IES Street and Area Lighting Conference

LLD & LED: Choosing the Right Light Loss Factor for LED Street Lighting

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Learning Objectives

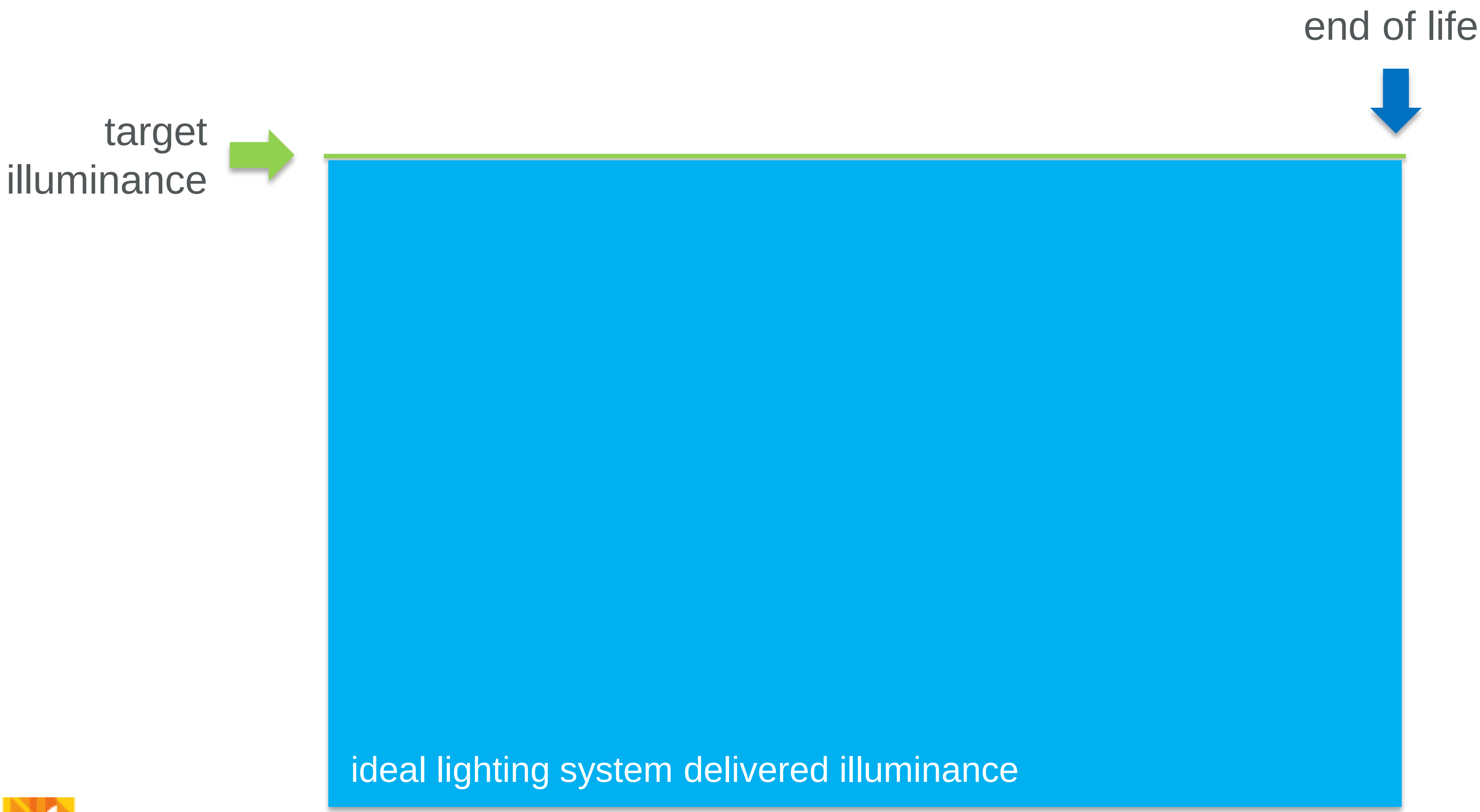
Participants will be able to:

1. Calculate appropriate light loss factors for street lighting applications
2. Describe the consequences of design decisions related to lamp lumen depreciation and light loss factors
3. Compare the lumen maintenance performance of conventional and LED luminaires
4. Apply their knowledge to select more appropriate luminaires

Light Loss Factors: What Are They?

- 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 is accounted for by using a Light Loss Factor (LLF) during the design process.
- A Light Loss Factor is a multiplier that is used to predict future performance (maintained illuminance) based on the initial properties of a lighting system.
- LLF = 1 – Expected Depreciation
- The Total LLF is determined by multiplying the independent effects of multiple factors.

Light Loss Factors: What Are They?



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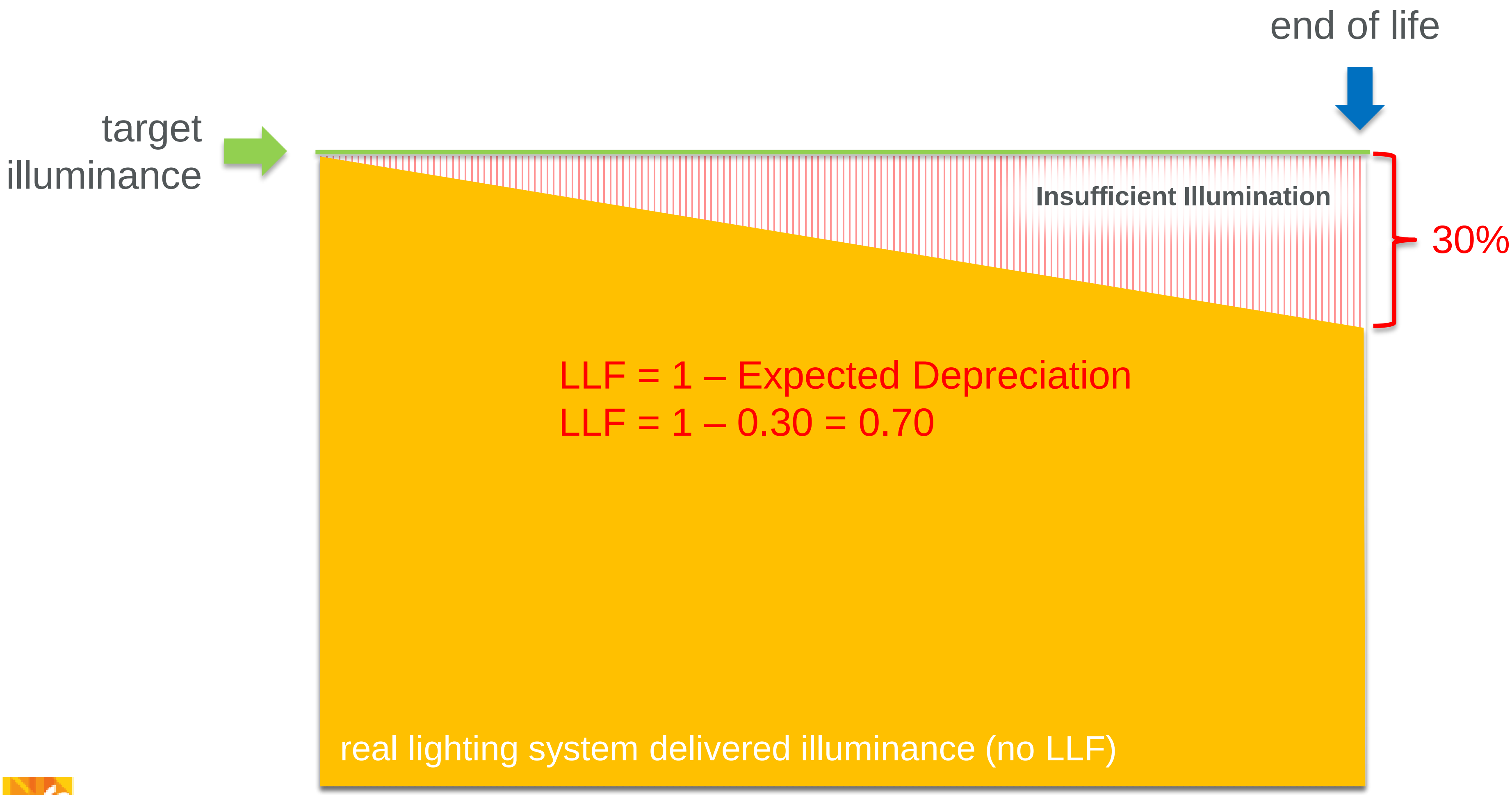

