U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Lumen Maintenance and Light Loss Factors:

Consequences of Current Design Practices for LEDs

September 2013

Prepared for:

Solid-State Lighting Program
Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:

Pacific Northwest National Laboratory

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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(8/2010)

Lumen Maintenance and Light Loss Factors: Consequences of Current Design Practices for LEDs

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September 2013

PNNL-22727

Abstract

Light loss factors are used to help lighting systems meet quantitative design criteria throughout the life of the installation, but they also carry ancillary consequences such as influencing first cost and energy use. As the type of light sources being specified continues to evolve, it is necessary to carefully evaluate the methods used in calculating light loss factors, as well as understand the broad effects of performance attributes like lumen maintenance during the selection process. Because of the unique operating characteristics of LEDs and lack of a comprehensive lifetime rating—as well as the problematic relationship between lifetime and lumen maintenance—determining an appropriate lamp lumen depreciation (LLD) factor for LED products is difficult. As a result, a unique solution has been advocated: when quantity of light is an important design consideration, the IES simply recommends using an LLD of not greater than 0.70. This method deviates from the typical practice for conventional sources of using the ratio of mean to initial lumen output, and can misrepresent actual performance, increase energy use, and inhibit comparisons between products. This paper discusses the complications related to LLD and LEDs, compares the performance of conventional and LED products, and examines alternatives to the current recommended approach for determining LLDs for LED products.

Keywords

Lamp lumen depreciation, light loss factor, solid-state lighting, light-emitting diode (LED), energy savings

1. Introduction

1.1 Light Loss Factors

A basic goal of lighting design is to meet the needs of end users over the life of an installation. One element of that goal is producing the desired amount of light. However, unless otherwise adjusted, all lighting systems decline in lumen output over time due to reductions in lamp emissions and changing surface properties—lamp, luminaire, and room, if applicable. This decline, as well as other differences between calculations and real-world situations, is typically be accounted for by applying a light loss factor (LLF) during the design process. In essence, a LLF is a multiplier that is used to predict future performance (maintained illuminance) based on the initial properties of a lighting system. Using a LLF less than 1.0, as is typical, means the initial light level will be above the recommended target value, but as time progresses, the light level will decline toward—and potentially below—the established criterion.

The total LLF (LLF_T) applied during the calculation process is the product of numerous individual factors. Some of the factors are considered recoverable; that is, they can be changed through maintenance, and generally vary over time. Others are considered non-recoverable; that is, they are factors of the site and equipment, and are generally fixed or unpredictable over time. The IES *Lighting Handbook* [DiLaura and others 2011] lists three recoverable LLFs: lamp lumen depreciation (LLD), luminaire dirt depreciation, and lamp burnout. Ballast factor is a common non-recoverable LLF.

Using a LLF closer to 1.0 during the design process has two potential consequences: (1) the system may not provide enough light as it nears end of useful life; and/or (2) fewer luminaires or lamps with lower lumen output can be used to meet design targets, effectively reducing the cost of the system. In contrast, using a LLF substantially less than 1.0 may result in excessive energy use, over lit spaces, glare, light trespass, and/or unnecessary sky glow.

1.2 Uncertainty in Light Loss Factors

The difference between actual illuminance depreciation over time, IES-recommended predictive LLFs, and the LLFs (or lack thereof) commonly used by lighting specifiers can sometimes be unclear. This analysis defers to current IES-recommended practices as specified in the 10th Edition of the *Lighting Handbook* [DiLaura and others 2011]. Although IES recommendations are important within the industry, lighting specifiers are ultimately responsible for the methods they use in designing lighting systems.

The ability of a designer to use an LLF to accurately predict future performance is limited by several factors. Although many LLFs are empirically based, specifiers must estimate many things, such as the operating cycle or the cleanliness of the environment; often, these attributes depend on the behavior of the occupants or maintenance staff. Further, LLFs approximate average characteristics; variation from installation to installation can create additional uncertainty in predicted performance. Some known causes of light loss, such as environmental and equipment-based thermal characteristics or lamp tilt, are often disregarded by practitioners. In some instances, these disregarded factors are too nebulous to predict accurately and their omission is warranted; nonetheless, they may contribute to differences between predicted and actual performance. Finally, light loss factor calculation methods intended for a group relamping schedule are sometimes applied when spot relamping is utilized, or vice versa. Differences in maintenance can lead to substantial variation in performance over time.

Is there more uncertainty for LEDs, as a whole, than conventional sources? One could argue this is true, given that the expected lumen depreciation of LEDs is largely based on predictive models, and further, these models are for LED packages that become components within an integrated LED lamp or LED luminaire. At the same time, it may also be reasonable to conclude that this uncertainty is within the overall "slop" associated with light loss factors—or lighting calculations as a whole—and that using predicted LED lumen maintenance is no different from ignoring a tilt factor, thermal factor, or operating cycle for high-intensity discharge (HID) or fluorescent lighting. Further, calculations using conventional sources rely on relative photometry, rather than absolute photometry as used for LED sources; although this does not affect light loss factors, it can influence the accuracy of design calculations. For example, data from the U.S. Department of Energy's CALiPER program has shown the lumen output of luminaires using fluorescent lamps and relative photometry to be overrated by 15% or more when evaluated against absolute photometry measurements [DOE 2009; DOE 2010; DOE 2012].

