Illuminating Engineering Society of Australia and New Zealand
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POSITION STATEMENT

LED/SSL Light Sources and LED/SSL Luminaires Lifetime and Lumen Maintenance

Designing with or specifying LED (SSL) luminaires is no different to any other luminaire. Depreciation and maintenance factors should be applied according to good lighting design practice and the appropriate application standard.

LED lamps are also known as SSL - solid state lighting. This paper uses LED as the generic term.

Despite the marketing claims of long life, LED lamps suffer a loss of light output over time just like any other light source.

Because of their long life, specifying the maintenance factors requires a slightly different approach but the fact remains any design or specification must include factors for losses.

Professional and responsible lighting designers should always follow best lighting practice; and provide practical and sensible information to the client and the general public at large.

"IES: The Lighting Society expects its members to demonstrate leadership, integrity and professional competency by adhering to accepted lighting design principles and to also provide clarity on such matters when communicating to their clients. It is a demonstration of these qualities that should define and identify a Member of the IES to the broader community"; Steve Coyne, Past President (2009-2012), IESANZ.

BACKGROUND

LED lamps have been around for a long time – even the 'white light LED' appeared in 1996 - but recently the technology and marketing has taken a quantum leap. LED lamps have become the flavour of the moment!

LED lamps are still in a relatively early stage of development and a long way from being a mature product. Efficiencies, colour quality and reliability will continue to significantly improve over the coming years.

It is quite possible that the LED modules of today (2012) will be obsolete within five or at least 10 years. It is extremely important therefore to be aware of the implications of the claimed so-called super long lifetimes.

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How to specify or provide professional advice on this topic is not that new. Consider these claims:

- *Long lifespan – between 65,000 and 100,000 hours depending on lamp model.*
- *Very high energy conversion efficiency of between 62 and 90 Lumens/Watt.*
- *Minimal Lumen depreciation compared to other lamp types.*
- *"Instant-on"*

Is this an LED lamp? It could be but this 'white light' lamp became commercially available over 20 years ago (1990) and like the LED lamp was actually invented decades earlier. These performance descriptions are of the (fluorescent) **induction lamp**.

So the issue of how to specify and design with long life lamps has been with us for some time. It is only because of the rapid market penetration and possibly dominance of the LED lamp that the lifetime issue has become a hot topic.

US EnergyStar Definition: Rated Lumen Maintenance Life (Lp): The elapsed operating time over which the LED light source will maintain the percentage, p, of its initial light output, e.g. L_{70} (hours): Time to 70% lumen maintenance. (IES LM-80-08).

Unlike other commercial lamps (incandescent, halogen, fluorescent or HID) but similar to the induction lamp, generally the LED itself never really 'burns out' – it just gets dimmer over time.

So, internationally, the lighting industry has settled on defining LED lamp lifetime metric by emphasising lumen depreciation.

The standards to define and control this approach are in their infancy but the most common metric is the L_{70}.

Typically the industry standard for LED lamps is around 50,000 hours to 70% lumen maintenance. Like all lamps the light output will degrade over the first few thousand hours of operation followed by a slower rate of depreciation by up to 30% after 50,000 hours.

For decorative and accent applications, it is common to recommend useful life as the length of time it takes an LED light source to reach 50% of its initial output (L_{50}).

For further information see:

- The IEC has published two important performance requirement PAS (Publicly Available Specification) documents: IEC/PAS 62717, LED Modules Performance and IEC/PAS 62722-2-1, LED Luminaires Performance. http://infostore.saiglobal.com/store/Details.aspx?ProductID=1464484 and http://infostore.saiglobal.com/store/Details.aspx?ProductID=1477198
- LRC (Lighting Research Center) *"ASSIST: Alliance for Solid-State Illumination Systems and Technologies"* www.lrc.rpi.edu/programs/solidstate/index.asp and www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp
- EnergyStar.[1] www.energystar.gov/index.cfm?c=lighting.pr_what_are#all_equal

Like the induction lamp before it, the life of the LED lamp is dictated by the driver electronics which typically has a 50,000 hour rating. Of course, in practice other factors will affect the real lifetime – most critically ambient temperature and thermal properties. This is especially true of poorer design quality LED luminaires.

