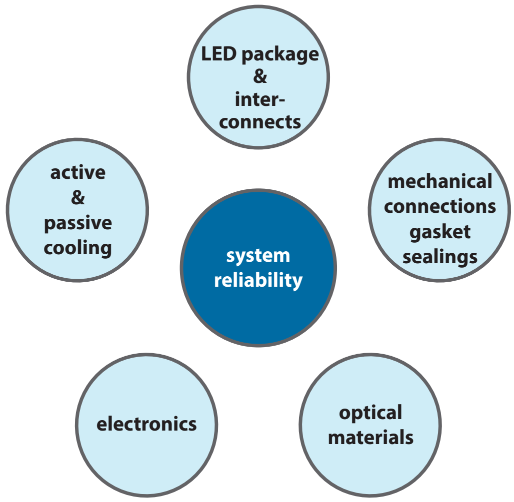


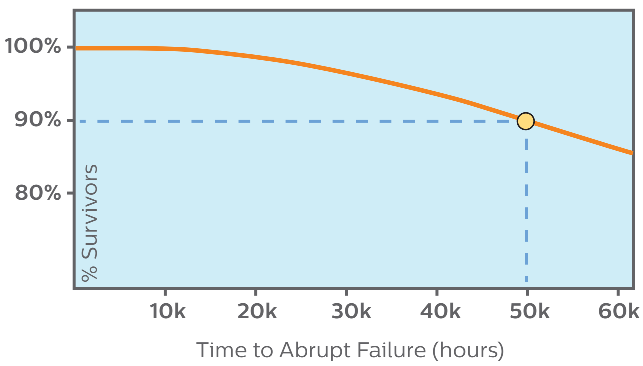
Figure 5 – – Critical components LED based luminaire

The IEC lifetime metric therefore also specifies Time to Abrupt Failure, which takes into account failure modes of critical components in the LED based luminaire design.

The abrupt light output degradation of a population of LED based lighting products at a certain point in time is called Time to Abrupt Failure and is expressed as L_0C_y. Time to Abrupt Failure describes the situation where the LED based luminaire no longer gives any light at all.

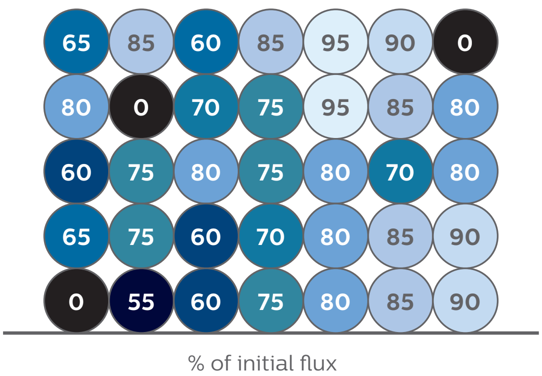
'L_x' describes the lumen maintenance: L_0 means that the LED based luminaires of this certain type give 0% of their initial light output. 'C_y' describes for what percentage of the population that is true.
The example L_0C_{10} reflects the age (in hours) at which 10% of the population have failed abruptly.

If we take a closer look at a failure curve, we can see what percentage of failures we have at a given time:



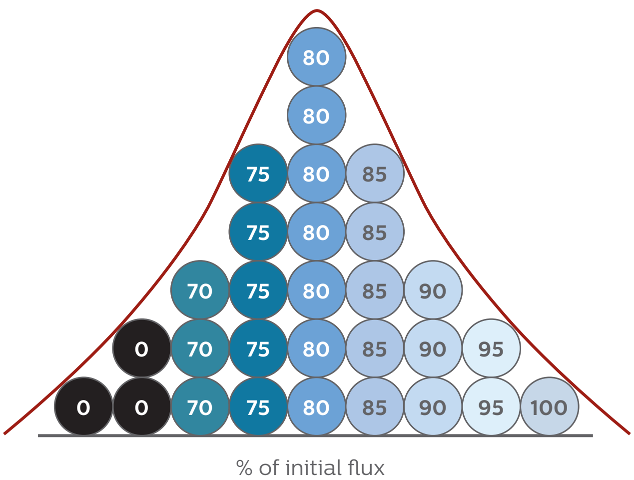
However, to understand the Time to Abrupt Failure of the respective LED based luminaires, we need to investigate what is actually happening at that point.

