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Benefits of improved illuminance uniformity for parking lot lighting

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Based on a presentation given at the IES SALC 2014

Study Objective

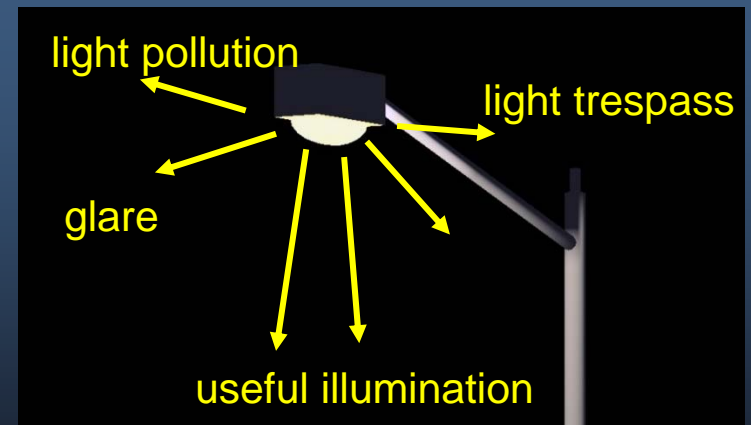
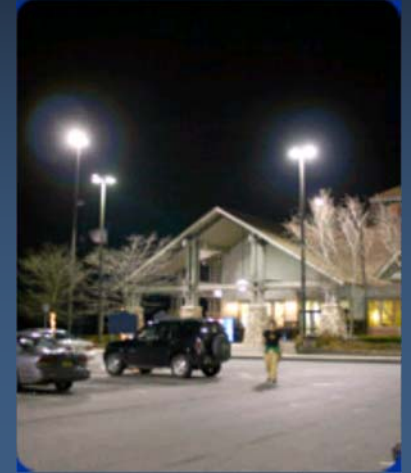
The objective of this study was to investigate the benefits of improving illuminance uniformity in parking lots



Introduction

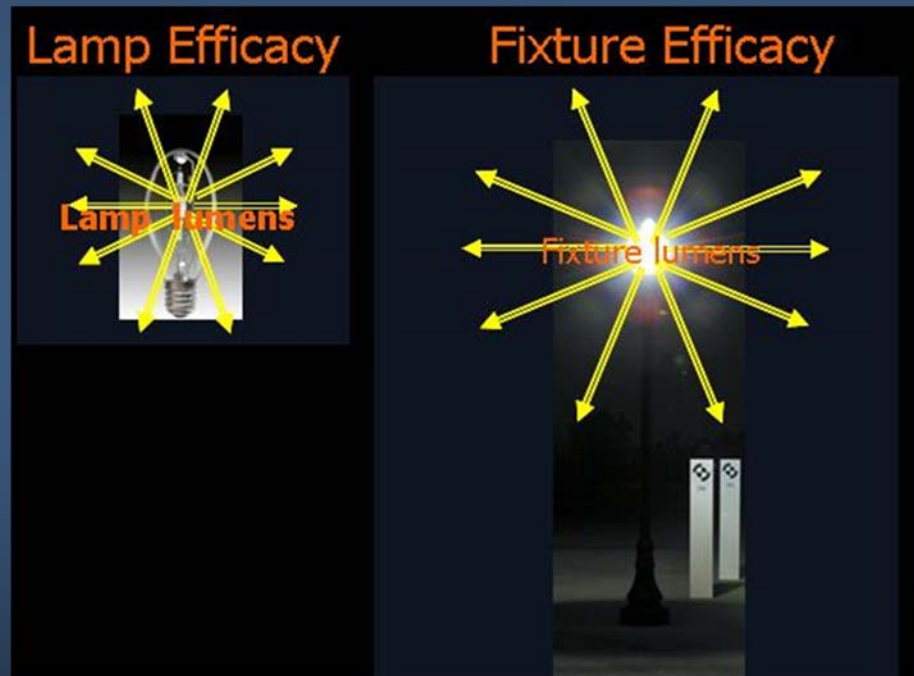
- ◆ The purpose of parking lot lighting is to satisfy visibility requirements while providing a sense of safety and security, comfort, and aesthetic appeal.
 - Other considerations
 - Cost effectiveness
 - Environmental impact
- ◆ Considerations when selecting a luminaire