[1] ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping us all save money and protect the environment through energy efficient products and practices.

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Quality Performance Over Life

Lumen maintenance is only one of many factors in determining the quality of an LED lamp or LED luminaire. The important factors are:

- Initial Luminaire Lumen Output L_{100}.
- Photometry at L_{100}.
- Lumen Depreciation Life L(x); where x is the percentage of L_{100} at the declared life – L_{90}, L_{80}, L_{70}; and L_{50} (for decorative lighting applications). *Note: standards and terminology are still evolving and sometimes, confusingly, lumen depreciation will be noted differently.*[2] *The Lx system appears to be the most accepted*[3].
- Failure Fraction F(x); where x is the percentage of failures at L(x).
- Colour Temperature at L_{100} and any shift at 25% of rated life.
- Standard Deviation of Colour Matching (SDCM) for colour consistency – values at L(x).
- Colour Rendering Index (CRI) Value.
    - *Note:* a new method of defining colour rendering is being discussed internationally, the CQS- the Colour Quality System developed by the (US) National Institute of Standards and Technology (NIST)[4].
- Colour Maintenance or Colour Rendering Index Value Shift at L(x).
- Luminaire Electrical Characteristics; total power consumed, power factor at initial and 25% of rated life (with a maximum duration of 6000 h).

A System Approach

Most important of all, assessing, specifying or designing LED life should be based on a system approach. In the real world the LED lamp will be housed in some sort of luminaire – however basic or sophisticated. The LED lamp or 'module' also requires electronic control gear known as a 'driver'. A LED module may have a L_{70} lifetime of 100,000 hours but if the driver lasts only 50,000 hours, the combined 'system' or 'LED light engine' can only practically be considered to have a life of 50k hours. Most reputable or responsible manufacturers standardise their drivers as having a 50,000 hours lifetime – which thus becomes the practical life of their LED lamps.

It is not uncommon to find lifetimes of only 10-15,000 hours for a LED driver - a fact to be aware of.

The other parts of the heart of the LED luminaire system are the mechanical, thermal and electrical interfaces at the 'back end'; and the photometric interface at the 'front end' of the LED light engine.

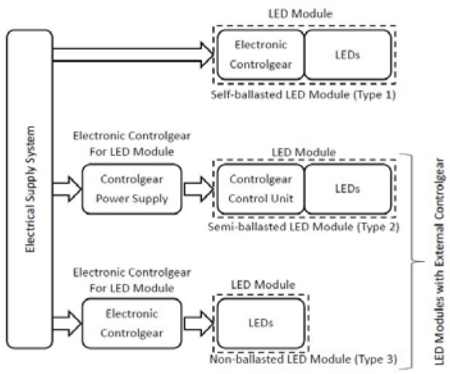

Figure 1 IEC-PAS 62717 Overview of LED Modules

Be aware too of efficacy – there is module efficacy and system efficacy e.g. a module could claim 94 lm/W but the system efficacy (with the control gear) could be 79 lm/W.

All these factors can directly affect the performance of the LED lamp.

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[2] Confusingly, L_{90} can be noted as Cat 1 or Code 1 or Code 9. Similarly L_{80} as Cat 2, Code 2 or Code 8 and L_{70} as Cat 3, Code 3 or Code 7!
[3] IES of North America IES LM-80-08 "Measuring Lumen Maintenance of LED Light Sources"
[4] Colour Quality Scale (CQS), US National Institute of Standards and Technology (NIST), to evaluate the colour rendering properties of light sources for general illumination; developed together with a colleague by Dr Wendy Davis, Associate Professor in the Faculty of Architecture, Design and Planning at the University of Sydney. http://www.nist.gov/pml/div685/grp05/vision_color.cfm

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Ten Things To Note or Be Wary Of:

