Cree Edge™ and LEDway® by Cree®
Compared to Induction Lamp Luminaires

Executive Summary

There are many excellent reasons to select a Cree lighting system over one based upon induction technology, even though on the surface induction may look like a good competitor for LED. Some of the main reasons to select LED are as follows:

1. Cree lighting products have unprecedented optical control. Each LEDs is covered by a precision formed secondary optic (NanoOptic®), which actually controls and re-directs100% of the light leaving the LED chip. The Cree luminaires utilizing the NanoOptic are able to duplicate and often improve on the typical lighting distributions available today in area, flood, parking structure, wall packs, bollards and other luminaires using incumbent technologies. This level of optical control delivers lighting projects with more uniform lighting levels with dramatically lower "hot spots" directly under the luminaire. The user gains a better lighting layout with lower average levels of illumination, but with equal or greater minimums. The end result is greater energy savings with Cree luminaires over the life of the installation.
2. Maintenance of lighting systems is important for both safety and security. All lamps exhibit lumen depreciation over life and at some point fail completely. The Cree luminaires have rated operating hours from 50,000 to 100,000+ depending upon the drive current and ambient temperature in which they are operated. For LED luminaires, the rated life is defined as the point in operating hours where the luminaire loses 30% of its initial light level. During this rated life, the expected failure rate of the installed luminaire base is predicted to be less than 1%. This means that 99% of the installed luminaires should require no maintenance. In an induction system, at 60,000 hours 10% of the products will have failed and at 100,000 hours, 50% are predicted to have failed. For each induction failure it is recommended that both the lamp and the induction generator be replaced.
3. Cree lighting systems are modular and scalable. Almost all Cree luminaires can be sized to fit the lighting needs of the project. The LEDway luminaires can incorporate as few as 10 LEDs in one light bar up to 120 LEDs in 6 light bars. The Beta Edge luminaires utilize as few as 20 LEDs in one light bar up to 240 LEDs in 12 light bars. Induction technology Products are limited to only a few wattages and outputs.
4. A number of cities have performed evaluations of Cree products (and other LED manufacturer's products) against those products utilizing incumbent technologies, including induction. This work was performed as part of their due diligence for the selection of a new lighting system. These studies were not run by Cree, but by the cities themselves. These were truly independent evaluations. Cree products have consistently been selected in these head to head comparisons.

Introduction

Both Cree Edge and LEDway luminaires by Cree demonstrate some significant advantages over the other current ultra long life technology, induction. LED lighting systems have only made their entry into general lighting applications over the last 4 to 5 years. Before that they have been seen in more specialized (traffic signal, indicator) and lower light output applications (decorative wall sconces, landscape lighting, etc). The primary reason for LED's entry into general lighting applications has been the dramatic increases in efficacy with the blue-white high brightness LEDs.

Induction lighting systems have been available in the market for over 20 years. Induction still represents a very small share of the general lighting market in spite of their claims of 100,000 hours of life. Since the introduction of LED products for general lighting applications, induction technology products seem to be enjoying a revival of interest. One reason for this revival is the long rated lifetimes of the induction systems that sound very competitive to those of LED. Another reason is that many of the induction products in the market today are being manufactured in China and Korea and are available at a lower initial cost than current LED technology products. The question to be answered here: is this lower initial cost worth it?

This paper will compare the current Cree and LEDway technology products with those available which utilize induction lamp technology. The comparisons will be done at three levels: Technology, Luminaire and Application. At the technology level we will compare the key characteristics of each technology. At the luminaire level we will look at the performance of the two systems and the impact of the luminaire and its ability to control the light output from the two sources. Lastly, we will apply the fixture photometry to an actual application and observe the results.

For this paper, Beta LED comments and observations will encompass both Edge and LEDway Luminaires unless otherwise stated.