Luminaire efficacy = $f(\text{lamp, ballast, optics})$ [lm/W]



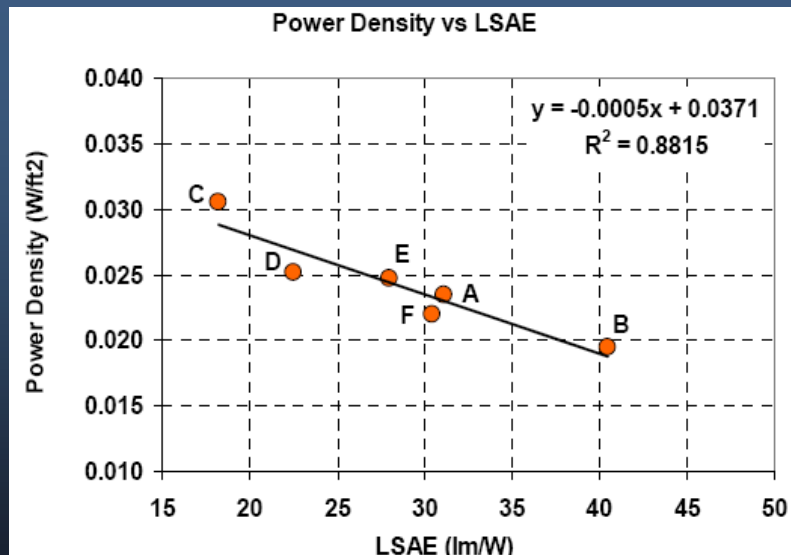
Myth

- ◆ Highly efficacious light sources or luminaires guarantee energy efficient applications.



Luminaire System Application Efficacy (LSAE)

- ◆ In 2009, ASSIST recommended a technology independent metric (LSAE) to evaluate parking lot luminaires based on the concept of application efficacy, which considers
 - Only the luminous flux on the target surface that met the IES RP-20-98 criteria for minimum light level (2 lx) and uniformity ratio (20:1; max:min)
 - LSAE has a good correlation with a parking lot's lighting power density.



Lighting power density as a function of LSAE for six commercial luminaires, showing correlation between higher LSAE and lower power density.

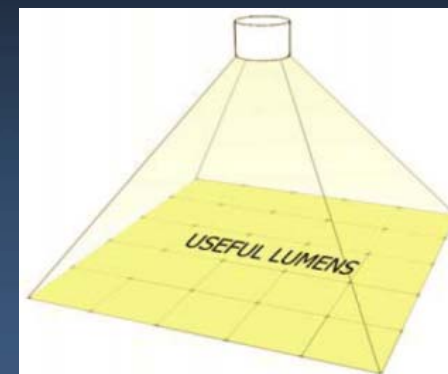


<http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/parkinglot.asp>

LSAE Metric – 2009

<http://www.lrc.rpi.edu/programs/solidstate/assist/recommends/parkinglot.asp>

- ◆ Determine useful luminous flux within an established area (parking lot)
 - Calculate illuminance and determine which “grid cells” meet the target criteria*
 - cells that are between 2 lx and 40 lx
- ◆ Derive “useful luminous flux”
 - Luminous flux = illuminance × area of the cell (2.5 ft × 2.5 ft)
 - Useful luminous flux = luminous flux × percentage of cells that meet criteria
- ◆ Calculate application efficacy
 - $LSAE = \text{useful luminous flux} \div \text{luminaire power}$



Useful lumens, flux used for illuminating the task area while meeting the target criteria.