Taking a closer look at our data we can see more detail:

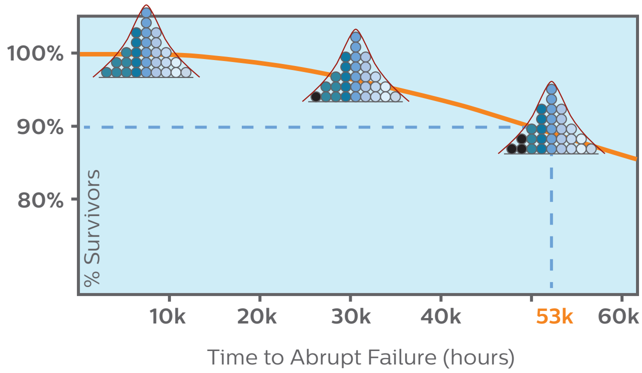


Within our sample batch of LED products we can see that some have failed completely or abruptly. This may be due to a mechanical failure, driver failure or anything that would cause abrupt failure.

If we order this data in a similar way as we did before we can see that the failures are a percentage of the total:

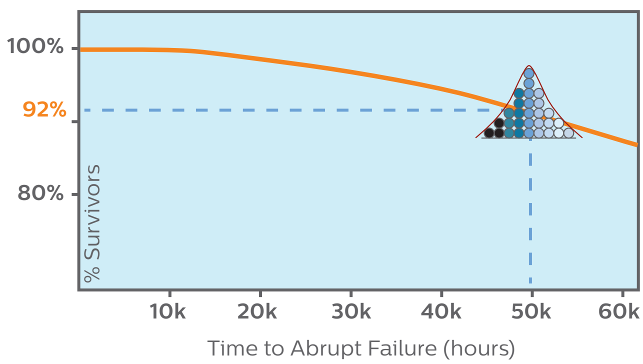


So at any given point on our failure curve we simply plot the percentage of failures compared with the original sample and note the time at which this occurs:



Note that here we are only concerned with abrupt failures and not failure due to loss of light.
We call this the ‘time to abrupt failure’ or C_y. In this example the Time to Abrupt Failure (C_{10}) = 53,000 hours.

Now we can look at a specific failure that occurs at the Rated Median Useful Life:



The Rated Abrupt Failure Value (AFV) is the percentage of LED based lighting products that fail to operate at the Rated Median Useful Life L_x. In this example, the Rated Median Useful Life is 50,000 hours and the Rated Abrupt Failure Value is 8%.

Unfortunately, the industry has not yet reached consensus on what critical components have to be taken into account when calculating Time to Abrupt Failure. Therefore, Philips Lighting has decided not to publish this value as long as there is a risk of apple-to-pear comparison.

2.2.3 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.

Philips has 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.

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

What Philips Lighting publishes on performance over time

The 'over time' performance specifications of Philips LED based luminaires are calculated using the IEC lifetime metric for LED based lighting products.

For **indoor** LED based luminaires Philips Lighting will publish two IEC-compliant quality criteria:
1. number of hours that correspond to the Median Useful Life values $L_{90}B_{50}$, $L_{80}B_{50}$ and $L_{70}B_{50}$;
2. the driver failure rate* at 5000 hours.

For **outdoor** LED based luminaires Philips Lighting will publish two IEC-compliant quality criteria:
1. number of hours that correspond to the Useful Life value $L_{80}B_{10}$;
2. the driver failure* rate at 5000 hours.

Over time life claims are specified at an ambient temperature of 25ºC with 12 burning hours per day and a number of switches in line with the main application.

For specific projects, tailor-made L_xB_y and L_0C_y calculations are available upon request.

* NOTE: As soon as there is industry consensus on what failure modes of critical components to include in the calculations, Philips Lighting will publish the Abrupt Failure Value belonging to the number of hours specified for the (Median) Useful Life values mentioned above.

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