TABLE 1 - Points of Comparison at the Technology Level

	Induction Technology	Cree Technology
1. Source Size and Optical Efficiency	The source sizes are very large compared to other incumbent technologies such as metal halide and high pressure sodium. A large source size means that the luminaire which houses these sources must be fairly large and that the fixture efficiencies will not be very good. The result is often a rather ill defined blob of light beneath the fixture.	The small size of the LED source and the NanoOptic™ developed by Cree allow for excellent optical control of 100% of the light emitted by the LED. The result is more uniform lighting with lower average levels of illumination but equal or better minimums. The result equals greater energy savings.
2. Dimming & Compatibility with Lighting Controls	The Induction lighting systems are not dimmable and may not be compatible with certain types of lighting controls such as dimmers and occupancy sensors. There has been some talk of a dimmable induction generator being available soon.	LEDs are continuously dimmable and compatible with all types of lighting controls including occupancy sensors and dimmers. LED luminaires with occupancy sensors offer the end user the opportunity to save even more energy, particularly in applications such as parking decks.
3. Rated Life and System Mortality	The ICETRON QUICKTRONIC systems (Osram Sylvania) and the Philips QL systems have rated lives of 100,000 hours. The system mortality is such that at 100,000 hours only 50% of the systems will be operational. At 60,000 hours of operation they are predicted to have a 10% failure rate. Many manufacturers offer a five year warranty (43,800 hours of operation).	The rated life of Cree luminaires are based on lumen depreciation predictions using the protocols on IESNA's LM-80 and extrapolation of the LED manufacturer data to the temperature characteristics measured in the luminaire itself. The Cree luminaires will experience less than 1% failures during the published L_{70} life.
4. Electromagnetic Interference	Some of these products interfere with radios, cordless telephones, remote control devices, pacemakers, and computers.	The LED drivers meet all standards with regard to electromagnetic interference.

	Induction Technology	Cree Technology
5. Low Ambient Temperature Operation	Induction lighting systems are basically a special class of fluorescent lamps. If they are not installed correctly, they will not perform well in applications with ambient temperatures below 32°F.	LED's operate even better as the temperature decreases as they operate cooler and provide for better initial light output and slower lumen depreciation resulting in longer operating lives to L_{70}.
6. Initial Cost	Induction systems can cost less initially than LED systems delivering the same initial light output.	The higher initial cost of the LED system is quickly recovered in the reduced maintenance expenses and better optical control, resulting in less luminaires and lower energy costs.
7. Maintenance of the Lighting System	It is recommended by some lamp manufacturers that both the lamp and ballast be replaced in the event of a non-operational system.	In the event of a Cree system failure, the luminaire will be repaired or replaced free of charge during the first five years of operation. Both the drivers and light bars are field replaceable.
8. Mercury & Sustainable Design Features	The Induction lamps contain mercury and need to be disposed of utilizing special precautions.	The Cree luminaires contain no mercury and are RoHS compliant. The Cree luminaires are made predominantly of Aluminum which can be recycled at the end of life. The Cree luminaires can also be field upgraded with higher performance LEDs in the future.
9. Color Temperature and Color Rendering	2700, 3000 or 4000 K All at 80 CRI	6500 K – 75 CRI 4500 K – 75 CRI 3500 K – 80 CRI

Comparisons at the Luminaire Level

Table 2 below shows a comparison for LEDway luminaires compared to both an 85 and 165 watt Philips QL Induction systems with 60% optical efficiencies. These fixtures were felt to be representative of typical induction fixtures for this application. There are some induction fixtures in the market which have higher fixture efficiencies.

For the Cree systems we selected two LEDway products with each operated at 350 mA and 525 mA. Both LEDway products are designed to produce comparable delivered lumens to the induction products at 50,000 operating hours. The 525 mA LEDway luminaires have fewer LEDs and a subsequent lower initial cost. The tradeoff is the energy savings are a bit lower.

Following IESNA's LM-79 standard, the Cree luminaire reports absolute photometry performance. Therefore, the optical efficiencies of the Cree NanoOptic™ are already captured in the reported lumen output number.

In the induction luminaire, photometry starts with a lumen output for the light source and uses relative photometry to determine the optical efficiency of the luminaire. In table 2, the line entitled "Initial Luminaire Delivered Lumens" demonstrates the impact of the optical efficiency for the induction luminaire. A value of 60% for optical efficiency was selected as this is representative of those seen with typical luminaires for this application.

Using data from the induction lamp manufacturers and the Cree lumen depreciation values, the lumen output at 50,000 hours was determined for both systems. In order to provide a fair comparison between LED luminaires and those of any incumbent technology, one must take into account lumen depreciation. Metal halide systems will always outperform LED on an initial lumen basis, but their poor lumen maintenance characteristics cause them to finish a distant second to LED luminaires when performance over life is considered. The final line in the table is an approximate magnitude of the energy savings that the Cree systems will deliver compared to either the Philips 85 watt or 165 watt QL systems.

The Results:

1. LEDway luminaires with 40 LED's driven at 350 mA provide 38% energy savings as compared to the 85 watt Induction system.
2. LEDway luminaires with 30 LED's driven at 525 mA provide 29% energy savings as compared to the 85 watt Induction system. This luminaire will also have a lower initial cost than the 40 LED product.
3. LEDway luminaires with 80 LED's driven at 350 mA provide 43% energy savings as compared to the 165 watt Induction system.
4. LEDway luminaires with 60 LED's driven at 525 mA provide 37% energy savings as compared to the 85 watt Induction system. This luminaire will also have a lower initial cost than the 80 LED product.