This metric used the requirements of RP-20-98 because at the time there was no evidence to use a different uniformity criterion.

*For basic illumination in this example

Lighting transformation

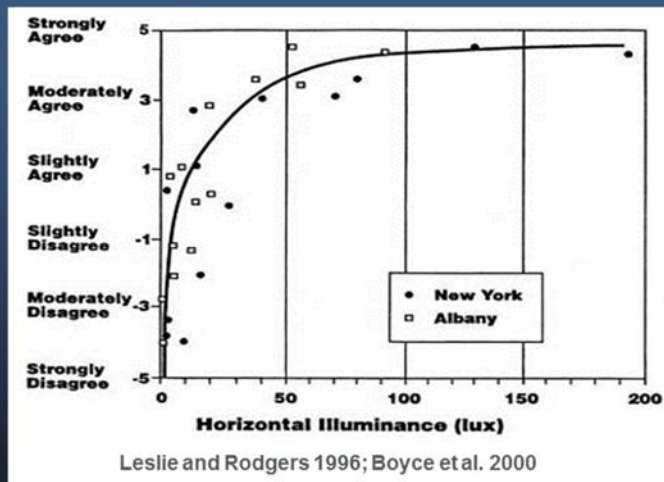
- ◆ Transformation from HID to LED
 - potential to save energy and reduce maintenance cost.
- ◆ Commonly, LED luminaires are built to match beam distributions of traditional HID luminaires
 - To maintain similar light levels and distribution in retrofit applications
- ◆ LED luminaires can efficiently direct light to where it is needed
 - Can achieve highly uniform illuminance on the parking lot surface.



Is there a benefit to uniform illuminance?

Literature review

- ◆ Practitioners design to an average illuminance and then ensure that RP-20-98* recommendations for minimum illuminance and uniformity are met.
 - Visibility: Recommendations for minimum light levels (~ 2 lx) can be justified based on visual performance research
 - Perceived safety: Past research has shown that users prefer more light for increased perception of safety and security



"This is a good example of security lighting."

*Presently revised.

Literature review

- ◆ Even though uniformity of outdoor illumination is mentioned qualitatively as beneficial in several literature references, there are only a few recent studies that have shown benefits to visibility and perceived safety in tunnels and pathways.
 - [Kimura et al., 2013; Haans and de Kort, 2012; Viliunas et al., 2013].

Knowledge gap: There are not any past studies that have shown the benefits of uniform illuminance in parking lots.

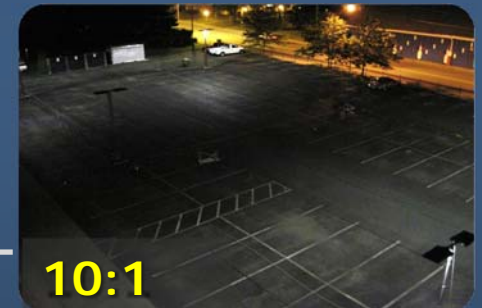
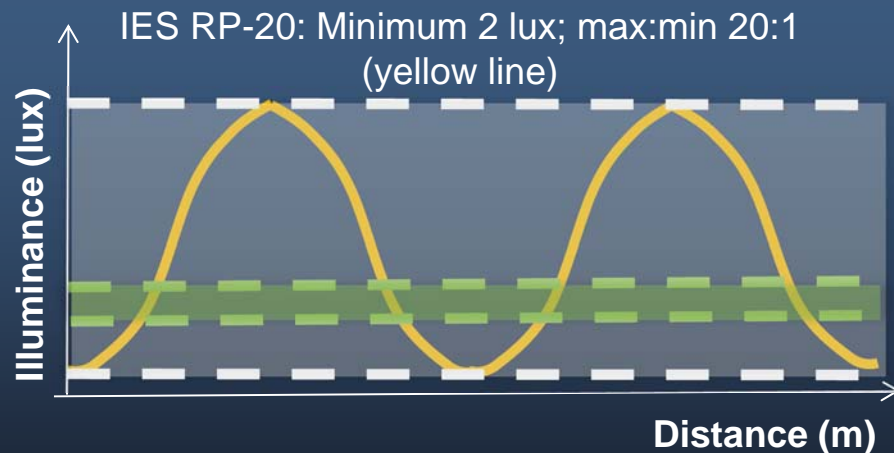
Studies