1. A marketing claim: *"The extremely long life of an LED bulb will virtually eliminate your maintenance costs."* The key word is "virtually" – not "totally".
   - The reality is there will be failures; and the luminaire itself will accumulate dirt and dust needing cleaning. In instances where LED lamps are justified to be used in "high, difficult to access" locations, cleaning will still be an issue – thus a maintenance cost.
2. A 50,000-hour "life" for an LED lamp is not equivalent to lamp life rating.
   - L_{70} LED life is rated where it has reached 30 percent lumen depreciation. At the L_{70} figure, say 50kh, an LED would still be operating but at an ever decreasing lumen output.
3. LEDs have relative limited temperature tolerance. Heat severely affects light output and life.
   - The LED itself generates a lot of heat and a well designed heat sink is critical to its performance.
   - The heat sink[5] gets hot – that's its job – but that heat needs dissipating.
   - Some reputable manufactures state that if the chip temperature is increased by 10 degrees, the lifetime will be halved.
4. Take care with retrofit solutions – the physical shape and size of the lamp plus the delicate thermal control issues can severely alter the optical and other performance factors especially life.
   - *Example: many LED MR16 replacement lamp claims 50,000 hours of lamp life with the provisos:*
     - *i. Requires adequate ventilation around the lamp housing to ensure peak performance and lifetime expectancy*
     - *ii. Is not recommended for use in sealed luminaires*
     - *iii. Is not recommended for use with recessed luminaires or within small enclosures unless air exchange or cooling within the enclosed air space is provided*
5. Not all manufacturers comply with the L_{70} (and L_{50}) standards when stating lifetime; and consider warranties carefully against the product 'lifetime' claim of, say, 100,000 hours.
6. Be aware of the difference between module efficacy and system efficacy.
7. LEDs operate better in cooler ambient environments.
8. Some LEDs can flicker. There are many different LED "driver" technologies – some producing a variety of flicker characteristics in SSL systems under specific conditions, notably dimming.
9. Standards (for LED sources), both Australian and International, are constantly evolving. Regularly check the status of applicable standards.
10. Always look for a reputable LED luminaire manufacturer that publishes detailed product specifications that are measured in compliance with the IEC and Australian Standards performance requirements. And read the small print. Consider quality as a priority every time!

... and one more:

Saving energy should never be the only objective – appropriate and elegant design suited to the application should always override all else. *"The right light in the right place at the right time!" ... an old adage but still true!*

[5] The heat sink may form an integral part of the luminaire or self-contained 'lamp'.

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Designing and Specifying Lifetimes

The overall important approach is to use common sense.

With the claimed long "lifetimes" the designer is faced with what values to use for the usual lighting design parameters, in particular the maintenance cycle.

Ensure the LED source lifetime is matched to the application – L_{70} being the norm (except for decorative and accent applications where L_{50} is common) and based on recommended operating conditions.

Opt for a reputable LED manufacturer – both module and luminaire - who offer a comprehensive set of published specifications, photometric data, and related information.

Leading LED luminaire manufacturers, using quality components, design their luminaires to be durable, reliable and outlive the LED source. Choose an integrated component quality complete system over a mix-n-match.

Indoor Applications

Leaving aside the room surface depreciation factor, the luminaire dirt depreciation factor becomes the main decision. By definition of course L_{70} value translates to a 0.7 lumen depreciation factor. With lifetimes of 50,000 to 100,000 hours, the luminaire cleaning cycle takes on a relatively more important influence.

It would also be worth considering raising the IP rating when specifying or designing a project. With no apparent need to change the lamp, there is no need to access the 'internals' of the luminaire – in theory it could be sealed. This would improve the maintenance cycle (less accumulated dirt of optical chamber) and reduce cleaning times (less surfaces to clean).

The 'sealed' luminaire of course would have to be designed to cope with the thermal issues of the LED engine to ensure the lifetime performance of the LED lamp.

Outdoor Applications

In outdoor applications the IP rating of an LED luminaire takes on a more significant role. If an LED source is chosen for, say, a street lighting project on the basis that the exceedingly long life means drastically reduced maintenance costs, then the IP rating becomes a critical factor.