Despite such challenges in accurately predicting future performance, the goal should always be to forecast performance as effectively as possible, following a methodology that is consistent across all types of lighting systems. One of the most important questions that a specifier must consider is whether a lighting system must meet the target illuminance at all times, or if some deviation below the target is acceptable. If some deviation below the target is allowed, how much can be tolerated and for how long? Regardless of the criteria that are chosen, it is important for products to be evaluated under equal conditions.

1.3 Comparisons and Consequences of Lamp Lumen Depreciation Factors

This paper examines LLD, a recoverable light loss factor that characterizes the decline in lumen output of a light source over time. For all light sources besides LEDs, LLD is commonly calculated as the ratio of mean to initial lumens [DiLaura and others 2011], where mean lumens are defined as the output at a certain percentage of rated life, based on the lumen depreciation curve for a specific product. In contrast, *when quantity of light is an important design consideration,* the IES recommends using an LLD of not greater than 0.70 for LEDs, regardless of the rated lifetime or lumen depreciation characteristics of the product. This has created a de facto rule-of-thumb LLD of 0.70 for all LEDs, despite well-documented variation in product performance. This approach hinders specifiers' ability to differentiate products based on their lumen maintenance performance, and energy may be used to unnecessarily over-light spaces.

Nonetheless, the question remains, "Is 0.70 too low, too high, or just right?" [Houser 2012]. The answer is likely dependent on the specific product and the accuracy of current predictive models, but it is a debate with serious consequences for responsible energy use. A change in LLD from 0.70 (resulting in an initial light level at 143% of the target) to 0.80 (initial light level at 125% of the target) can reduce energy consumption by roughly 13% over the life of the system. With all the effort that is put into improving luminous efficacy in the name of energy efficiency, the effect of LLFs on energy use may deserve more attention, with more care given to using an LLD that best represents expected performance for a given installation. Similarly, while extending rated lifetime may reduce life cycle costs, improving lumen maintenance characteristics can have an immediate impact on both initial and lifetime costs, while saving substantial amounts of energy. At the same time, it is imperative for both specifiers and manufacturers to understand the consequences of products with poor lumen maintenance characteristics, which require the use of a lower LLD and thus use more energy over the life of the system.

2. Lumen Maintenance Characteristics and Calculations

2.1 Conventional Sources

Generalized lumen maintenance functions for several source types are shown in Figure 1. Although there is often substantial variation within a product type, these curves are useful for comparing the broad range of lumen depreciation characteristics. Additional information on lumen depreciation can be found in the IES *Lighting Handbook*, and curves for specific products may be available from manufacturers. As shown, lumen maintenance characteristics can vary substantially. In general, incandescent and halogen lamps exhibit continuous lumen depreciation over their relatively short lives. In contrast, the rate of lumen depreciation for fluorescent lamps tends to decline over time, with lumen output nearing an asymptote. The most varied product type is HID, for which the rate of lumen depreciation may either increase or decrease.

For conventional lamps, LLD is commonly calculated as the expected lumen output at a given point in time (*mean lumens*) divided by the initial lumen output (*initial lumens*), notwithstanding cases where a