- ◆ We performed a three-part study.
 - Part 1: Human factors study
 - To understand if uniform lighting can improve visibility and perception of safety and security
 - To determine the minimum light level required to achieve highest user satisfaction under uniform and non-uniform lighting conditions
 - Part 2: Optical ray tracing analysis
 - To understand how much uniformity is achievable with LED fixtures
 - Part 3: LSAE Analysis
 - To estimate the potential for energy savings from systems that provide uniform lighting

◆ Part 1: Human factors study

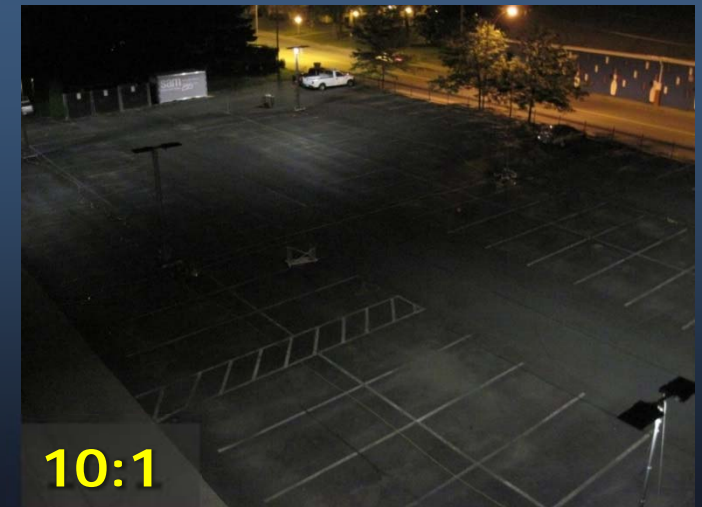
Study objectives

- ◆ To understand if uniform lighting can improve
 - Visibility, perception of safety and security, and energy demand
- ◆ To determine minimum light level requirements
 - when the illuminance is more uniform



Subjective evaluations

- ◆ Field evaluation
 - RPI campus parking lot (Troy, NY)
 - Two levels of uniformity,
 - 3:1 Uniform
 - 10:1 Non-Uniform
 - Six nominal light levels from 2 lx to 60 lx