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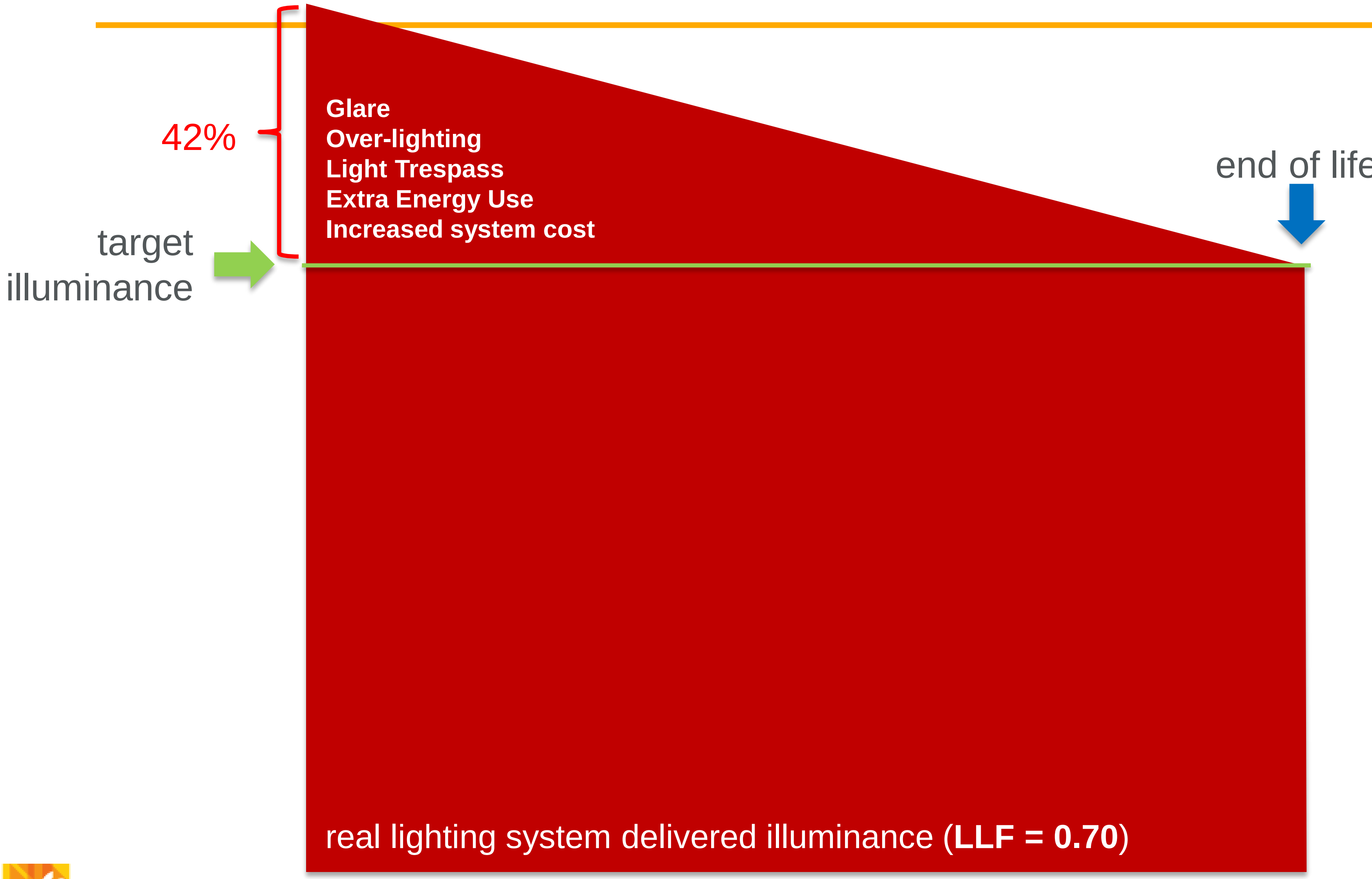