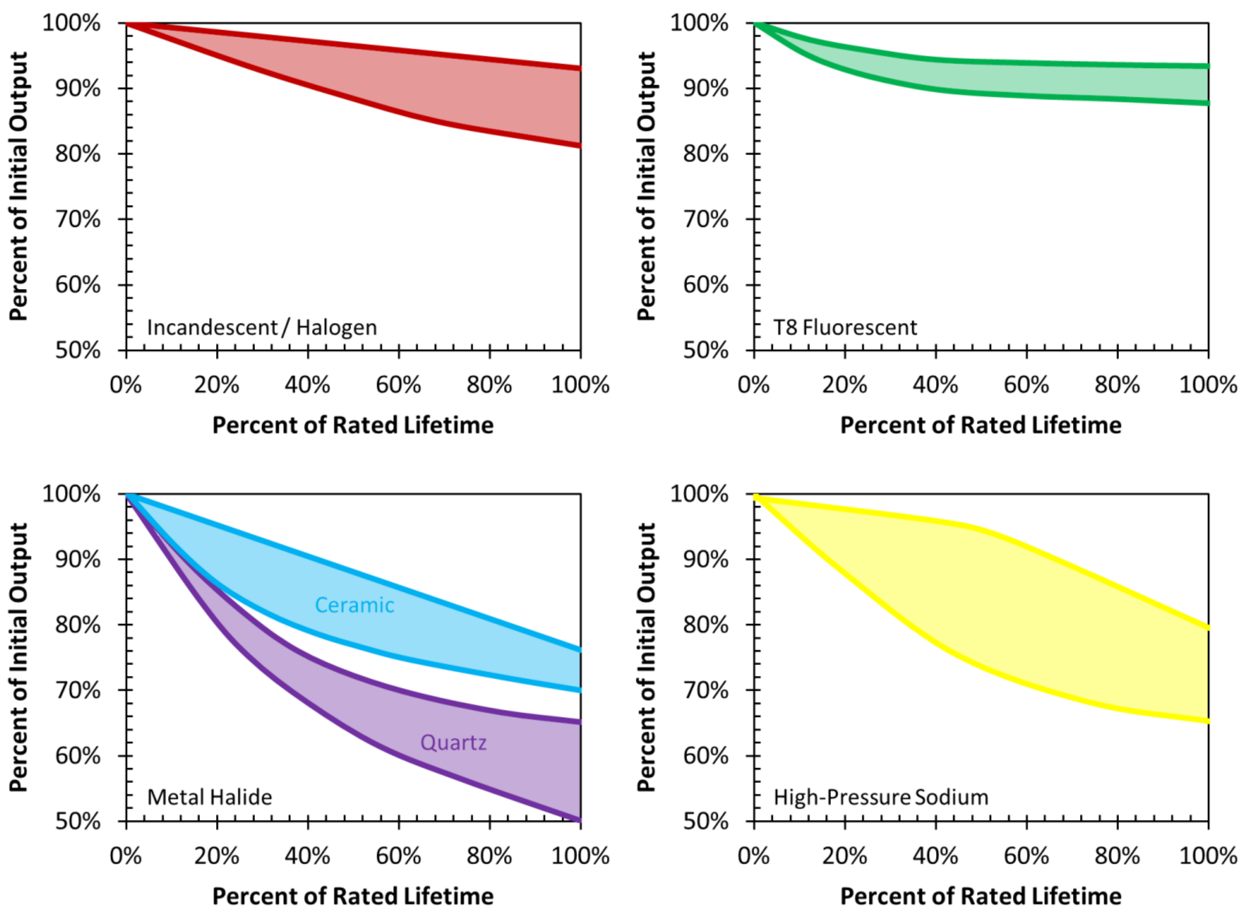

Figure 1. Typical lumen maintenance characteristics for different light sources. Note that the rated lifetimes in hours can be substantially different for these light sources, which are just a subset of many different available source types.

rule-of-thumb value is used instead (e.g., 0.80). The specific point in time used for determining mean lumens is given as a percentage of the rated life.[1] For fluorescent and metal halide lamps, 40% of rated life is typically used, but for other lamp types, 50% is more common. For example, if a metal halide lamp's rated life were 20,000 hours, the value for mean lumens would be the expected lumen output at 8,000 hours. To be precise, mean lumens should be determined for the specific ballast and for the expected operating cycle (e.g., 12 hours per start). However, this level of specificity is not always considered. In practical settings, a specifier will calculate the ratio of mean to initial lumens using the values listed in a lamp catalog. The conditions for a manufacturer's derivation of mean lumens may be given, but they may or may not match the conditions of the intended application.

The use of mean lumens may not strictly adhere to the fundamentals of light loss factors, which are intended to ensure that target light levels are met throughout the life of the system. Nonetheless, the use of mean lumens is acknowledged as common practice in the IES *Lighting Handbook,* and it is noted that this can result in light levels below the design target for a portion of the rated life. Importantly, IES maintained illuminance targets are intended to be the minimum maintained target value, but are not rigid designations like codes or standards. In applications where minimum light levels are required by code or a conservative approach is preferred, the use of mean lumens may be inappropriate; instead the expected output at the specified time of group relamping (e.g., 70% of rated life) or at the end of rated life could be used in lieu of mean lumens.

2.2 LED Sources

2.2.1 Typical Lumen Maintenance

Because LED technology is still developing at a rapid pace—and because the lifetime of LED packages is often tens of thousands of hours—it is usually not realistic to measure the lumen output of LED products beyond a portion of their expected lives. Most publicly available data extends to 6,000 hours, with a small percentage going beyond 10,000 hours. While data in this form is often available for LED packages, it is rare to find any kind of long-term measured data for integrated LED lamps or LED luminaires.

The IES has established LM-80-08 [IES 2008] to standardize lumen maintenance measurements of LED packages and TM-21-11 [IES 2011] to establish a method for extrapolating LM-80-08 data to up to six times the number of tested hours. Notably, the measurements may not represent real world performance, given the steady state operating conditions that are prescribed. TM-21 defines an exponential least squares curve fit for extrapolating data, although in many cases the estimated depreciation is approximately linear. Because of the length of time and the small amount of measured data, plots of LED lumen maintenance are often shown with a logarithmic scale for the x-axis. To an uninformed observer, it may appear that output declines precipitously, although this is just a result of the plotting method.