With a typical lifetime at L_{70} of 50kh, a best case scenario of (say) IP65 and a very clean environment, the luminaire dirt depreciation factor (LDD)[6] is around 0.87. So the design factor from a maintenance standpoint is 0.87 x 0.7 = 0.6 which could be considered an "uneconomical proposition"!

Practical applications e.g. car parks, industrial spaces etc, the LDD ranges from 0.59 to 0.79. Thus the design factor could be between 0.41 and 0.55. The economic argument for LED becomes not so crystal clear.

These scenarios of course assume no cleaning cycles are applied. The real world of economics does not often include cleaning outdoor luminaires unless a lamp change is required.

Using an LED light engine, an outdoor luminaire can afford to have a higher IP rating – to reduce the need for cleaning internal surfaces. Therefore cleaning could become a question of 'self-cleaning' (rain) or 'hosing' (common for instance in tunnel lighting). See also "LED Array Issues".

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[6] *Note also: LLD = lamp lumen depreciation; LLD + LDD = LLF (light loss factor).*

Consider Supersession and Obsolescence

At the current rate of 'turbo' development, today's LED products may be obsolete in 5 years ... certainly superseded! LED technology is not mature and, at best, the products and standards today could be considered 'transitional'. But LED systems being designed and installed today will have an expectation of having an extended life. The designer still needs to apply the same professional design standards to the project.

> *Example: an international manufacturer's Zhaga compliant module provided 52 lm/W when launched in 2009; the exact same module in its 3rd generation (2012) produces 95 lm/W and 80% increase – in 3 years. Other newer module types (2012) are now reaching 135 lm/W surpassing T5 fluorescent lamps.*

LED Array Issues

LED sources are small and you need a lot of them to get equivalent light output to conventional lamps. In many cases a luminaire relies on having an integrated array of regimentally arranged LEDs. This is typical of the higher lumen package luminaires like floodlights and street lights. The question of reliability of the LED sources becomes a critical issue. Choosing a reliable and reputable manufacturer is an important consideration and should be carefully balanced against the relative cost of the system components.

An LED array has the potential for discrete failures in specific parts of the lighting distribution and in applications such as street lighting, this could be critical. Outwardly the luminaire may still appear to be functioning yet its original designed light distribution is compromised. It is clear that the failure rate of an LED array-based luminaire cannot be accurately defined by applying the individual LED module failure rate.

Other array based luminaires could potentially express such a problem – for example a floodlight with an asymmetric light distribution.

Maintenance recommendations and procedures need careful consideration.

In reality it is no different to current technology streetlights which may utilise more than one (fluorescent or HID) lamp – the issue has always been there. New 'smart' technology may permit practical ways of dealing with the problem.

Particularly for street lighting, future standards may require some sort of local internal failsafe switch to turn off the luminaire should an individual LED fail? ... or some other 'intelligent' control?

End of "Life" Considerations

The end of useful life of the LED technology is a major issue. At the end of the LED rated life e.g. 50,000 hours, what to do? For those who remember, there is a danger of the "Mercury-Vapour Lamp Syndrome". In inaccessible areas and outdoor – especially street lighting – the old MV lamp had a habit of lasting 'forever'. Very little light coming out of it but it was still 'operational'.

We are faced with the same issue for LED. An L_{70} 50kh LED installation on a 24 hour duty cycle will be ready to be replaced in about 5 years (taking into account irrecoverable losses recommended in AS1680). A possibly typical commercial instillation might be 10 years. In each case the LEDs will still be producing light! Perhaps an electronic message is generated to warn the owner, perhaps an automatic switch off, some other digital wizardry? Drastic, yes, but realistic and practical alternatives need to be considered so that the installation remains compliant.

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The Future

Two things are absolutely certain – one is that LED lighting is here to stay and will become the dominant light source technology; and, two, that LED lighting technology will evolve rapidly.

Today's LED modules and systems will change, will improve, and ... will be superseded! Standards will struggle to keep up.

Look for quality ethically designed future-proof technical philosophies from reputable global manufacturers.