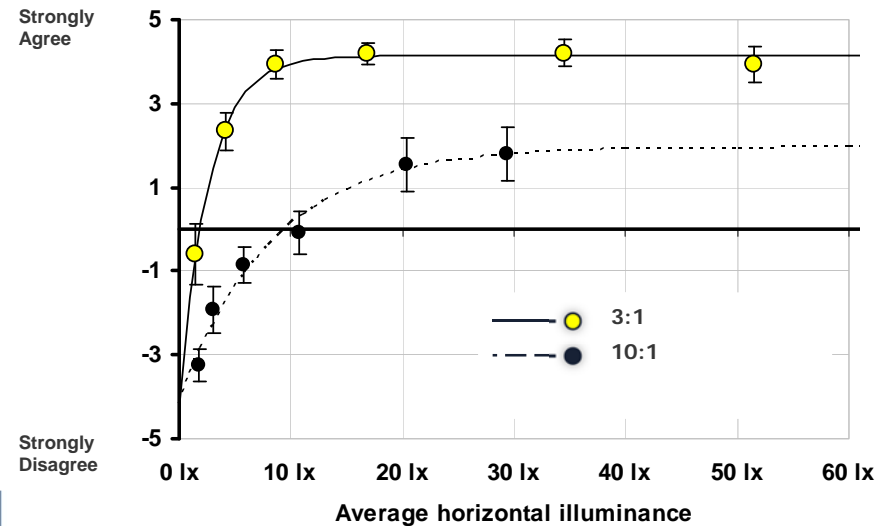
Subjective evaluations

- ◆ Gathered subjective impressions from 43 participants
 - Neighbors, visitors, frequent users of the parking lot
 - 15 participants evaluated all combinations of light level and uniformity, the rest evaluated both uniformity conditions but not all light levels
- ◆ Asked questions about perceptions of brightness, visibility, safety, glare, uniformity, and how well the parking lot is lighted

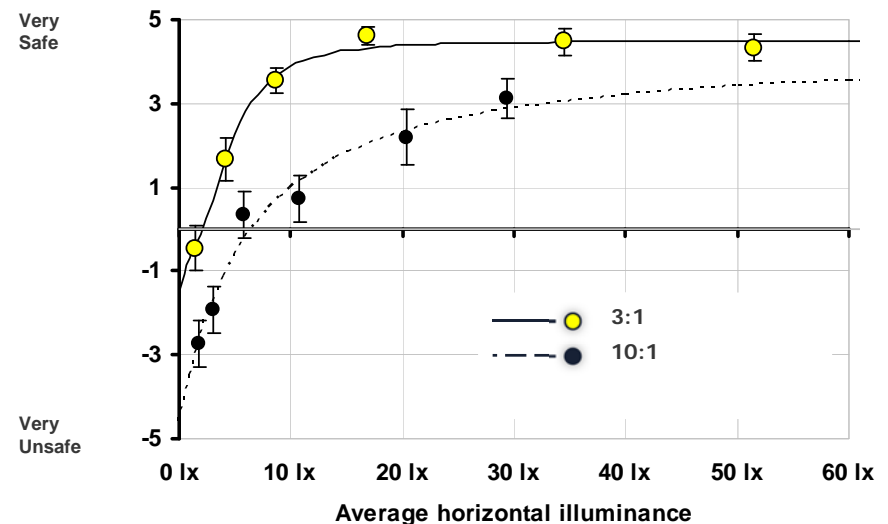
Results

- ◆ When the illumination is
 - Uniform: perceptions of how good the lighting is and how safe people feel reach high ratings at much lower light levels
 - Non-uniform: subjective ratings are not as high even for increased illuminance

Overall, the lighting in this parking lot is GOOD
Average subjective rating (\pm sem; n=15)



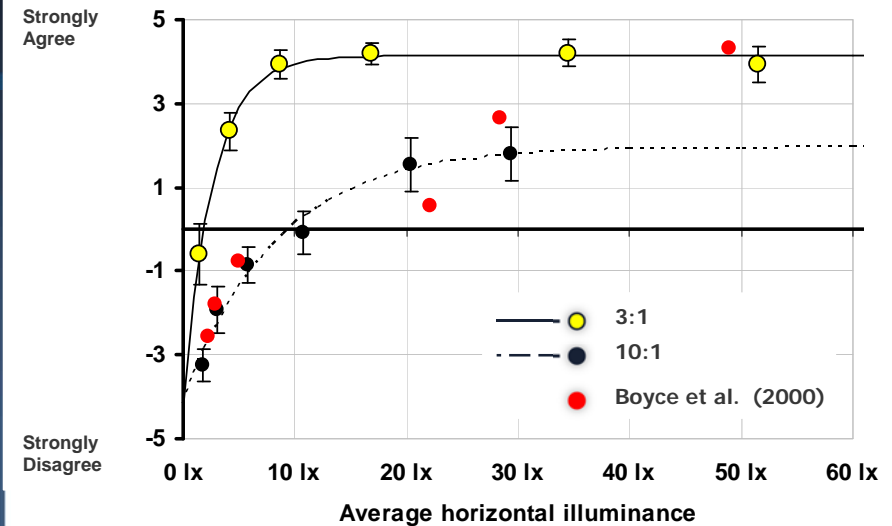
How SAFE would you feel walking here alone at night?
Average subjective rating (\pm sem; n=15)