Importantly, lumen depreciation for LED packages is affected by operating conditions and varies substantially between different products. As shown in Figure 2, the expected lumen maintenance for a single type of LED package can be very different based on the junction temperature, which is affected by the drive current, ambient temperature, and thermal performance of the lamp or luminaire in which the

[1] Rated life is defined as the expected number of hours when 50% of a large sample of lamps can be expected to have failed ("burned out").

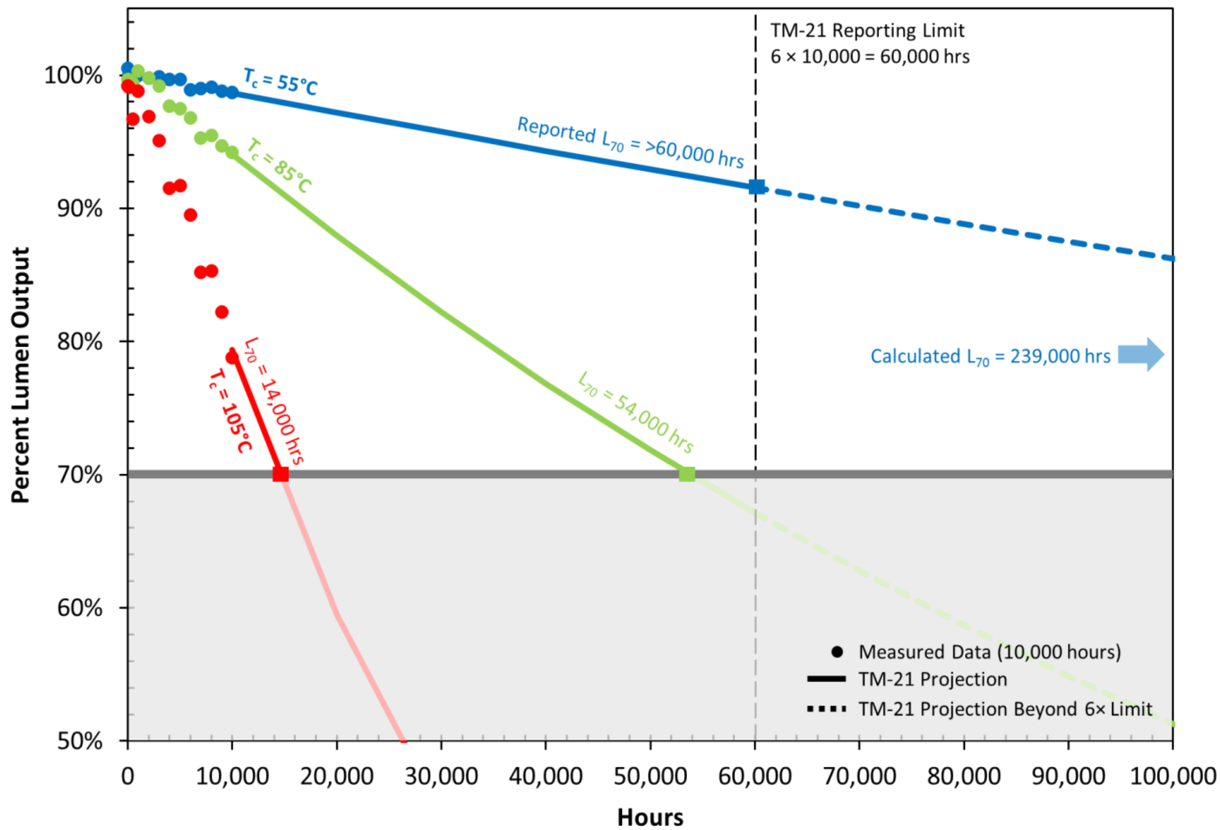

Figure 2. **Measured and projected lumen maintenance of one type of LED package at three different case temperatures.** Thermal characteristics can have a dramatic effect on performance over time.

package is used. A similar situation arises with conventional lamp types, for which the lumen depreciation may be influenced by operating characteristics, like the number of hours per start or voltage. These long-term effects are independent of the relationship between lumen output and operating conditions at a given time, which is similarly an issue for many light sources.

LM-80 and TM-21 may be tenuously applied to integrated LED lamps and LED luminaires by ensuring the in situ operating temperature of the LEDs is within the range tested. This is accomplished through an In Situ Temperature Measurement Test (ISTMT). Manufacturers may or may not take this step to ensure the accuracy of life claims they make, and it is very difficult to account for real world differences in ambient temperature. IES LM-84 and IES TM-28, both in progress, are intended to further address the measurement and projection of lumen maintenance for integrated LED lamps and LED luminaires.

