

SSL Technology Application R&D

DOE SSL R&D Workshop
Raleigh, NC
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DOE SSL R&D Elements

Core Research

Scientific research to fill technology gaps, provide enabling data

Product Development

Projects to develop or improve commercially viable materials, devices or systems

Manufacturing R&D

R&D to reduce costs through improvements in equipment, processes

Technology Application R&D

Field and laboratory evaluations, technical support for standards, technology competitions

Technology Application R&D: What is it?

- A method to speed product improvement cycle
- Efforts focus on performance of products in application
- Complements traditional, government co-funded R&D
- Theory: key information from DOE can increase efficiency of the market

What is It?

Uses a combination of methods, but primarily:

1. Investigations and testing of commercially available products
2. Product and technology competitions that advance the state of the art in exchange for recognition, publicity, and sometimes cash awards
3. Technical support of new industry standards development

Examples of SSL Technology Application R&D

- L Prize Competition
- Next Generation Luminaires Competition
- GATEWAY Field Studies
- CALiPER Investigations

L Prize Example



L PRIZE®

U.S. Department of Energy

60W
COMPETITION

Inspired a global
team and a new
platform

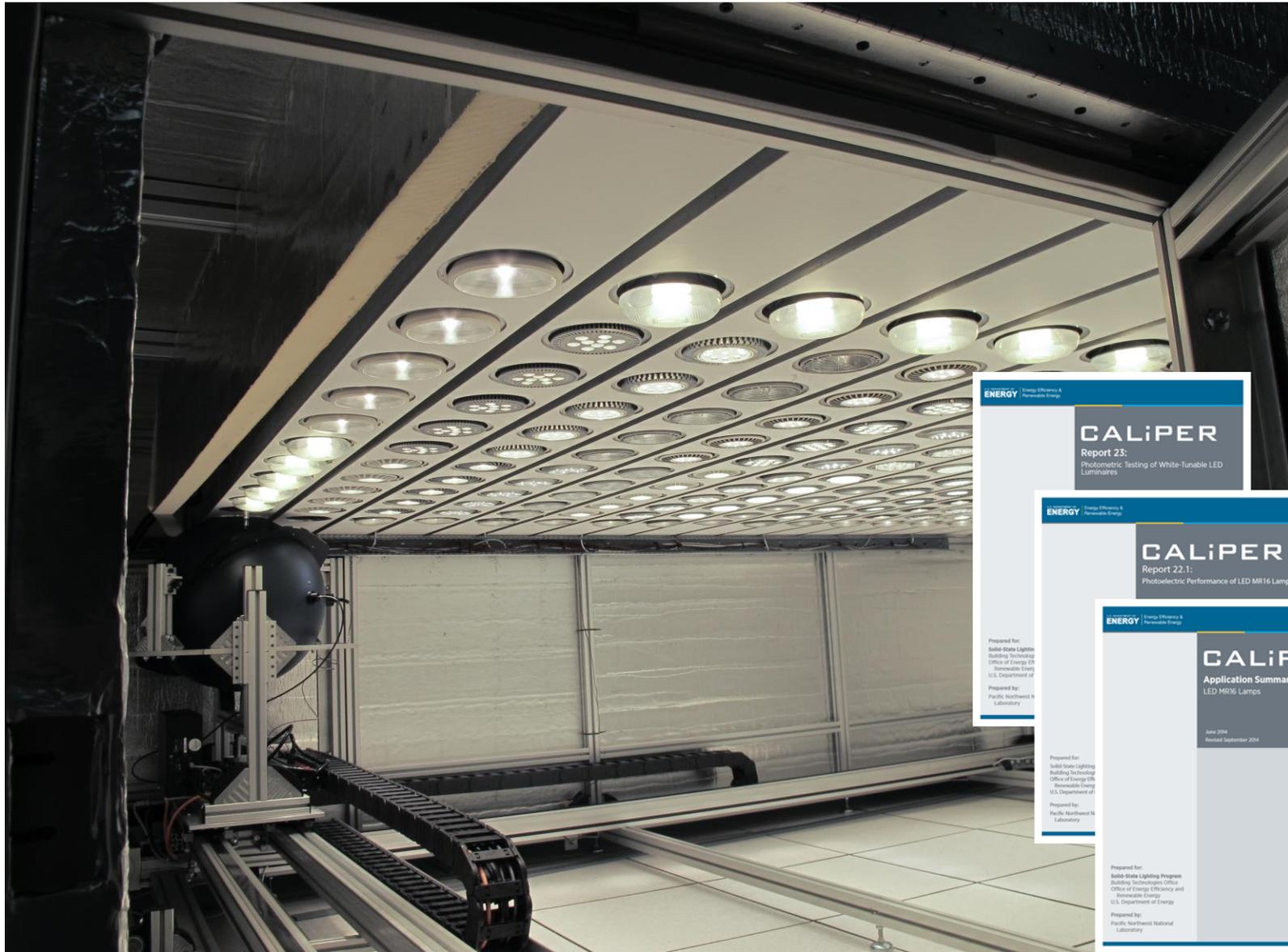


2012
L Prize
Production
Version

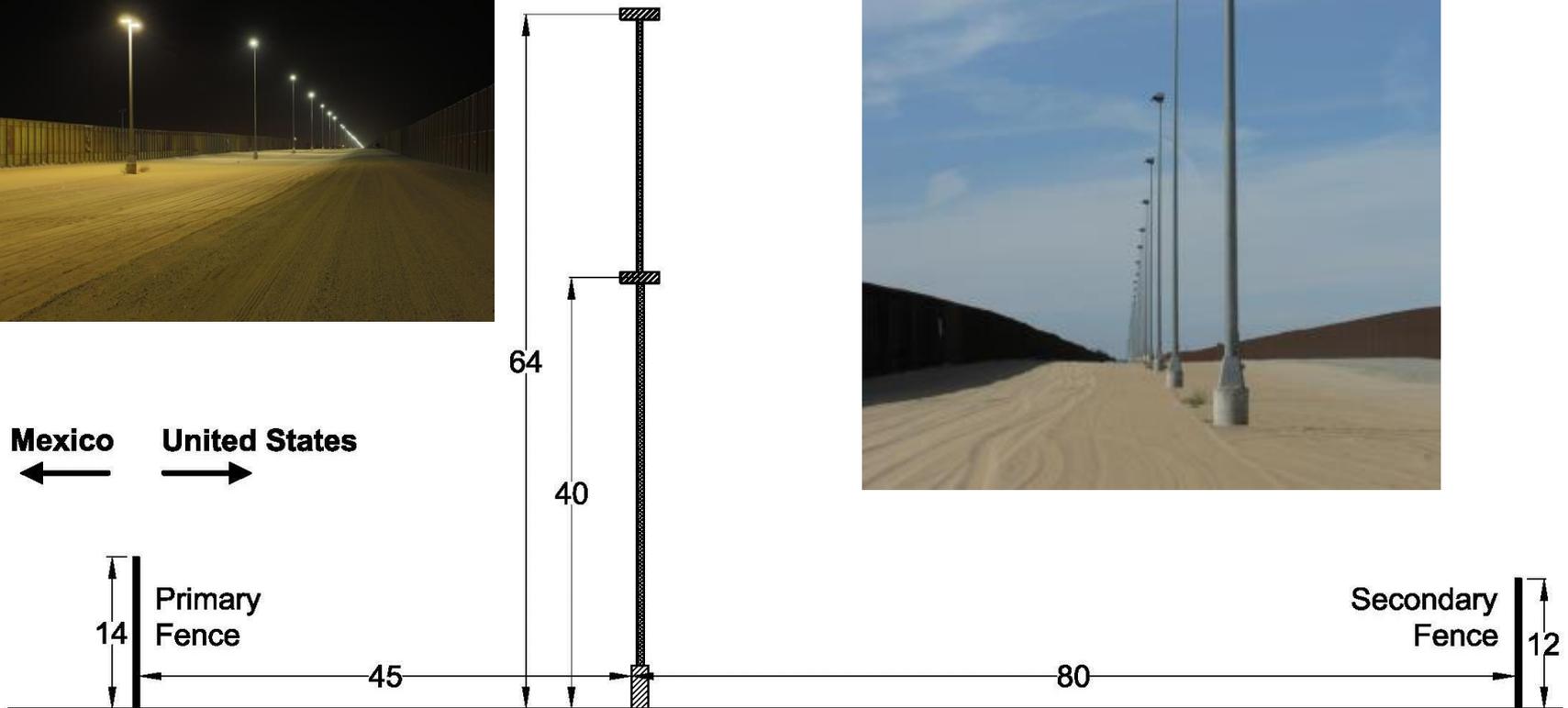
Next Generation Luminaires Competition Example