The big LED developments today are in power management and optics. Integrated power systems show real reductions in energy use. Optical design is searching out new possibilities in light distribution and control.

LED lighting will evolve into a vastly new, different, more efficient and varied choice.

Designing with or specifying LED luminaires is no different to any other luminaire.

Depreciation and maintenance factors should be applied according to the appropriate application standard and good lighting design practice.

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Further Reading:

- The IESANZ website has a collection of useful up-to-date information on LEDs – see RESOURCES › Technical Information › Lamps. www.iesanz.org/resources/technical-information/lamps/ and more on the Standards page, see RESOURCES › Standards www.iesanz.org/resources/standards/
- "*Guidelines for Specification of LED Lighting Products*" – a [European] Guide produced by the Lighting Industry Liaison Group: www.iesanz.org/_dyn/media/r313/system/attrib/file/962/LED%20Specification%20guide%202011%20Final%20v3.pdf
- 'Lighting' magazine: the official voice of the Illumination and Engineering Society of Australia and New Zealand. www.rala.com.au/lighting/overview.do
- LCA SSL Quality Scheme. The Lighting Council of Australia has a scheme *"based on a scheme introduced by the US Department of Energy in conjunction with the US lighting industry. The SSL Quality Scheme is a voluntary industry scheme that provides confidence to the market that a luminaire carrying the Scheme's label matches certain performance claims made by the supplier."* www.lightingcouncil.com.au/ssl/overview.php and www.lightingcouncil.com.au/pdf/news/Lighting%20Council%20Australia%20Technical%20News%20No%2018%20amended%20version.pdf
- CELMA[7] Guide on LED Quality and Standards www.celma.org/archives/temp/CELMA_TF_Apples_Pears(KR)009_CELMA_Guide_quality_criteria_LED_luminaires_performance_Sept2011_FINAL.pdf and www.celma.org/archives/temp/CELMA-ELC_LED_WG(LCB)001_CELMA_ELC_Guide_LED_related_Standards_3rd_Edition_Final_July2011.pdf
- Be aware of such initiatives as interchangeability of LED light sources made by different manufacturers. An example of an industry-wide cooperation between companies is Zhaga[8] www.zhagastandard.org/
- LED tubes are different to fluorescent lamp tubes – Safety Concerns: www.justice.qld.gov.au/fair-and-safe-work/electrical-safety/forms-and-publications/outlook/autumns-2010-issue/nled-lighting-products
- Modifying T8 and T5 lighting using LED tubes - Safety risks: www.sa.gov.au/subject/Water,+energy+and+environment/Energy/Electricity+and+gas+safety/Electricity+and+gas+safety+and+technical+regulation/Manufacturers+and+importers/Safety+risks+of+changing+or+modifying+T8+and+T5+lighting
- Equipment Energy Efficiency Program (E3): a joint initiative of Australian, State and Territory and New Zealand Governments www.energyrating.gov.au/products-themes/lighting/leds/ and http://www.eeca.govt.nz/node/12732
- US EnergyStar® initiative: www.energystar.gov/index.cfm?c=lighting.pr_what_are
- US Department of Energy SSL: http://www1.eere.energy.gov/buildings/ssl/index.html
- Illuminating Engineering Society of North America LM-80-08 "Approved Method: Measuring Lumen Maintenance of LED Light Sources" http://www.ies.org/store/product/approved-method-measuring-lumen-maintenance-of-led-light-sources-1096.cfm
- An EC (European Commission) website which informs consumers, professionals and the media about the wide range of energy efficient lamps currently available, the phase-out of inefficient lamp types, lamp performance package labelling and what European legislation is already in place. http://ec.europa.eu/energy/lumen/index_en.htm

[7] CELMA Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in the European Union. www.celma.org

[8] Zhaga creates specifications that enable interchangeability of LED light sources made by different manufacturers simplifying LED applications for general lighting. Zhaga specifications cover the physical dimensions, as well as the photometric, electrical and thermal behaviour of LED light engines. An LED light engine is a combination of an LED module and the associated control gear.