2.2.2 LED Rated Lifetime

Before it is possible to understand LLD for LEDs, it is important to recognize that LED rated lifetime is not considered in the same way as conventional sources. When well designed and manufactured, LED packages rarely fail catastrophically, but rather exhibit a continual decline in lumen output. However, other components in a complete LED product can fail catastrophically, and the real world balance of these two actions over time is not certain.

The failure of any LED system component—not just the array of LED packages, but also the electronics, thermal management, optics, seals, or connectors, for example—can directly or indirectly lead to product failure. While some LED products will fail in a familiar catastrophic way, others may exhibit parametric failure—meaning they no longer produce an acceptable quantity or quality of light. A complete characterization of the useful life of an LED product must consider the possibility of catastrophic or parametric failure for each system component, operating together as a system. At this time, however, there is no standard or well-accepted method for performing such a characterization [NGLIA and DOE 2011]. Instead, the rated lifetime of LED lamps and luminaires provided by manufacturers is typically based on only the lumen maintenance of the LED package. This measure is officially termed *lumen maintenance lifetime*, but being the only accepted measure of lifetime for complete LED products, it has become the de-facto method for providing rated lifetime for LED products. Nearly exclusively for architectural lighting products, the lumen maintenance lifetime of LED products is quoted as L_{70}, or the time in hours when lumen output is expected to be at 70% of initial. The genesis of this practice is research that found human observers began to notice diminished light levels at 70% of initial [LRC 2006]. Thus, if a product reaches that output level, it would be considered to no longer be delivering an acceptable quantity of light.

The limitations of using L_{70} as a surrogate for rated lifetime are recognized. As it relates to light loss factors, linking lifetime to lumen maintenance complicates the practice of calculating LLD as the quotient of mean and initial lumens. If L_{70} is considered the rated lifetime of a product, using a value for mean lumens at 40% of rated life would result in an LLD of 0.88 (assuming linear depreciation); this value may be unreasonably optimistic, especially if it were to be applied to all LED systems. Then again, using an LLD of 0.70 for LEDs is strictly based on end-of-life lumens, rather than mean lumens, and other source types are rarely treated in such a conservative manner.

2.2.3 Current Recommended Methods for Calculation of LLD for LED

For LED products used in applications where the quantity of light is a key design criterion, the IES recommends that an LLD of not greater than 0.70 should be used. This applies to a majority of lighting applications. A less conservative approach is provided by the IES for use in situations where light loss is not a critical factor, such as decorative or direct view applications. This less conservative method follows the typical approach for conventional light sources: (1) establish a lifetime in hours for the given application; (2) determine the mean lumen output at the time corresponding to 40% of that lifetime, using data for the specific product; (3) calculate LLD as a ratio of mean to initial lumens using a lumen maintenance curve.

3. Discussion

Figure 3a demonstrates the lumen maintenance characteristics for:

1. An example of an LED package with good lumen maintenance. The dataset was provided by a luminaire manufacturer in conjunction with ISTMT data and other supporting documentation for components within the luminaire. The package is under-driven to maintain a low junction temperature; as shown in Figure 2 for the same package, reducing the temperature can greatly increase the projected lifetime of the product.

2. An example LED package with a shorter rated L_{70} lifetime that may be more typical of the broader LED luminaire market. The data were obtained for a GATEWAY demonstration project. Although the dataset is for a bare LED package tested according to IES LM-80 and extrapolated using IES TM-21, available ISTMT data suggests similar performance would be achieved in at least one type of luminaire. In other words, for this hypothetical comparison the dataset is a reasonable prediction of performance for a complete luminaire.
3. The DOE L Prize®-winning LED A lamp, which has been tested for more than 25,000 hours in a specially designed lumen maintenance test apparatus [DOE 2011]. A total of 202 samples were tested at an ambient temperature of 45°C, providing the most extensive publically available lumen maintenance data for an integrated LED lamp or luminaire. The product exemplifies the potential of LED products, with a calculated L_{70} of more than 400,000 hours (based on the mean performance). Of course, if applied to an LED lamp, TM-21 would only allow reporting the extrapolation up to 150,000 hours, at which point the average lumen output is expected to be 91% of initial, with the statistically relevant thirteenth worst sample at 89% of initial.
4. Two types of common T8 fluorescent lamps: one 32 W, 70s CRI, 3500 K lamp, and one high-performance, 32 W, 80s CRI, 3500 K lamp. The data were obtained for publicly available manufacturer literature. Even within a technology that is well established, there can be substantial variation in performance. The lumen maintenance characteristics of other light sources may be better (e.g., some T5 fluorescent lamps) or worse (e.g., some CFL and HID lamps); the T8 fluorescent lamps are simply point of comparison.