TABLE 2 - Points of Comparison at the Luminaire Level

Induction Systems vs LED Systems
25° C Ambient & 350 ma & 525 ma LED Drive Current

Parameter	Beta LEDway (40 LEDs) 350 mA Drive Current	Beta LEDway (30 LEDs) 525 mA Drive Current	Induction - 85 Watt	Beta LEDway (80 LEDs) 350 mA Drive Current	Beta LEDway (60 LEDs) 525 mA Drive Current	Induction - 165 Watt
Initial Performance Data						
Number of LEDs in Fixture	**40**	**30**		**80**	**60**	
LED Drive Current	350 mA	525 mA	na	350 mA	525 mA	na
Color Temperature	6500 K	6500 K	3000 K	6500 K	6500 K	3000 K
Predicted Life (L70 for LED)	150,000 hours	80,000 hours	100,000 hours	150,000 hours	100,000 hours	100,000 hours
Initial Source Lumens @ 25° C - Type II Optic	3,200	3,105	6,000	6,400	8,280	12,000
Optical Efficiency for Induction Fixtures			60%			60%
Initial Luminaire Delivered Lumens	**3,200**	**3,105**	**3600**	**6,400**	**6,210**	**7200**
System Wattage	**53**	**60**	**85**	**106**	**117**	**185**
Initial Lumens per Watt (LPW)	**60.4**	**51.8**	**42.4**	**60.4**	**53.1**	**38.9**
50,000 Hour Performance Data						
% Lumens @ 50,000 hours	86%	74%	73%	86%	74%	73%
Lumens at 50,000 hours	**2,752**	**2,298**	**2,628**	**5,504**	**4,595**	**5,256**
LED Lumens as a % of Induction	**105%**	**87%**		**105%**	**87%**	
Average Delivered LPW @ 50,000 hours	**51.9**	**38.3**	**30.9**	**51.9**	**39.3**	**28.4**
Approximate Energy Savings	**38%**	**29%**		**43%**	**37%**	

This comparison however is still not the whole story. To finish this comparison the products must be compared at the application level. Optical efficiency is one measure of luminaire performance that is being compared here. However, the distribution produced by the luminaire and its ability to direct the light output from the source to the target area in question must also be taken into account.

Comparisons at the Application Level

If the Cree NanoOptic™ and its ability to control the distribution of the light output from the LEDs is as good as claimed, there should be some benefit observed to when utilizing Cree luminaires in an actual lighting task as opposed to the poor distribution control of the induction systems. In order to demonstrate that point, we will look at some actual application comparisons.

Example 1 – The City of Chula Vista, CA

The first comparison is based upon an actual evaluation performed by the city of Chula Vista, CA. They tested a number of roadway luminaires from a number of different manufacturers including two induction products. Only the data for the Cree and the Induction products is included in this comparison. The city had minimum light level and uniformity criteria in their street lighting specification. The city then performed a photometric layout for this sample street using the photometry data provided by each manufacturer and determined the minimum spacing at which they could place poles on the street to achieve their specification. Using their staggered pole spacing, the LEDway was with a type II optic with 60 LEDs was able to meet the minimum distance of 260 feet using the current generation of Cree XRE LEDs. Using the next generation of Cree XP LEDs increased the minimum spacing to 290 feet using the same number of LEDs (60) and the same drive current (350 ma). The US Lighting Technology Induction Luminaire would require the poles to be spaced at 190 feet in order to achieve the specification and the American Electric Luminaire would require poles and fixtures at every 162 feet. In practical terms this means that for the US Lighting Technologies solution, 37% more poles and fixtures would be required and for the American Electric solution 60% more poles and fixtures would be required as compared to the LEDway luminaires in order to meet the Chula Vista specification. Obviously, this increase in poles and luminaires adds considerable initial cost.

Luminaire manufacturer	Beta (Gen B Type II 60 LED 350mA)	Beta - Prelim (Gen C Type II 60 LED 350mA)	US Ltg Tech (Induction)	Am Electric Ltg (induction)
staggered pole spacing (pole distance on same street side)	260'	290'	190'	162'

AVG	0.59	0.51	0.93	0.69
MAX	1.37	0.84	2.09	1.21
MIN	0.28	0.26	0.27	0.27
AVG:MIN	2.11	1.96	3.44	2.56
MAX:MIN	4.89	3.23	7.74	4.48
Watts - no IES file info given	76.6	75	150	85 Watt QL
initial delivered Lumens (b/4 .8 LLF)	4917	5594	7950	6000

Note also the increased uniformity (max:min and avg:min) with the Ledway type II products and the improvement in moving from the current Gen B LEDs to the Gen C LEDs. Also note that in both cases there is an energy savings available by utilizing the LED solution.