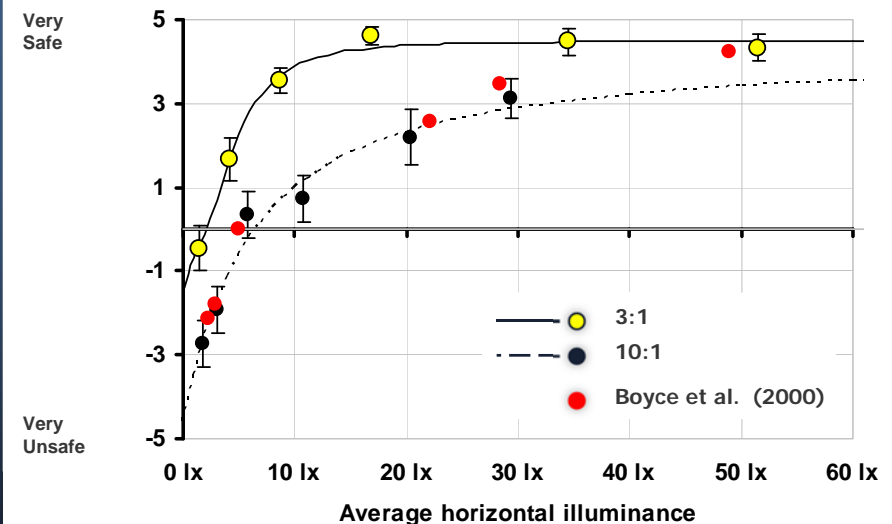
Results

- ◆ When the illumination is
 - Uniform: perceptions of how good the lighting is and how safe people feel reach high ratings at much lower light levels
 - Non-uniform: subjective ratings are not as high even for increased illuminance
 - Consistent with Boyce et al. (2000)

Overall, the lighting in this parking lot is GOOD
Average subjective rating (\pm sem; n=15)



How SAFE would you feel walking here alone at night?
Average subjective rating (\pm sem; n=15)



Results summary

- ◆ The perceptions of good lighting and safety reach high ratings at
 - >9 lux: for **Uniform**; 3:1 ratio
 - Maximum rating ~ +4
 - >40 lux: for **Non-uniform**; 10:1 ratio
 - Maximum rating ~ +2