Figure 3b shows the same set of lamps, but illustrates the predicted light level over time using LLDs that are generally considered common practice: 0.70 for the LEDs, mean lumens for the fluorescent lamps (0.92 and 0.95 for the standard and high-performance lamp, respectively). The figure does not consider other LLFs in order to provide a direct comparison of the effects of LLD calculations. As the figure shows, the light levels are predicted to drop below the target for the fluorescent lamps, but not for the LEDs. In fact, using an LLD of 0.70 for the LED systems dictates that the target light levels will be exceeded for the entire rated life of the systems—and potentially beyond, if L_{70} is not reached within TM-21 projection limits. This may be 10, 20, 30 or even more years in the future. Additionally, initial light levels are substantially higher than the target for all of the LED products, resulting in the many aforementioned consequences. Figure 3 illustrates differences in lumen depreciation characteristics, but more importantly, it demonstrates a prevalent conceptual difference in treatment of LED and conventional products. Some specifiers prefer a more conservative approach where illuminance levels provided by conventional sources are not predicted to drop below the design target; Figure 3 could be redrawn to show this approach, but there would still be dramatic differences in the expected lights levels relative to the target for the LED and T8 fluorescent products.

Of particular note is the performance over time of the L Prize lamp. Because it exhibits very little lumen depreciation, the predicted illuminance level remains well above the target for well over 100,000 hours—roughly 30 years at eight hours-of-use per day—which is beyond the lifetime of many architectural spaces. A similar consequence likely exists for example LED 1, although at this point the predicted performance is based more on models than measurements. In essence, the practice of limiting the LLD to 0.70 for all LED products is most detrimental to better-performing products, and greatly

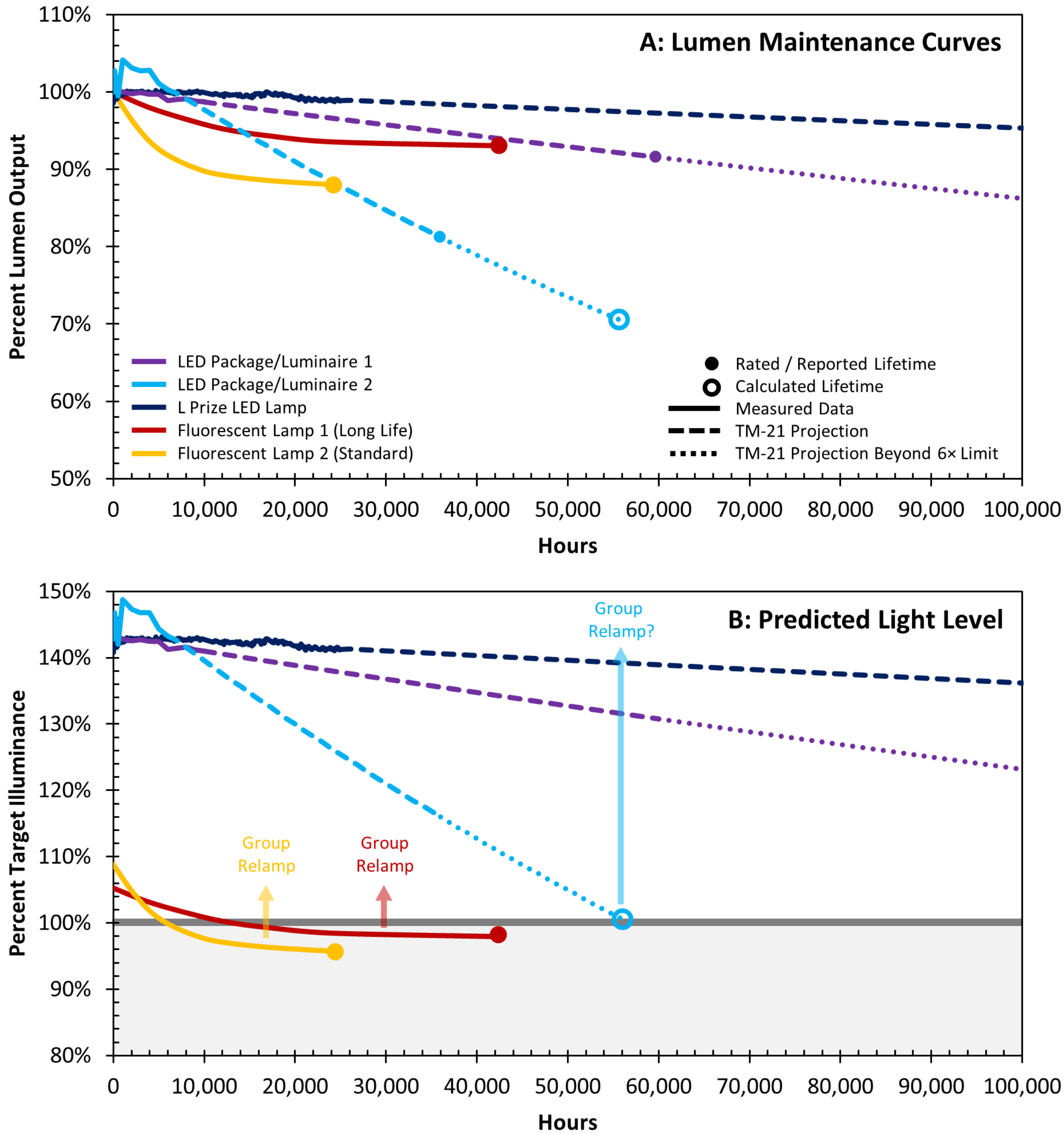

Figure 3. **A. Lumen depreciation characteristics for three LED and two fluorescent sources.**
B. Illuminance level relative to the target for the five different sources. The LEDs have LLDs of 0.70, whereas the fluorescent lamps have LLDs of 0.92 (standard) and 0.95 (high-performance).

reduces the incentive to design or purchase a lamp with more consistent lumen maintenance in order to save energy.