CALiPER Example



GATEWAY Example (Yuma Border Patrol)



Initial
Illuminance
Measurements
Feb 2014

| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 8 ft | 4.2 | 4.2 | 4.4 | 4.8 | 5.5 | 6.3 | 6.5 | 6.5 | 5.9 | 5.0 | 4.4 | 4.4 | 4.6 |
| 4 ft | 4.5 | 4.6 | 4.9 | 5.5 | 6.5 | 7.2 | 7.4 | 7.4 | 6.9 | 6.0 | 5.5 | 5.4 | 5.7 |
| Secondary Fence | | | | | | | | | | | | | |
| N75 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.3 | 4.4 | 4.3 | 4.1 | 4.0 | 3.9 | 3.8 | 3.7 |
| N60 | 6.5 | 6.5 | 6.7 | 6.8 | 7.2 | 7.6 | 7.8 | 7.6 | 7.2 | 6.8 | 6.7 | 6.5 | 6.5 |
| N45 | 13.1 | 13.1 | 12.6 | 12.9 | 13.6 | 14.7 | 14.9 | 14.7 | 13.6 | 12.9 | 12.6 | 13.1 | 13.1 |
| N30 | 19.3 | 20.7 | 22.0 | 22.0 | 23.8 | 25.4 | 25.4 | 25.4 | 23.8 | 22.0 | 22.0 | 20.7 | 19.3 |
| N15 | 25.1 | 25.8 | 26.7 | 27.2 | 32.7 | 38.8 | 40.7 | 38.8 | 32.7 | 27.2 | 26.7 | 25.8 | 25.1 |
| Pole | 26.8 | 28.6 | 28.7 | 30.7 | 33.1 | 36.3 | 44.0 | 36.3 | 33.1 | 30.7 | 28.7 | 28.6 | 26.8 |
| S15 | 27.1 | 27.7 | 28.6 | 29.7 | 33.5 | 37.7 | 40.2 | 38.0 | 35.3 | 32.2 | 31.6 | 29.8 | 27.4 |
| S30 | 26.2 | 26.8 | 27.0 | 27.0 | 27.9 | 29.2 | 29.2 | 29.7 | 29.7 | 28.1 | 29.8 | 28.9 | 26.4 |
| S45 | 22.3 | 23.0 | 21.6 | 21.3 | 22.7 | 23.2 | 23.7 | 24.1 | 23.2 | 21.8 | 22.2 | 22.0 | 20.4 |
| Primary Fence | | | | | | | | | | | | | |
| 4 ft | 24.2 | 25.4 | 27.1 | 28.2 | 29.8 | 32.0 | 30.8 | 31.1 | 29.3 | 25.8 | 27.5 | 25.2 | 23.4 |
| 8 ft | 20.7 | 22.8 | 26.9 | 31.4 | 32.6 | 35.3 | 35.6 | 35.3 | 33.4 | 30.9 | 27.9 | 22.6 | 20.8 |
| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |



2500 hr
Illuminance
Measurements
Sep 2014

| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 8 ft | 4.4 | 4.5 | 4.7 | 5.2 | 5.9 | 6.6 | 6.9 | 6.8 | 6.2 | 5.3 | 4.7 | 4.6 | 4.7 |
| 4 ft | 4.8 | 4.9 | 5.2 | 5.9 | 6.9 | 7.6 | 7.8 | 7.8 | 7.2 | 6.3 | 5.7 | 5.5 | 5.6 |
| Secondary Fence | | | | | | | | | | | | | |
| N75 | 2.5 | 2.8 | 3.2 | 3.5 | 4.0 | 4.2 | 4.0 | 4.0 | 4.0 | 3.7 | 3.5 | 3.4 | 3.4 |
| N60 | 4.5 | 4.8 | 5.4 | 6.2 | 6.8 | 8.0 | 7.4 | 7.5 | 6.9 | 6.6 | 6.2 | 5.7 | 5.5 |
| N45 | 8.7 | 9.2 | 10.0 | 11.5 | 13.8 | 15.5 | 14.7 | 15.4 | 13.9 | 12.3 | 11.3 | 11.2 | 10.6 |
| N30 | 15.3 | 16.6 | 18.4 | 20.0 | 24.4 | 27.2 | 27.3 | 28.0 | 25.6 | 21.9 | 19.7 | 17.3 | 15.7 |
| N15 | 19.2 | 21.2 | 23.0 | 27.8 | 35.9 | 43.5 | 45.8 | 44.8 | 36.5 | 28.1 | 24.1 | 20.9 | 19.7 |
| Pole | 20.5 | 23.1 | 26.5 | 31.1 | 36.1 | 42.3 | 55.6 | 42.3 | 36.5 | 30.5 | 25.1 | 21.8 | 20.4 |
| S15 | 19.3 | 22.2 | 25.6 | 29.8 | 36.7 | 43.3 | 46.8 | 43.4 | 36.3 | 28.1 | 22.9 | 20.1 | 19.5 |
| S30 | 17.6 | 20.0 | 22.6 | 25.1 | 28.2 | 30.6 | 31.1 | 29.4 | 25.6 | 21.1 | 18.8 | 17.5 | 17.5 |
| S45 | 15.5 | 16.5 | 16.2 | 17.1 | 19.2 | 19.8 | 20.2 | 19.3 | 17.1 | 14.8 | 13.4 | 12.9 | 13.2 |
| Primary Fence | | | | | | | | | | | | | |
| 4 ft | 16.4 | 18.7 | 20.0 | 21.2 | 23.9 | 27.3 | 26.5 | 25.7 | 22.5 | 19.7 | 17.8 | 15.9 | 15.3 |
| 8 ft | 14.4 | 16.6 | 23.5 | 25.2 | 26.2 | 29.3 | 29.9 | 28.4 | 26.1 | 20.0 | 16.7 | 14.0 | 13.7 |
| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |



5000 hr
Illuminance
Measurements
Mar 2015

| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 8 ft | 4.1 | 4.2 | 4.5 | 4.9 | 5.7 | 6.5 | 6.7 | 6.7 | 6.1 | 5.1 | 4.6 | 4.4 | 4.6 |
| 4 ft | 4.6 | 4.7 | 5.1 | 5.8 | 6.9 | 7.6 | 8.6 | 7.6 | 7.2 | 6.2 | 5.6 | 5.4 | 5.5 |
| Secondary Fence | | | | | | | | | | | | | |
| N75 | 3.1 | 3.2 | 3.2 | 3.5 | 3.9 | 4.3 | 4.3 | 4.1 | 4.0 | 3.7 | 3.6 | 3.4 | 3.2 |
| N60 | 4.8 | 5.1 | 5.3 | 6.0 | 6.9 | 7.9 | 8.0 | 7.8 | 7.1 | 6.4 | 5.9 | 5.4 | 5.0 |
| N45 | 8.7 | 8.7 | 9.5 | 11.2 | 13.3 | 15.2 | 15.5 | 15.3 | 13.7 | 11.7 | 10.6 | 9.7 | 9.1 |
| N30 | 14.1 | 14.7 | 16.6 | 19.3 | 24.0 | 27.1 | 28.0 | 27.7 | 24.7 | 20.6 | 17.8 | 15.1 | 13.4 |
| N15 | 17.4 | 18.4 | 20.9 | 26.6 | 35.0 | 43.6 | 46.5 | 44.0 | 34.6 | 25.9 | 21.7 | 18.7 | 17.4 |
| Pole | 18.8 | 20.7 | 24.0 | 29.0 | 35.1 | 43.6 | 55.9 | 40.5 | 34.5 | 28.1 | 22.8 | 20.3 | 18.7 |
| S15 | 17.9 | 19.8 | 23.0 | 27.4 | 34.4 | 42.0 | 45.3 | 40.2 | 32.8 | 25.6 | 22.1 | 19.6 | 18.5 |
| S30 | 17.0 | 18.4 | 20.3 | 22.5 | 25.6 | 28.3 | 28.3 | 27.5 | 24.4 | 21.1 | 19.5 | 18.1 | 17.4 |
| S45 | 14.8 | 15.5 | 15.4 | 16.9 | 19.1 | 20.5 | 20.8 | 20.2 | 18.2 | 16.1 | 15.1 | 14.3 | 13.9 |
| Primary Fence | | | | | | | | | | | | | |
| 4 ft | 16.2 | 17.3 | 16.4 | 19.9 | 24.1 | 27.2 | 27.6 | 26.5 | 24.6 | 19.3 | 19.1 | 16.9 | 15.9 |
| 8 ft | 13.5 | 15.5 | 18.0 | 22.6 | 26.7 | 30.2 | 30.6 | 29.6 | 25.8 | 21.3 | 18.3 | 15.2 | 13.9 |
| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |

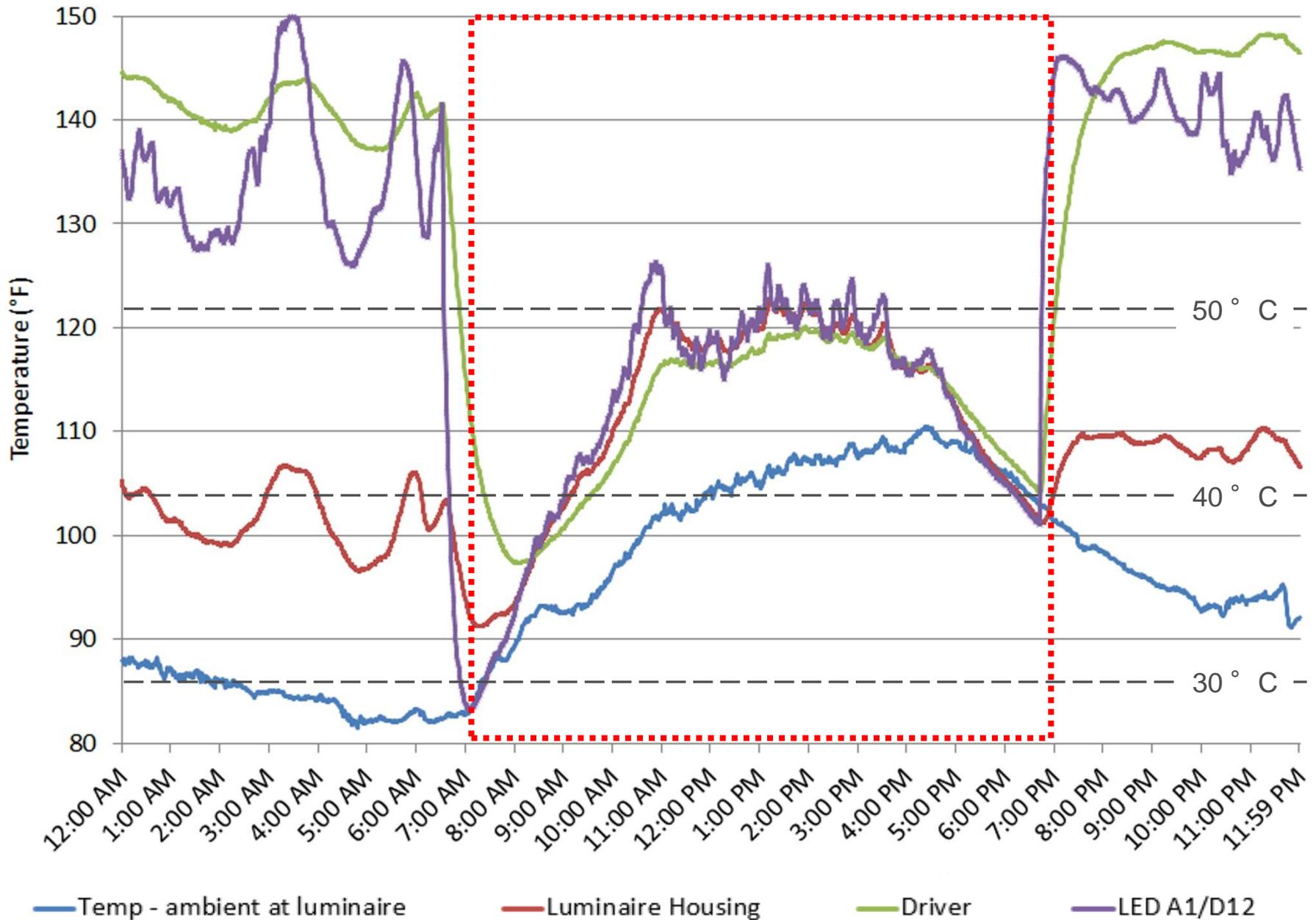


7000 hr
Illuminance
Measurements
Sep 2015

| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 8 ft | 3.7 | 3.8 | 4.2 | 4.8 | 5.7 | 6.4 | 6.4 | 6.2 | 5.5 | 4.8 | 4.1 | 3.7 | 3.7 |
| 4 ft | 4.5 | 4.6 | 4.9 | 5.6 | 6.7 | 6.9 | 7.2 | 7.0 | 6.3 | 5.2 | 4.5 | 4.1 | 3.8 |
| Secondary Fence | | | | | | | | | | | | | |
| N75 | 2.2 | 2.6 | 3.0 | 3.4 | 3.8 | 4.0 | 4.1 | 4.1 | 3.8 | 3.6 | 2.9 | 3.1 | 2.9 |
| N60 | 3.9 | 4.4 | 5.1 | 5.7 | 6.7 | 7.7 | 7.6 | 7.6 | 7.1 | 6.0 | 5.4 | 5.1 | 4.7 |
| N45 | 7.5 | 8.0 | 9.5 | 10.2 | 12.8 | 14.9 | 15.1 | 15.1 | 13.7 | 11.2 | 10.3 | 9.5 | 8.6 |
| N30 | 11.7 | 13.5 | 15.6 | 18.0 | 22.3 | 25.9 | 26.8 | 26.9 | 24.9 | 19.4 | 16.9 | 14.7 | 12.7 |
| N15 | 14.5 | 16.9 | 19.4 | 24.0 | 32.4 | 41.7 | 45.2 | 42.8 | 33.7 | 24.5 | 19.9 | 17.5 | 15.3 |
| Pole | 14.9 | 18.1 | 22.1 | 27.4 | 33.9 | 42.3 | 54.7 | 40.5 | 32.9 | 26.8 | 21.5 | 18.2 | 16.0 |
| S15 | 13.9 | 17.2 | 21.0 | 26.3 | 33.6 | 41.2 | 45.3 | 40.6 | 33.2 | 25.6 | 20.7 | 17.2 | 15.2 |
| S30 | 12.8 | 15.5 | 18.6 | 20.5 | 24.3 | 28.8 | 29.7 | 28.1 | 24.1 | 18.0 | 17.3 | 15.1 | 13.9 |
| S45 | 10.8 | 12.7 | 13.6 | 15.5 | 18.1 | 19.5 | 19.8 | 19.0 | 16.7 | 13.9 | 12.5 | 11.2 | 10.5 |
| Primary Fence | | | | | | | | | | | | | |
| 4 ft | 11.8 | 13.9 | 18.6 | 21.8 | 22.9 | 25.5 | 26.0 | 24.8 | 20.7 | 16.2 | 14.3 | 12.6 | 10.9 |