Replacing RP-20-14 recommendations from

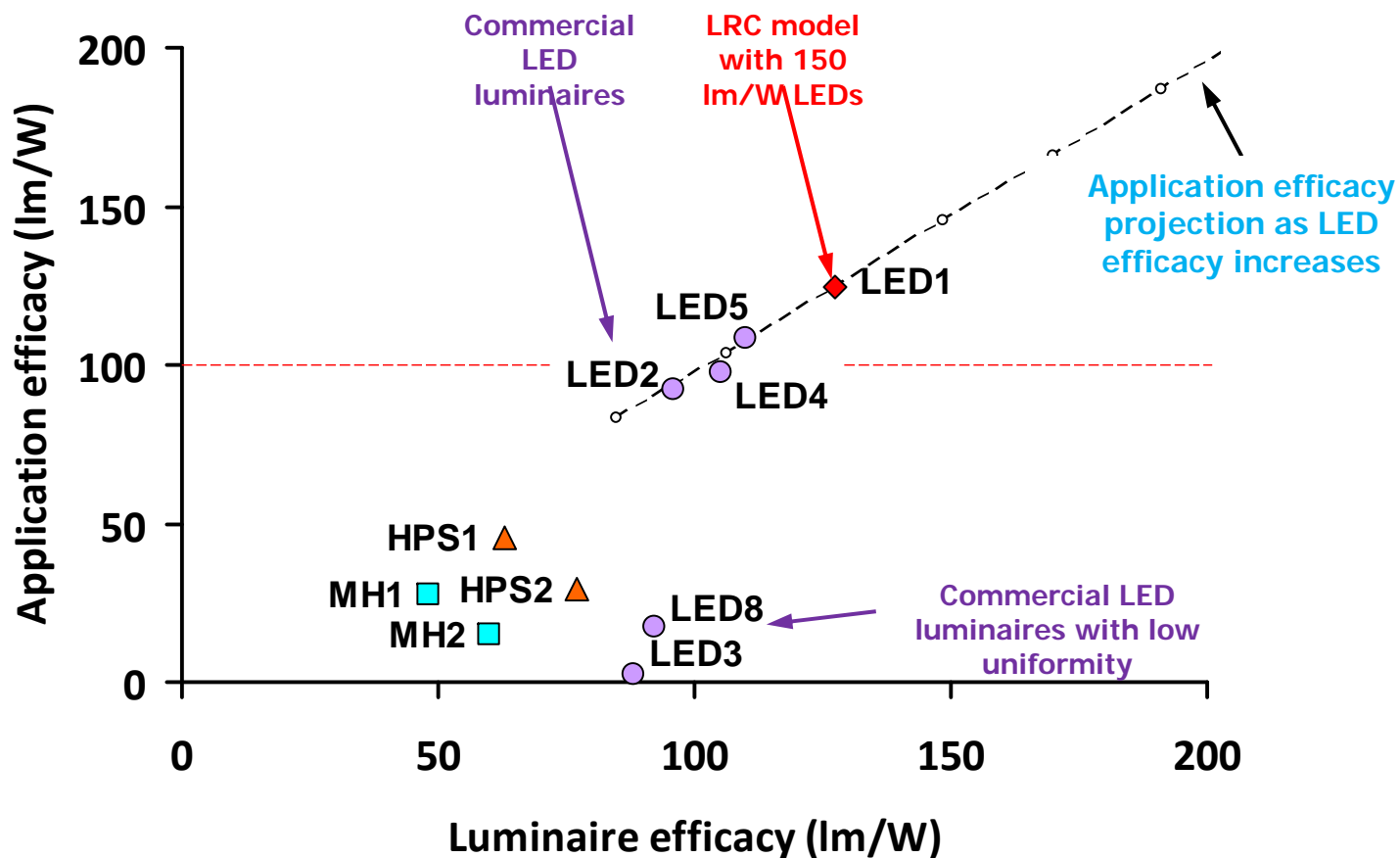
- Minimum light level of 5 lux
- Uniformity ratio (max/min) of 15:1 (max: 75 lx)

to

- Minimum light level of 4.5 lx
- Uniformity ratio of 3:1 (max: 13.5 lx)
- Average light level of 9 lux

will yield better illuminated parking lots.

LSAE comparisons



Conclusions

- ◆ In parking lots, for equal average illuminance, uniform lighting provides
 - higher ratings of visibility and brightness perception
 - higher ratings of perceived safety and security
 - lower energy use
 - uniform lighting allows equal or higher occupant ratings at much lower light levels; when using LEDs this is expected to translate to energy savings of 40% or more
- ◆ Smaller light sources have an optical advantage over larger size sources in creating uniform beam distributions and can be dimmed to achieve lower target light levels without reducing uniformity.
 - With present day LED luminaires, an application efficacy of close to 100 lm/W is possible by tailoring the beam to provide an average of 9 lx with a (max/min) 3:1 or better uniformity.

LSAE is a more useful metric than light source or luminaire efficacy

Final remarks

Recommending

- minimum light level of ~ 4.5 lx
- uniformity ratio of 3:1 (13.5 lx max)
- target average illuminance of ~ 9 lx

and adopting the LSAE metric

will encourage more effective lighting (visibility, perceived safety, low glare) in parking lots at much lower energy use.

Thank you!



<http://www.lrc.rpi.edu/programs/solidstate>