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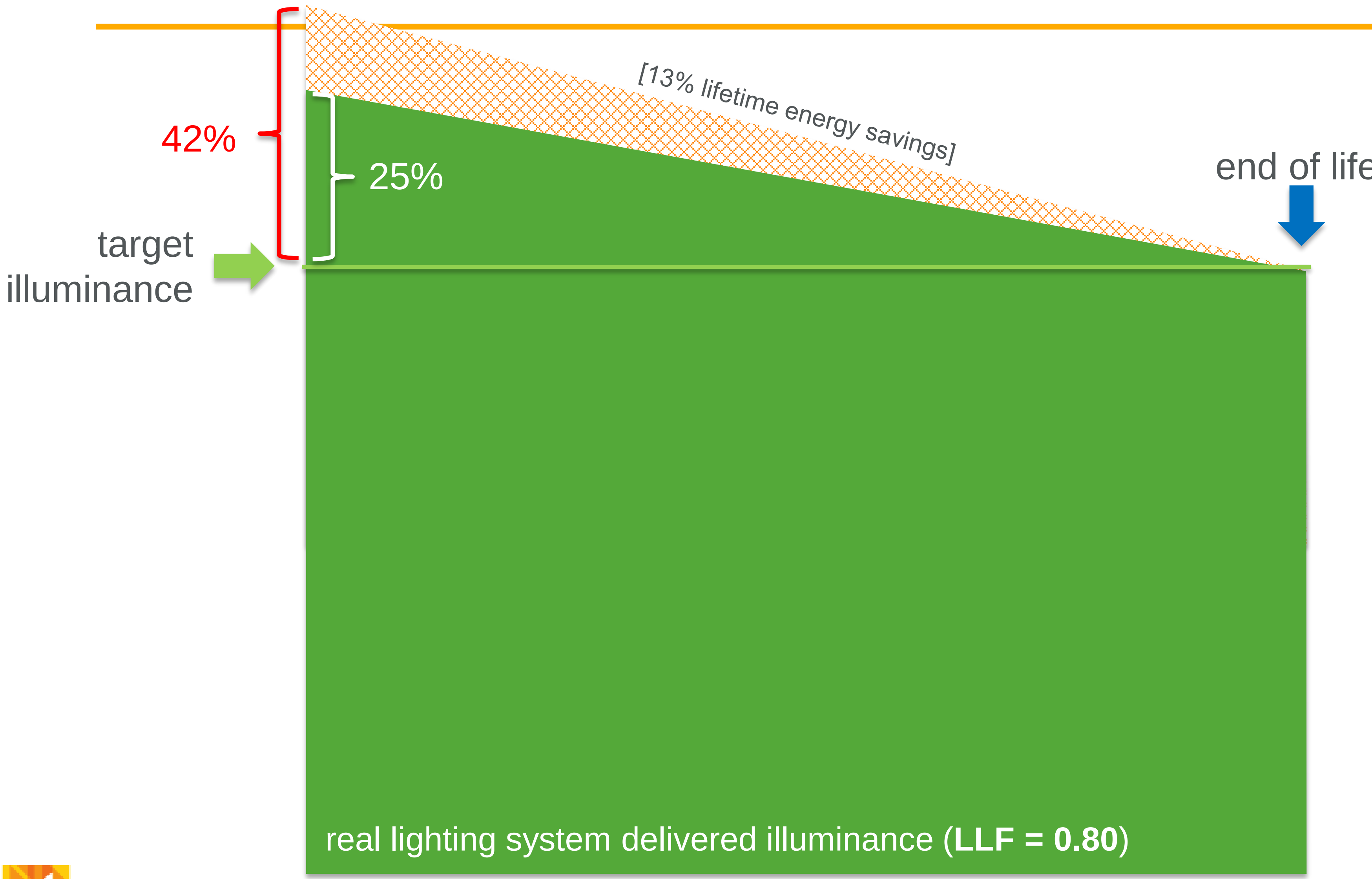

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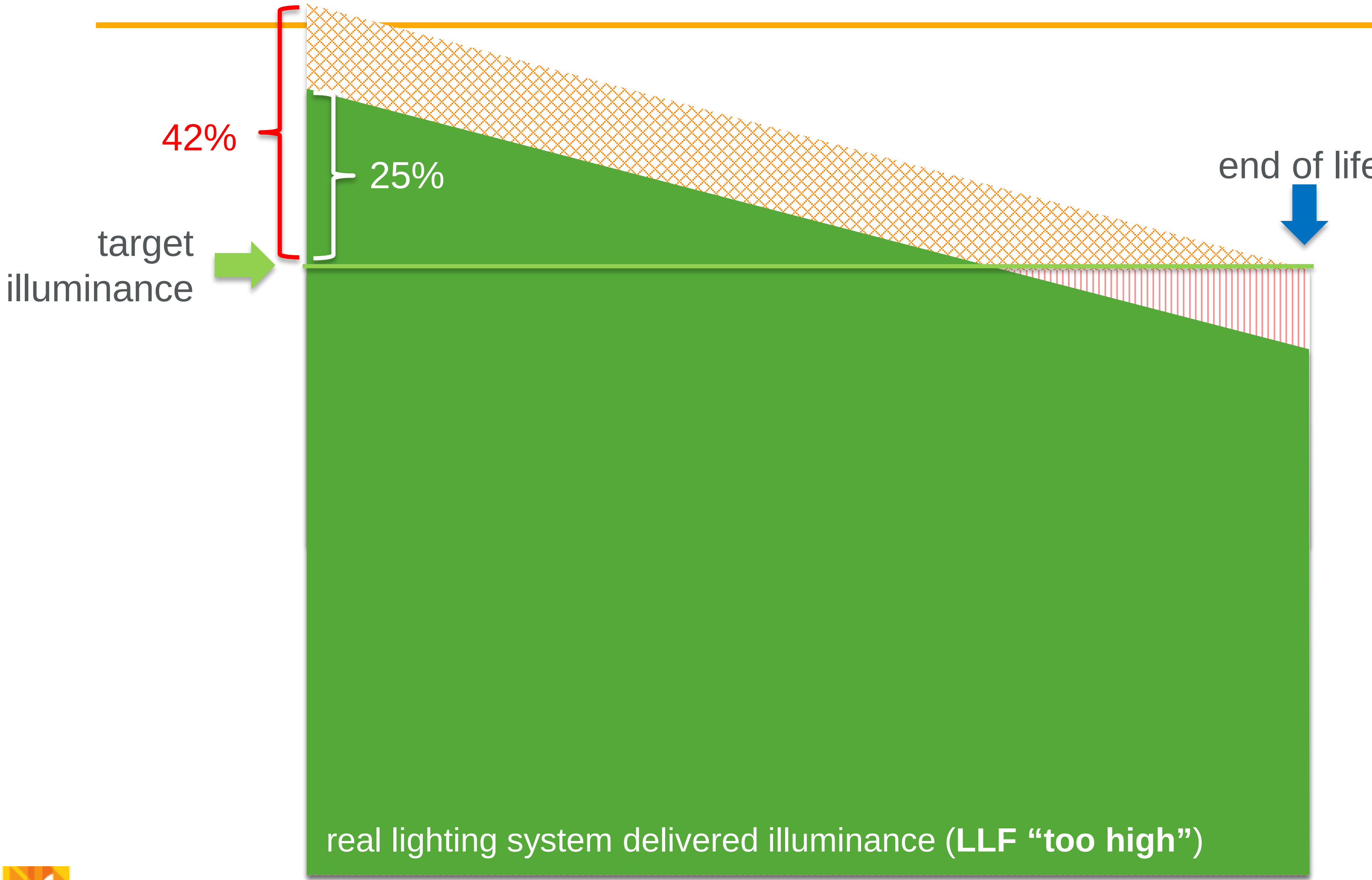