| 8 ft | 10.6 | 13.3 | 19.0 | 22.4 | 25.9 | 27.6 | 28.2 | 26.4 | 22.1 | 16.1 | 13.4 | 10.5 | 9.5 |
| | W90 | W75 | W60 | W45 | W30 | W15 | Pole | E15 | E30 | E45 | E60 | E75 | E90 |



A Day in a Luminaire: Minute by minute temp. measurements



Technology Application R&D Results

- Since results are shared widely with manufacturers and users, can be a highly cost effective way of speeding technology development
- Methods and focus areas have changed as the technology and markets have changed
- Good track record to date
- Contributions to many industry standards (LM-79, LM-80, TM-21, IEEE-1789, TM-30, etc.)

[T]his competition is quite impressive with the amount of rigor that the applicants and judges go through to identify and qualify leading SSL products. Such a competition is truly beneficial to help key decision makers, specifiers, and buyers understand that not all SSL lighting is equal.

– Christopher Walsh, Juno Lighting Group

Kudos to [DOE] for a very well-written paper regarding dimming of LEDs. . . . I'll be providing references to this paper for our salespeople and customers who are looking for more information on these challenges from a non-manufacturer source.

– Ethan Biery, Lutron (similar feedback received from OSRAM Sylvania and others)

I read your report this morning. It is super. . . . We are already using it to help Finelite build better luminaires.

–Terry Clark, Finelite