Conventional lamps, like T8 fluorescents, have regular and predictable catastrophic failure mechanisms. Thus, lighting specifiers can be confident that maintenance personnel will be alerted to the need to relamp, so light levels will not drop too far below the target. In other words, the lamps are expected to burn out before lumen output can drop too far. In contrast, LED products may not fail catastrophically before the end of their rated lifetime, providing no readily obvious signal to the maintenance personnel.

If an LED system were left in place beyond the hours-of-use at L_{70}, then the expected light level would decline indefinitely, but only assuming that other LED components will last similarly long. Based on current practices, for LED-based systems long-term illuminance depreciation below the target level is typically a result of improper maintenance or unexpected system degradation, whereas fluorescent systems are often designed to have such behavior.

Although lighting specifiers cannot guarantee proper maintenance of the systems they have designed, part of their role is to explain to the client the importance of maintenance for meeting lighting design targets, especially when energy codes and sustainable design goals limit the amount of lighting power that can be installed. When over-lighting and additional luminaires are an impractical approach to compensating for expected lumen degradation, responsible maintenance is essential. Specifiers can communicate to the owner the basis of their design (prior to construction), including a statement of the expected rates of lumen depreciation and an assumed maintenance schedule.

3.1 Alternatives to an LLD of 0.70

As LED-based products continue to increase their share of the lighting market, it is imperative that the lighting community prepare for the future by establishing appropriate LLFs, or initiating additional investigation if it is needed. An obvious alternative to using an LLD of 0.70 is to more widely adopt the less conservative method recognized by the IES, which is essentially analogous to the process used for conventional sources. However, given the current dependence of rated lifetime on lumen maintenance, as well as the scarcity of hard data for verifying long-term lumen maintenance predictions, this method is not without concerns. Most importantly, if L_{70} is considered the rated lifetime, the LLD for all LED products would be approximately 0.88, which may be above what is reasonable for some products, and does not address the issue of having a de facto rule-of-thumb for all LED lamps and luminaires. Adopting a more comprehensive lifetime metric might help to address this issue, but the availability of such a metric is not imminent.

In many cases, it may be more appropriate to use a known endpoint other than L_{70} (e.g., renovations of a building in 15 years) in establishing the end of life used for lighting calculations. This could be considered the design lifetime, and could be used in lieu of a more comprehensive lifetime rating system. An associated value for mean lumens could then be determined based on the measured (or predicted) output of the source at 40% or 50% of the design lifetime. Should the application dictate that lumen depreciation resulting in light levels below the target be unacceptable, the LLD could be based on the output at 100% of the design lifetime—with similar adjustments made for all competing technologies. These scenarios are shown in Figure 4, with an example design lifetime of 50,000 hours. The design lifetime method would allow specifiers to more easily distinguish between products with different lumen depreciation characteristics and design systems that are more energy efficient over their lifetime. For example, designing a lighting system using the L Prize lamp and an LLD of 0.98—for which illuminance is not predicted to drop below the target for the theoretical life of the installation (in this case, 50,000 hours)—would result in approximately 40% energy savings versus the baseline case using an LLD of 0.70.

Either scenario shown in Figure 4 is a possible design alternative that must be considered by a specifier, but the approaches in Figure 4a or Figure 4b should not be mixed. That is, it is not appropriate to compare an LED system that is expected to meet the target light level for the entire rated life of the