Light Loss Factors: Individual Components

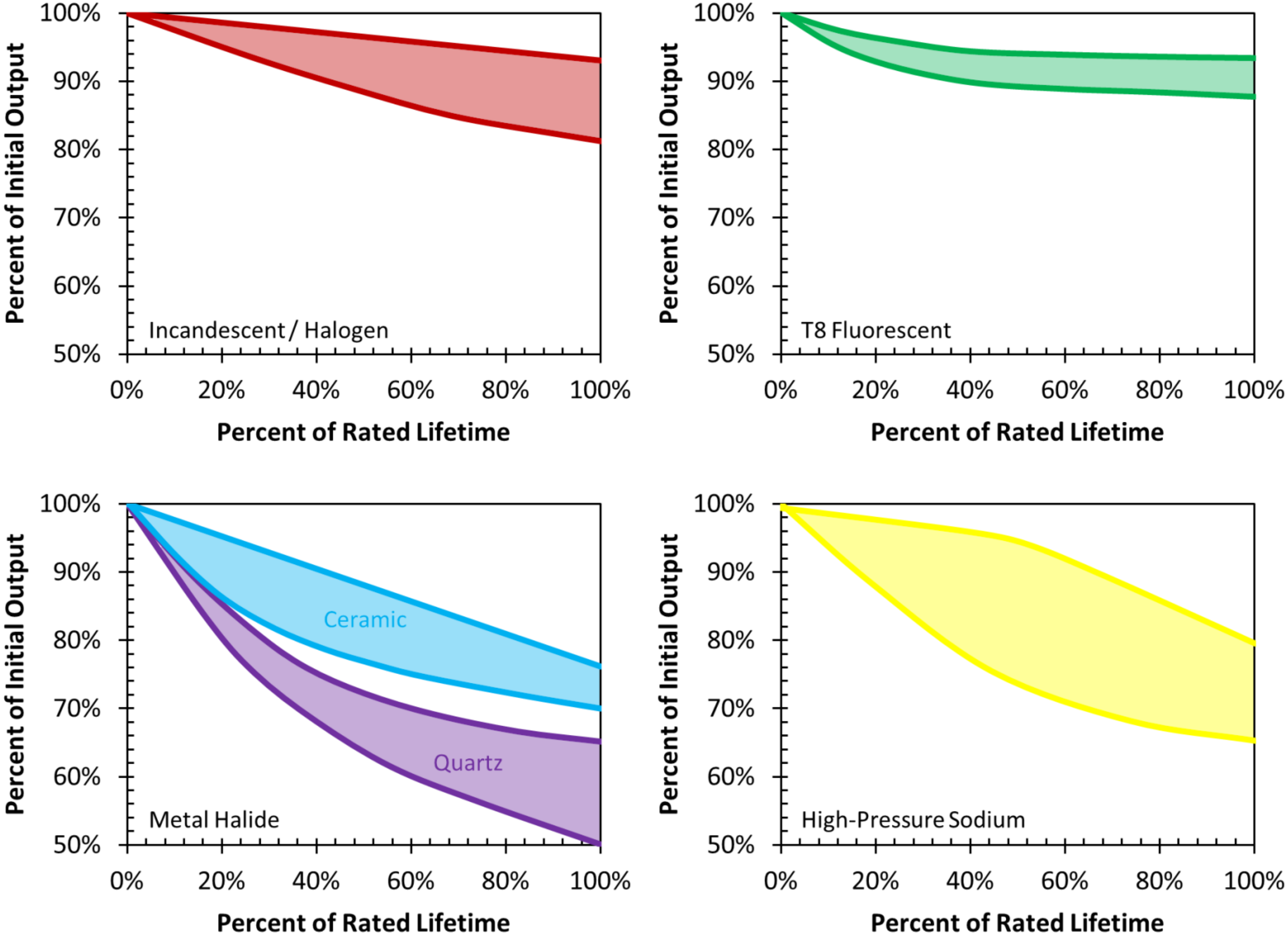
Recoverable Factors

- **Lamp Lumen Depreciation (LLD)**
- **Luminaire Dirt Depreciation (LDD)**
- Lamp Burnout (LBO)
- Room Surface Dirt Depreciation

Non-Recoverable Factors

- Luminaire Ambient Temperature
- Heat Extraction Thermal
- Voltage-to-Luminaire
- **Ballast**
- Ballast-Lamp Photometric
- Equipment Operating
- Lamp Position or Tilt

Lumen Depreciation for Conventional Sources



Adapted from: DiLaura DL, Houser KW, Mistrick RG, Steffy GR. Editors. 2011. The lighting handbook: Reference and application. 10th edition. New York (NY): Illuminating Engineering Society. 1,328 p.

