Low-Cost LED Luminaire for General Illumination

2014 Building Technologies Office Peer Review

Paul Fini

CREE Santa Barbara Technology Center

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

paul_fini@cree.com

CREE SBTC

Project Summary

Timeline:

Start date: 8/1/12

Planned end date: 7/31/14

Key Milestones

1. White LED with custom primary optic providing 95% optical efficiency compared to conventional hemispherical lens LED: August 2013 (complete)
2. Fixture surface luminance of 20 lm/in^2: February 2014 (complete)
3. Prototype mechanical fixture with a cost reduction of 33% over the mechanicals cost for the CR24 troffer product: July 31, 2014 (upcoming)

Key Partners: None

Budget:

Total DOE $ to date: $2,031,285

Total future DOE $: $312,662

Target Market/Audience:

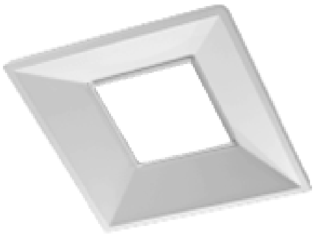
Numerous residential, commercial, and industrial end users who currently utilize conventional fluorescent troffers.

Project Goal:

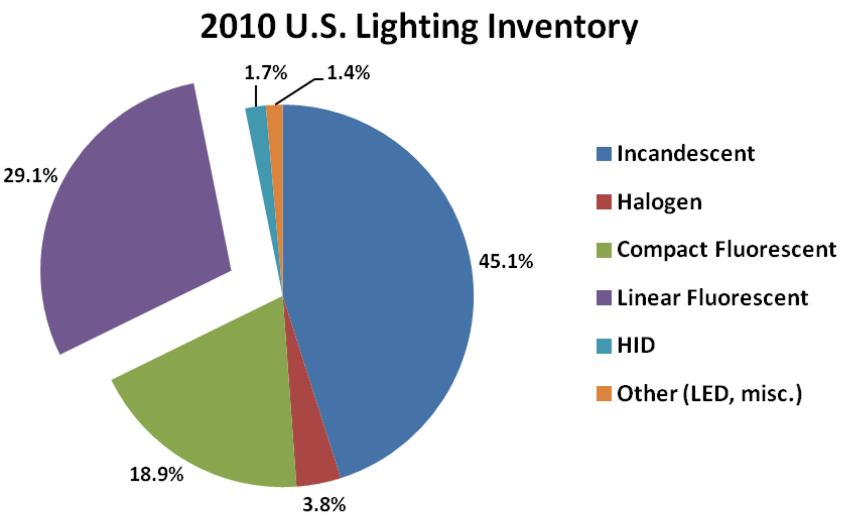
Develop a low-cost, high efficacy LED **troffer** suitable for indoor lighting. This troffer will provide 4000 lumens at an efficacy of >90 lm/W and a color temperature of 3500 K, with a color rendering index (CRI) of ≥90. A cost reduction of >30% will be achieved relative to Cree's CR24 troffer.

Purpose and Objectives

Problem Statement: **normalized cost** (in $/klm) of LED-based lighting has improved steadily, but needs a step function reduction to encourage broad replacement of low-cost fluorescent fixtures.



Target Market and Audience: there are **~2.4B** installed linear fluorescent fixtures in the U.S., most of which are in troffer form.* Replacing these with LED equivalents could yield **58 TWh** of energy savings by 2030.**