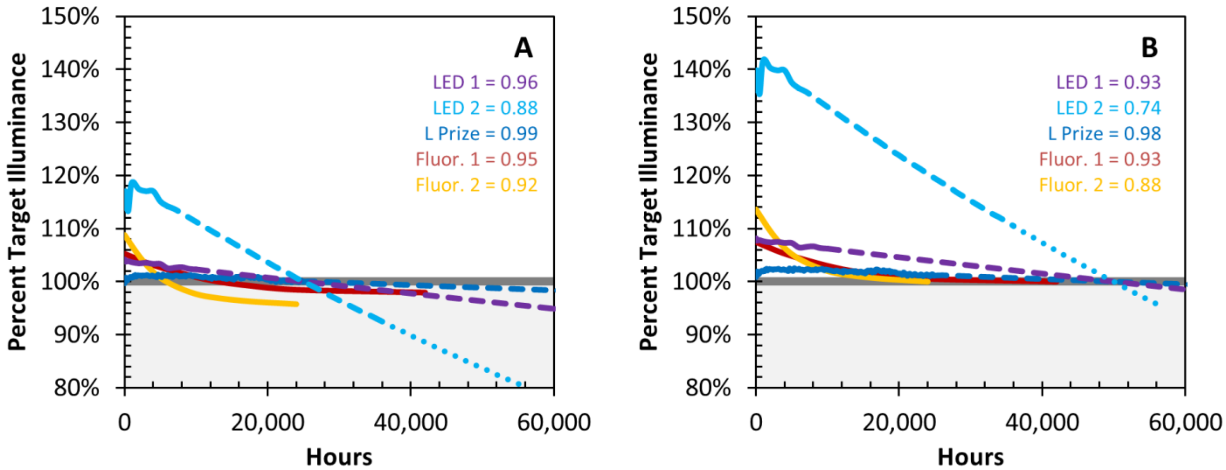

Figure 4. **A. Target light levels using LLDs based on 50% of the design lifetime (50,000 hours), as shown.** Using this method is similar to the current method used for conventional sources. For the second half of the design lifetime, light levels would be below the target. Poor performing LED products could result in substantial reductions in illuminance. For all sources, relamping or replacement would be needed if the product lifetime were shorter than the design lifetime.
B. Target light levels using LLDs based on 100% of the design lifetime (50,000 hours), as shown. The LLDs for the example fluorescent sources are also adjusted to reflect the expected output at the end of the rated lifetime. This method results in the system never being predicted to deliver less than the target illuminance during the design lifetime. For all sources, relamping or replacement would be needed if the product lifetime were shorter than the design lifetime.

system (Figure 4b) to a fluorescent system that is predicted to drop below the target illuminance for a percentage of the rated life (Figure 4a), or vice versa.

Shifting to a design lifetime process also provides substantial incentive for manufacturers to improve lumen maintenance characteristics. Longer rated lifetimes are attractive for reducing life cycle costs, but the advantages are not realized in the design process. In contrast, better lumen maintenance allows for a higher LLD, which can potentially allow for fewer products or reducing the lumen output (and wattage) of a given product while still meeting the illuminance design target. This can reduce both the initial cost and operating cost of the system (via reduced energy use), but only if the improved performance can be accounted for in the design process. Limiting the LLD for LEDs to 0.70 restricts the incentive to specify products with better lumen maintenance, thus reducing the demand for manufacturers to produce them.

3.2 Reporting Alternatives

Separate from calculation method, it may be helpful for manufacturers to report the lumen maintenance at a given hours-of-use, rather than the current practice of reporting the hours-of-use when a percentage of initial output is expected to be reached—or when the limitations of extrapolation are reached for TM-21. For example, the standardized value could be the lumen depreciation at 25,000 hours, which is already being implemented by the DOE's LED Lighting Facts program. Reporting lumen maintenance at a predetermined hours-of-use—which could vary based on product type—would allow for expedient product comparisons using manufacturer literature. However, 25,000 hours is unlikely to be an accurate design lifetime for many products, so specifiers would still be required to consider the effect of varying lumen maintenance and the associated LLDs during the calculation phase of the design process.

3.3 Future Considerations

Regardless of the method used for calculating LLD for LED systems, future technologies may require broader reevaluation of the principles behind LLFs. For example, advanced control strategies such as variable drive currents over lifetime may compensate for lumen depreciation but instead result in increasing energy use over time. More serviceable systems (e.g., those that have a replaceable driver) could result in the hour-of-use for the light source being extended, without the typical replacement cycle for the LED package. No methodology for determining an appropriate LLD can capture all possible scenarios, and the long-term performance of lighting systems will always be reliant on the availability of accurate lamp and luminaire data, the accuracy of design calculations, and proper maintenance. Nonetheless, having consensus recommended practices helps to reduce liability and promote consistency.

4. Conclusions

While it may seem a prudent approach for a relatively unproven technology, there are considerable consequences to capping the LLD for LEDs at not greater than 0.70, including substantial implications for energy use. Effectively applying the same LLD to all LED products ignores the large variation in performance and is inconsistent with current methodology for characterizing other lighting systems. Although limited, long-term test data shows that 0.70 is far too conservative for some LED products, and hinders efforts to ensure specification of high-quality products.

The current link between LED rated lifetime and lumen maintenance effectively precludes the use of traditional methods for calculating LLDs. Development of a more comprehensive lifetime metric could help, but probably will not completely disassociate lifetime from lumen maintenance. Alternative methods for more accurately characterizing the LLD for specific LED products, such as the design lifetime method, should be considered. Any revised method for determining LLDs should be consistent across different light source technologies and allow for effective comparisons of product performance, such that specifiers can differentiate products with less depreciation over time. In turn, this can save substantial amounts of energy and provide a more pleasing visual environment.

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