Lamp Lumen Depreciation (LLD) Factor, Conventional*

*Typical practice

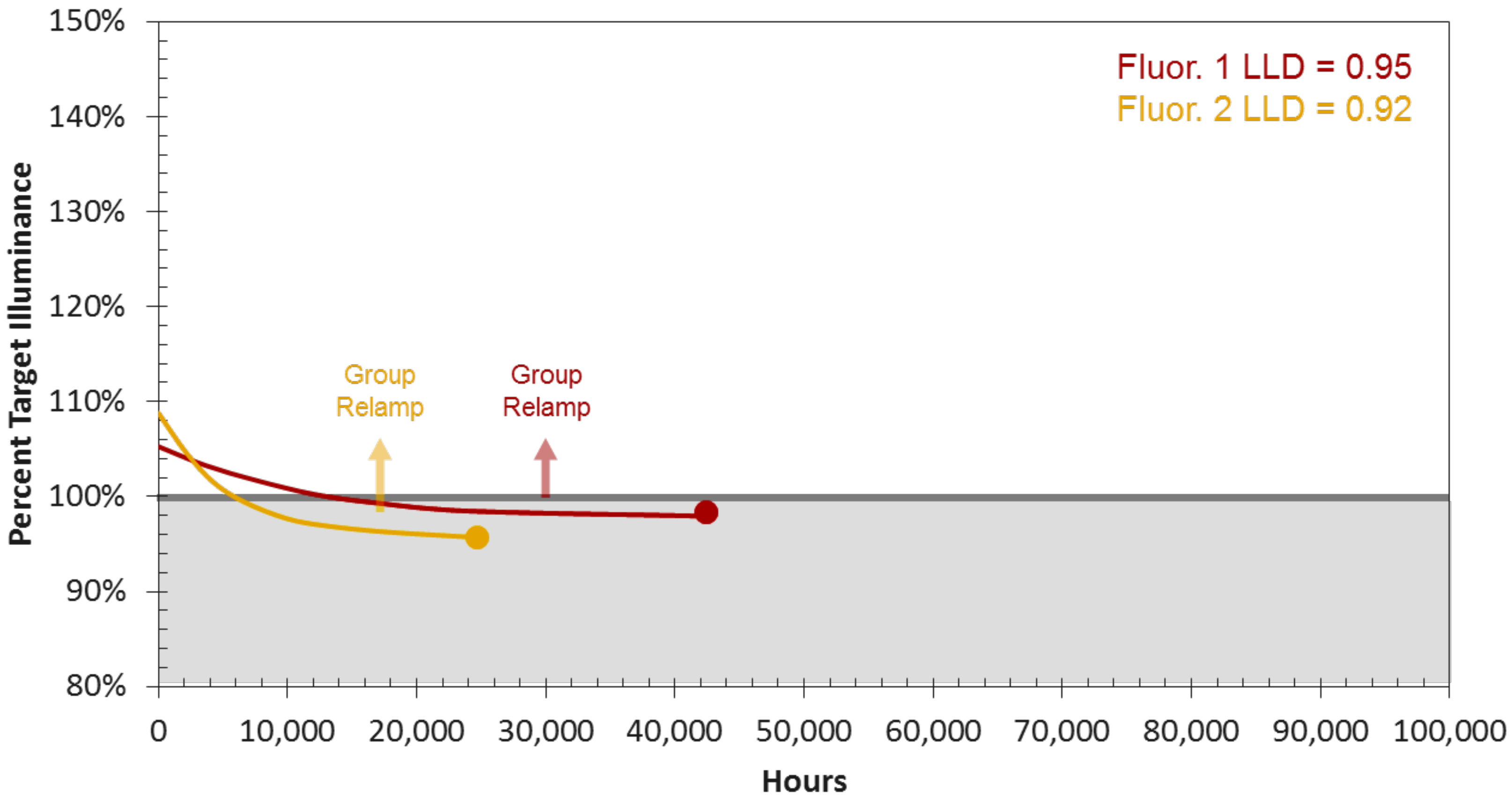
$$LLD = \frac{\text{Mean Lumens}}{\text{Initial Lumens}}$$

Often reported by manufacturers. Typically value at 40% or 50% of rated life.

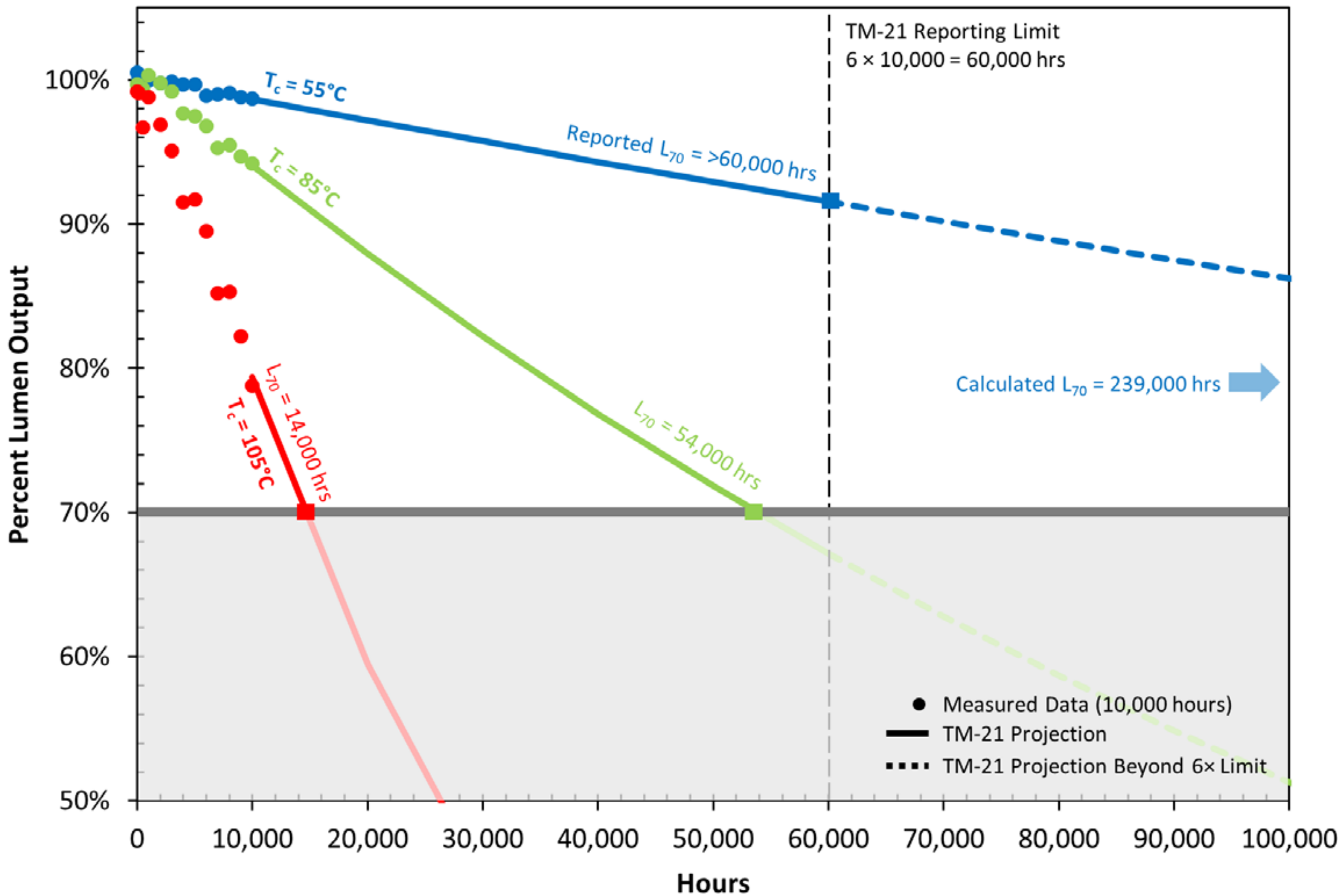
Reported by manufacturers. (Usually measured after burn-in)