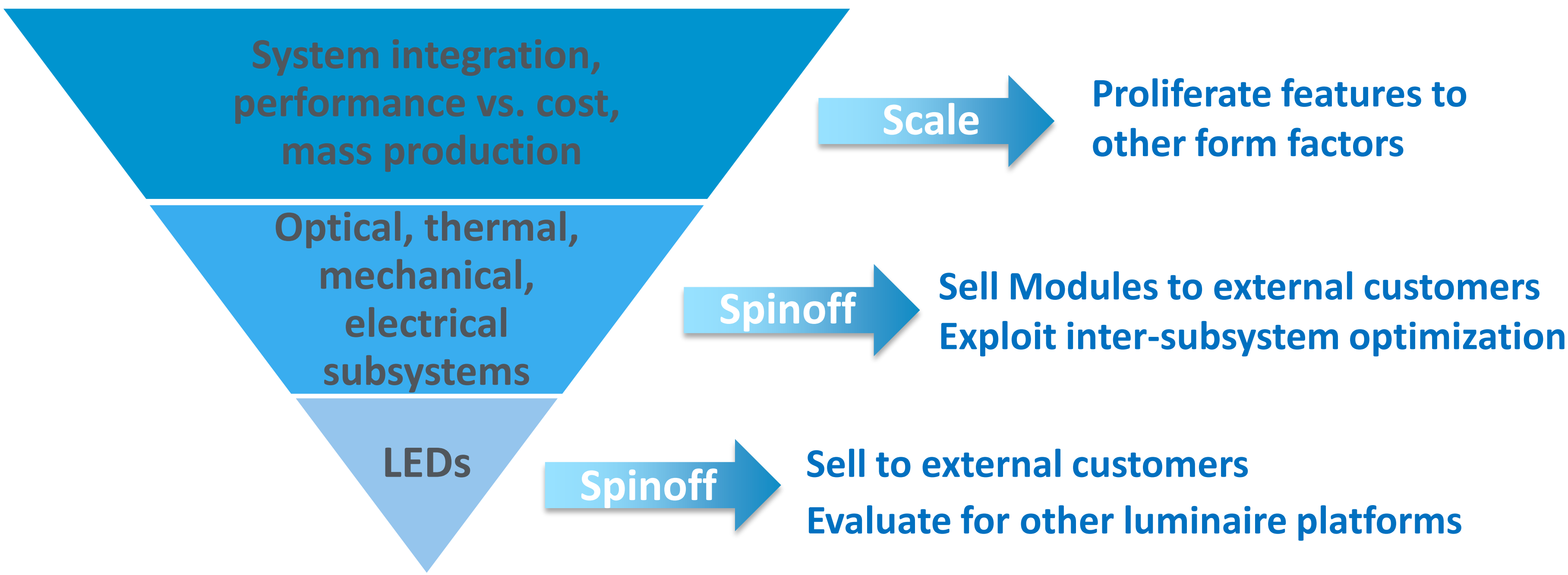
* “2010 U.S. Lighting Market Characterization”, Navigant Consulting 2012.

** “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Navigant Consulting 2012.

Purpose and Objectives (cont.)

Impact of Project:

1. **Output**: low-cost, high-efficacy, and high color quality LED troffer platform
2. **Impact path**:
   a. Near term: Evaluation of technology by Cree luminaire production groups
   b. Int. term: Mass manufacture of troffers based on adopted technology elements
   c. Long term: Further improvements in normalized cost; proliferation to other platforms



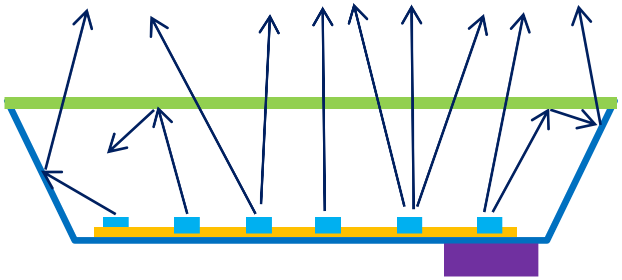
CREE

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

Approach

Approach:

- **Efficient LEDs** with desirable broad emission vs. angle: increase inter-LED spacing
- **High system optical efficiency** with minimized complexity, assembly cost
- **No heat sinks** and minimized mechanical elements
- **Cost-effective driver** with integrated controls



System Efficacy:

$$E_{sys} = E_{LED} * E_{op} * E_{th} * E_{el}$$

Key Issues:

- **LED Efficacy**: no compromises or color quality for desired wide emission profile
- **Thermal management**: achieved without conventional heat sinks
- **Optical Diffuser**: no glare and high luminance uniformity (no visible “pixelation”)

Distinctive Characteristics:

- Minimized optical losses within the system
- Combined subsystem functionality
- Simplified assembly, low Bill of Materials (BOM)

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

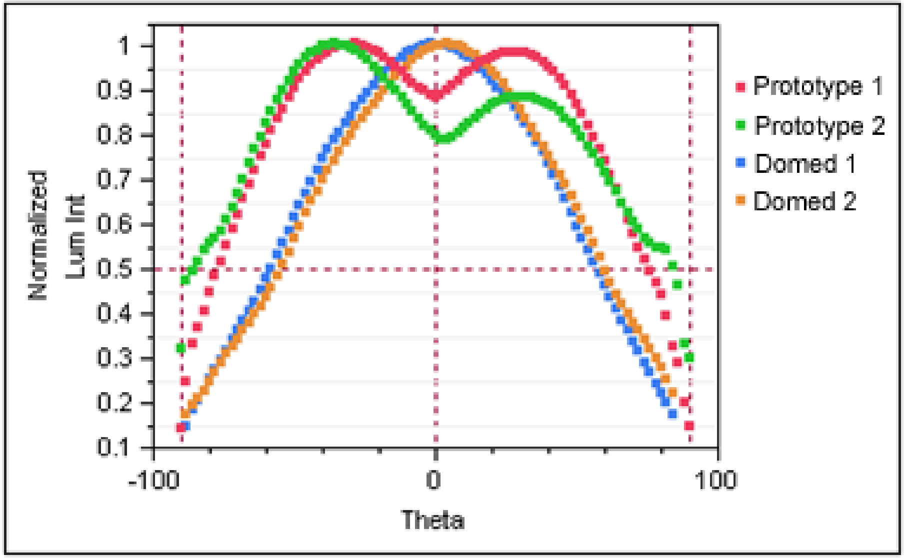
Progress and Accomplishments

Lessons Learned:

- Wider LED emission vs. angle: LEDs spaced further apart (fewer in system)
- Inter-LED and LED-diffuser spacing must be co-optimized
- Luminaire subsystems (optical, thermal, mechanical electrical) are interdependent

Key Accomplishments:

- **Novel LED**: efficacy at 3500K / 90CRI comparable to domed lens components
- **Luminaire**: < 4% LED luminous flux thermal roll-off at steady state without costly heat sinks
- **Luminaire**: Diffusing optics yielding system optical efficiency > 95%



Market Impact:

- LED design based on project prototype already adapted by Cree LED production group and ramped into mass production
- New LED design in use in Cree luminaires, and also being evaluated for new form factors

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

Project Integration and Collaboration

Project Integration:

- Cree Santa Barbara Technology Center (SBTC) leads project
- SBTC collaborates with other Cree R&D and pre-production groups to evaluate results and determine priorities & future direction

CREE's NPI approach

Partners, Subcontractors, and Collaborators:

- None

Communications:

- Project results reported monthly and quarterly to DOE staff
- Presentations made at DOE SSL workshops
- Selected Cree LED component customers appraised of progress

Next Steps and Future Plans

Next Steps and Future Plans:

- Fabricate and test full LED light engine from arrays of LEDs, with high (99.5%) solder attach yield
  - ✓ *Progress: 99% yield demonstrated for single LED array; optimization underway*
- Verify low thermal roll-off (< 6%) for LED light engine as installed in full-scale system
  - ✓ *Progress: 3% demonstrated for single LED array; building full-scale demos*
- Verify high optical efficiency (> 95%) of diffuser optics in full-scale assembled troffer
  - ✓ *Progress: 96% demonstrated for scaled-down prototypes*
- Confirm reductions in system costs (BOM, anticipated assembly) relative to Cree's CR24 troffer
  - ✓ *Progress: assessment begun based on anticipated LED, other sub-system content*

REFERENCE SLIDES

Project Budget

Project Budget: **$2.34M** Federal Share, **$700K** Cree Cost Share

Variances: None

Cost to Date: **$2.03M** Federal Share, **$597K** Cree Cost Share

Additional Funding: 20% Cree Cost Share, as detailed above

Budget History					
8/1/12 – FY2013 (past)		FY2014 (current)		FY2015 – 7/31/14 (planned)	
DOE	Cost Share	DOE	Cost Share	DOE	Cost Share
$1.17M	**$350K**	**$703K**	**$210K**	-	-

CREE

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

Project Plan and Schedule – Past Work

Project Schedule										
Project Start: 8/1/12		Completed Work								
Projected End: 7/31/14		Active Task (in progress work)								
		Milestone/Deliverable (Originally Planned)								
		Milestone/Deliverable (Actual)								
	FY2013				**FY2014**					
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)		
Past Work										
Custom LED primary optic defined										
White LED w/ primary optic w/ 95% efficiency of std. domed LED										
Light engine with 97% solder attach process yield										
LED primary optic mfg. method selected										
LED w/ >90% lumen maint., color shift <0.005 @ 500 hrs. accel. testing										
LED board integration process selected										
Specification of integrated thermal management										
Diffusing optics design specified										
Fixture thermal roll-off of <10%										
Diffusing optics with >85% optical efficiency										
Fixture surface luminance >20 lm/in^2										

Project Plan and Schedule – Current/Future Work

Project Schedule

Project Schedule		
Project Start: 8/1/12		Completed Work
Projected End: 7/31/14		Active Task (in progress work)
	◆	Milestone/Deliverable (Originally Planned)
	◆	Milestone/Deliverable (Actual)

Task	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)	
Current/Future Work									
LED light engine w/ 5500lm at 3500K, 90 CRI							◆		
Light engine wih 99.5% solder attach process yield								◆	
LED w/ >90% lumen maint., color shift <0.004 @ 1000 hrs. accel. testing								◆	
Light engine with >23% cost reduction over Cree CR24								◆	
Diffusing optics with >90% optical efficiency							◆		
Fixture thermal roll-off of <6%							◆		
Prototype fixture components procured							◆		
Prototype fixture mechnicals cost >33% lower than Cree CR24								◆	
2x4 ft. LED troffer emitting 4000lm @ 90 LPW, 3500K, 90 CRI								◆	
2x4 ft. LED troffer with COGS reduced by >30% from CR24								◆	