Example 2 – The City of Oakland, California

Oakland, CA also went through a comparative exercise a few years ago when they were interested in reducing electrical energy consumption from their street lights. As part of this evaluation process they also looked at both LED (4300 K) and Induction products. The following table captures the basic comparison data.

Performance Metric	Cree – 60 LED Type II	Induction 80 Watt	Induction 150 watt
Average Illumination Level	.42	.32	.53
Maximum Illumination Level	1.09	2.07	3.42
Minimum Illumination Level	0.2	0	.01
Average to Minimum Ration	2.1	NA	53
Maximum to Minimum Ratio	5.45	NA	342
Lumens	3955	4749	7824
Energy Consumption	79	87	145
Luminaire Efficiency (LPW)	50.1	54.6	53.96

The Cree product has a higher average illumination level as compared to the 80 watt induction system with much better uniformities. There is also a 9% energy savings when using the Cree system. When the Cree system is compared to the 150 watt induction system, the average illumination levels with induction are better, but the uniformities are still not good with the induction products. Lastly, there is a 46% energy savings with the Cree system.

One last item of discussion is maintenance. As noted earlier, the induction systems while rated for 100,000 hours life are expected to have 10% failures by 60,000 hours and 50% failures by 100,000 hours of operation. While these mortality rates are commendable compared to high pressure sodium and metal halide, against Cree products they do not measure up. The 350 mA Cree products have rated lives on the order of 150,000 hours. At 150,000 hours the predicted failure rates for both the LEDs and the drivers is less than 1%. Even the 525 mA Cree products have 80,000 hour rated lives. At 80,000 hours these products will have lost 30% of their initial lumen output, but will have failure rates for the LEDs and drivers of less than 1%. Therefore, in an induction installation of 10,000 streetlights, one would expect to experience 5,000 system failures by the end of 100,000 hours of operation. Compare this with an expected less than 100 failures with the Cree system. The maintenance costs for the induction system products will definitely be higher with the induction system installation.

Conclusions

Cree luminaires provide the end user an incredible opportunity to reduce energy usage in many lighting applications, including those of street, roadway, area lighting and in the lighting of parking structures. While Induction systems have some advantages over the incumbent high intensity discharge lighting systems they were intended to replace, they do not stand up well against the Cree system. Induction systems typically have poor optical control due to their large source size. The Cree systems are able to precisely control 100% of the light output leaving the LED by utilizing its patented NanoOptic™. This level of optical control is unprecedented in general lighting applications. The projects utilizing the Cree optical technology show greatly enhanced uniformities.

Induction lamps are essentially fluorescent lamps with no electrodes. The mercury within these products is excited by a high frequency generator. Fluorescent lamps are excellent light sources in indoor environments where the temperature is maintained over a fairly tight tolerance. In cold applications (less than 32°F) fluorescent lamps lose considerable lumen output. Induction technology products must be installed carefully in order for them to perform acceptably at lower ambient temperatures.

LEDs are also sensitive to temperature, but in the opposite direction. LEDs perform better in colder temperatures and actually increase their light output as the temperature drops. However, care must be taken with LED systems to recognize the negative impact that high operating temperatures can have. Thermal considerations have always been paramount in the design of all Cree and LEDway products. This care and consideration has allowed Cree products to obtain life ratings will in excess of 100,000 hours when operated at 350 mA. It has also allowed Cree products to deliver excellent performance at higher drive currents. The higher drive currents allow for the use of fewer LEDs in the products and subsequently lower costs.

The Cree systems are very modular and field repairable. LEDway products are offered containing from 20 to 120 LEDs in increments of 10 LEDs. The original Cree Edge products for area lighting are offered containing 40 to 240 LEDs in increments of 20 LEDs. This design flexibility allows the Cree products to precisely fit the application.

Lastly, the energy savings resulting from the use of this exciting new technology are significant. Many of the projects installed using Cree luminaires have energy savings of from 30% to 70% when compared to the incumbent lighting technologies. And this is only going to get better! Dimming drivers will allow excellent control of lighting levels such when people are not present, the systems can operate at lower light levels and consume less energy. Think about a typical parking structure where vehicular and pedestrian traffic may only require operation on high output mode for 20% of the time. By operating in a low power/low light level mode when traffic is absent, the energy savings will be increased dramatically. The future of LED lighting will feature a much expanded level of control possibilities. LED is the next generation of lighting technology – stay tuned!