Lamp Lumen Depreciation (LLD) Factor, Conventional*

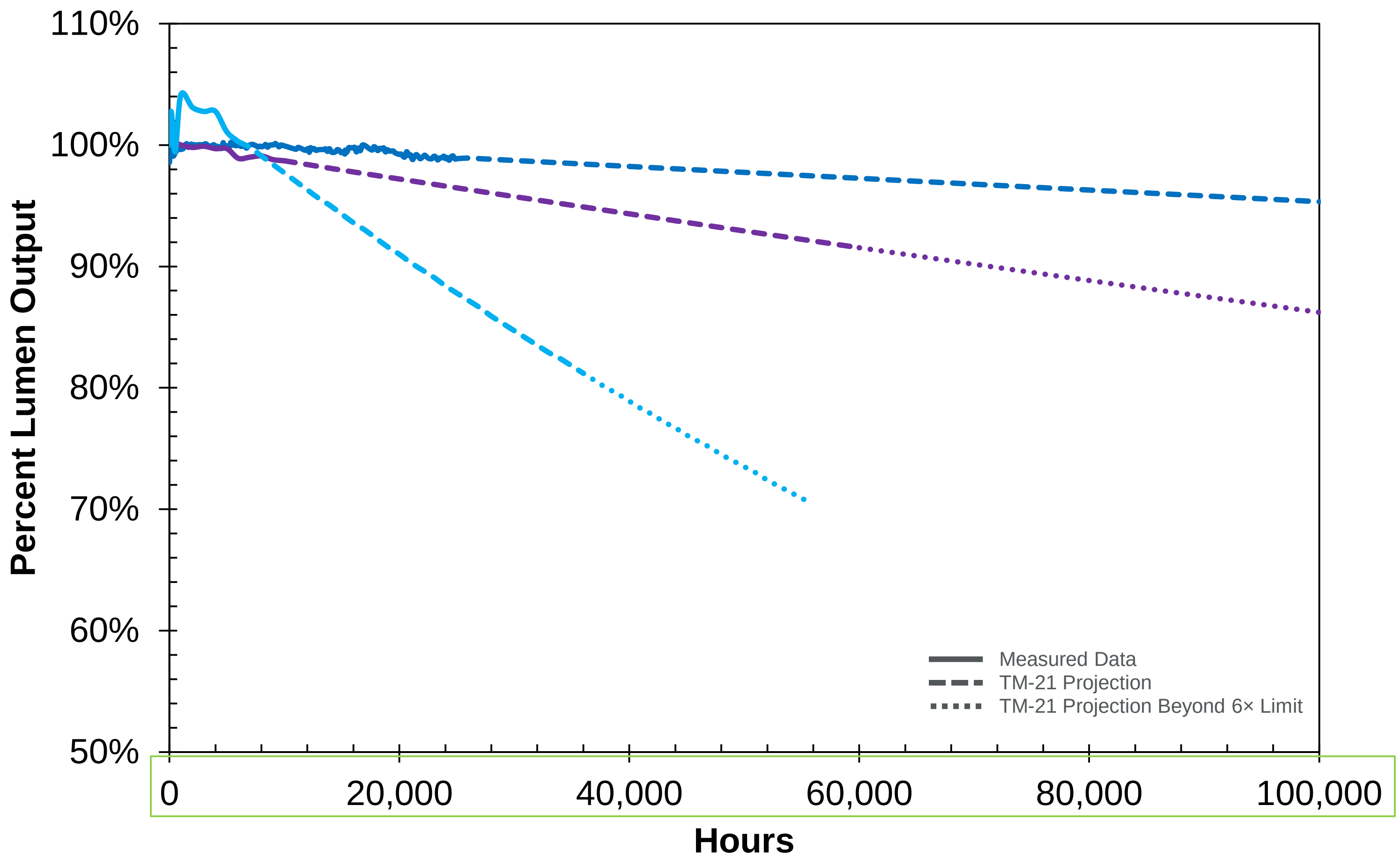
*Typical practice



Example Lumen Depreciation for One LED Package



Example Lumen Depreciation for LED Packages



Lamp Lumen Depreciation (LLD) Factor – LED

$$LLD = \frac{\cancel{\text{Mean Lumens}}}{\text{Initial Lumens}}$$

If rated life is based on 70% (or any percent) of lumen output, then mean lumens will always be a percentage (e.g., 88%) of initial..

Lamp Lumen Depreciation (LLD) Factor – LED

≤0.70

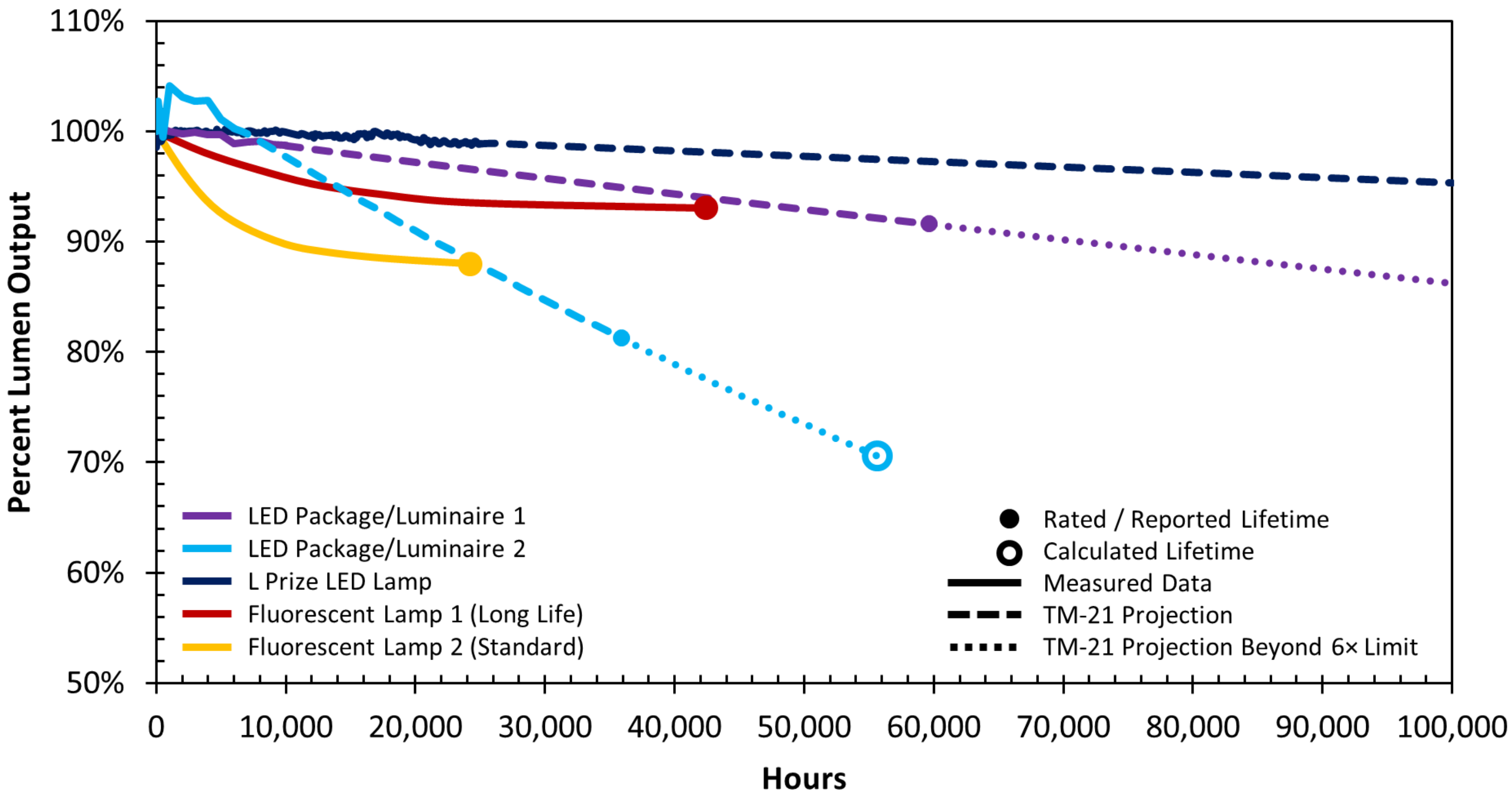
…according to the IES Handbook
…regardless of actual performance
…applies the same value to all LED products

If light level is not important, LLD can be calculated using mean:initial lumens.

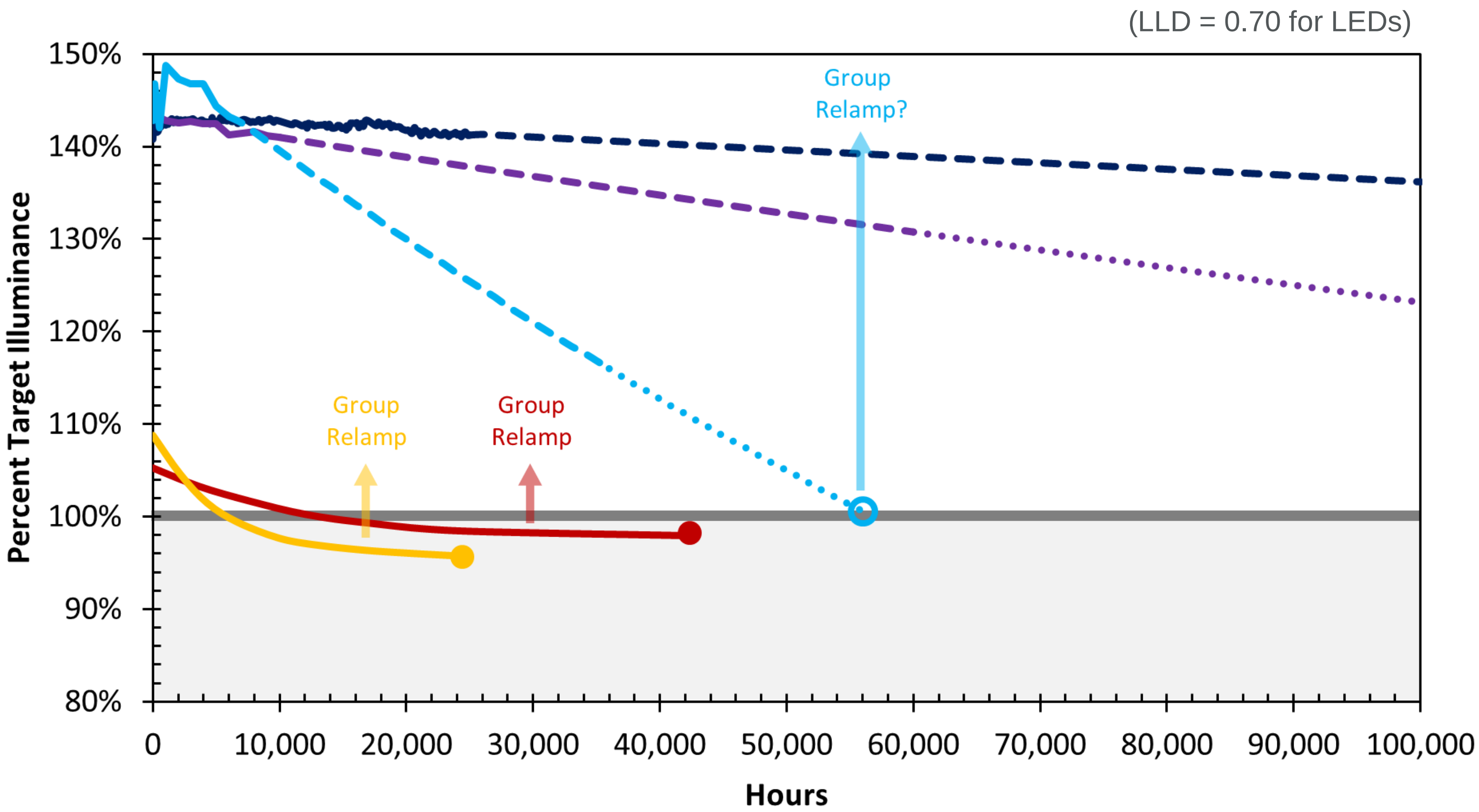
Important Considerations:

- Package, array, module, or luminaire?
- LED material properties
- Junction temperature
  - Ambient temperature
  - Thermal management
- Driver current
- Power quality
- Component materials degradation
- Cycling(?)
- Environmental conditions(?)

Example: Lumen Maintenance Comparison



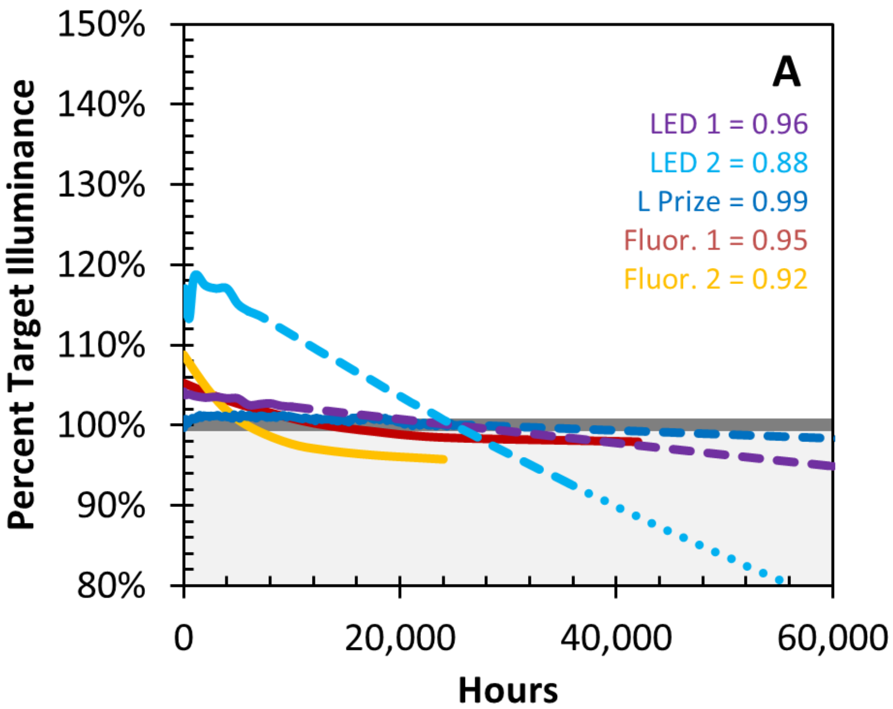
Example: Predicted Light Level Comparison



Alternatives to 0.70?

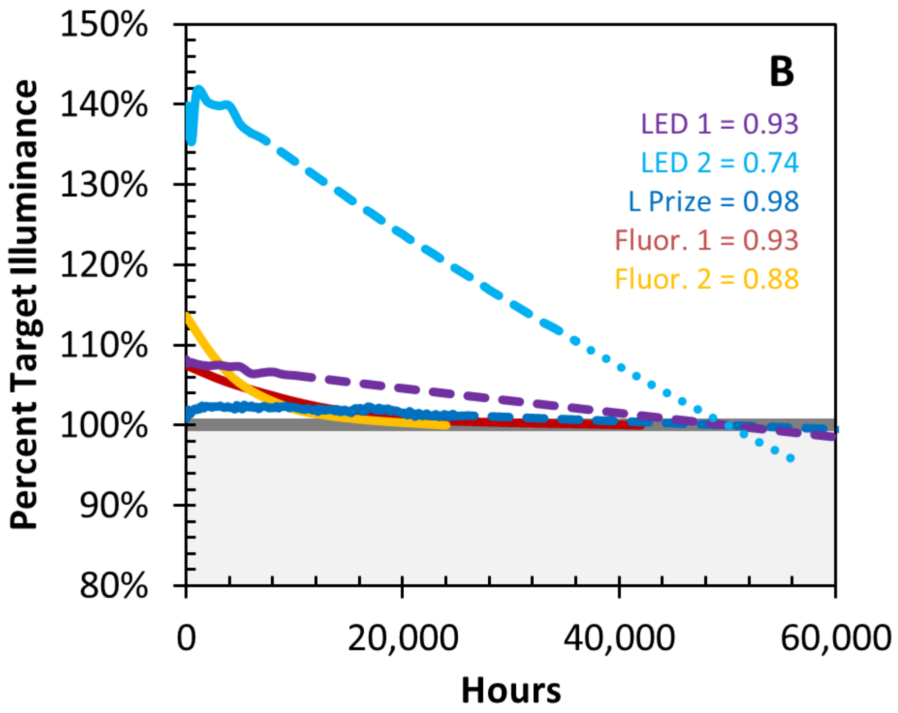
- There is no easy solution because there is no industry standard metric and test method that captures all the main potential failure modes for LEDs
- It is possible to use a "design lifetime" based on the specific application under consideration
- Important to allow for variable LLDs among LED products
  - Incentive to manufacturers to improve lumen maintenance
  - Incentive to designers/specifiers to choose better products
  - Potential energy savings are substantial
    - Higher LLFs = lower system cost, energy savings, but also potential for insufficient lighting
    - Lower LLFs = increased energy use, overlighting, glare, light trespass, etc.

Example: Predicted Light Level (Varying LLDs)



- 50,000 hour “design lifetime”
- **Use mean lumens for LLD calcs for LED and others**
- Acknowledge that light level is predicted to drop below the target for a substantial proportion of the system’s lifetime
- All types of sources are treated the same
- Products are evaluated on their own merits

Example: Predicted Light Level (Varying LLDs)



- 50,000 hour "design lifetime"
- **Use end-of-life lumens for LLD calcs for LED and others**
- Light level is predicted to exceed the criterion for the entire target lifetime (or product rated lifetime, if shorter)
- All types of sources are treated the same
- Products are evaluated on their own merits

LLDs for Street lighting: Important Questions

- What is the expected lifetime of the installation (i.e., how long will the luminaires be left in place before replacement)?
- Will the luminaires be spot-replaced or group-replaced?
- When will payback be achieved?
- Are the specified light levels targets or minimums (e.g., RP-8)?
- What happens when the design lifetime is reached?
- If the expected replacement interval is long, will cleaning take place? Is cleaning necessary? Should the LDD (luminaire dirt depreciation factor) be adjusted?
- Do all products being considered provide equal lumen maintenance performance? Rule-of-thumb numbers do not allow for effective comparisons.

Conclusions

- Light Loss Factors (LLF) are an important aspect of lighting calculations
- The Lamp Lumen Depreciation (LLD) factor is an important part of LLF, but it is not calculated in a consistent way for different technologies
- This is due in part to differing methods used for characterizing lifetime and lumen maintenance
- Under existing prescribed methods, there is no way to differentiate between LED products
- The IES-prescribed maximum LLD of 0.70 may be too conservative for some LED products, leading to excessive energy use
- Using an alternative method may allow for greater energy-efficiency, as well as product competition
- For street lighting applications, be sure to consider the expected lifetime and illuminance requirements, among other factors.

More Information

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

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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 an appropriate time to evaluate the methods used in calculating light loss factors and understand the broad effects of performance attributes like lumen maintenance. Because of the unique operating characteristics of light emitting diodes (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. The IES recommends using an LLD of not greater than 0.70 when quantity of light is an important design consideration. This approach deviates from the typical practice for conventional sources of using the ratio of mean to initial lumen output and may misrepresent actual performance, increase energy use, and inhibit com-

Discussion

- What about products with a 100,000+ hour lifetime? Will LDD become more of a factor?
- What about products that claim no lumen depreciation? Is an LLD of 1.0 acceptable?
- What about products that maintain output by changing power consumption?
- What about serviceable products, where everything could be replaced but the LEDs kept?
- What types of products (e.g., remote phosphor?) will have better lumen maintenance?
- What about operating conditions? Are predictions good enough?
- What are the best practices for the specifier? What is an effective balance of liability/performance and responsible energy use?

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