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Smart Lights | Smart Buildings

The Advantages of Using LEDs in Commercial Applications

Lighting accounts for as much as 40% of the energy used in commercial buildings.[i] Compared to other major systems of the built environment, retrofitting the lighting is a relatively simple and inexpensive solution for those who wish to slash their energy use while minimizing the capital expense to do so. People naturally look to new, energy efficient technologies to help them meet energy goals, and Light Emitting Diodes (LED) have quickly emerged as a solution with unique benefits in commercial lighting. Largely believed to be relegated to niche applications, there are a surprising number of LED general lighting fixtures available today. The following is designed as a guide for the specifier of lighting and those interested in the technology and the state of the art.

Lighting is a critical component of building performance. Building owners and specifiers face rapidly changing lighting technologies. The biggest, transformational change in lighting today is the rapid growth and penetration of LED choices for both exterior and interior lighting. From new fixture formats and luminaire types, to new ways to control and dim lights, to lighting quality considerations around color temperature and color rendering, purchasers and specifiers need a way to navigate and compare existing lighting technologies with LED options. This paper will examine several key advantages of using LED lighting across a realm of business and technical considerations—efficiency, costs, maintenance and lighting quality.

Key Advantages of LEDs

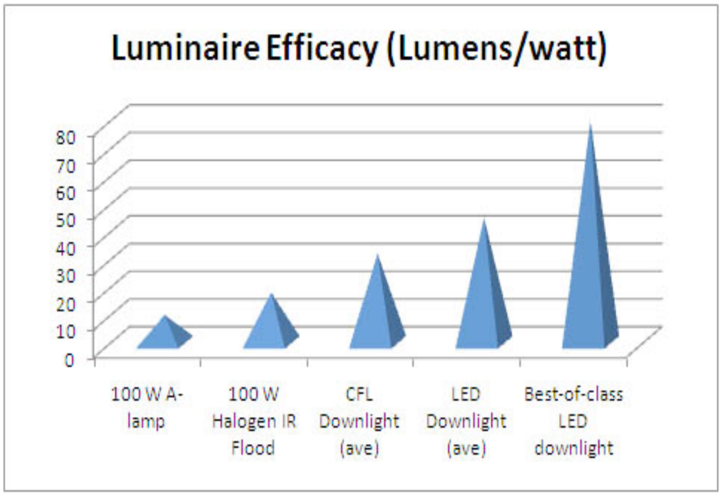
- Extremely long life reduces maintenance costs
- Limited heat emission reduces HVAC load
- Super-efficient and smooth dimming improves energy profile
- Environmentally friendly and rugged (no mercury or risk of breakage)
- Improved lighting quality may increase worker/student productivity

LEDs are more efficient and ultimately more cost effective than traditional technologies

Efficiency—the single biggest market driver for LED products are their improved efficiency over practically all other light sources (incandescent, halogen, HID, CFL, and linear fluorescent). The need for higher efficiency is driven by both the economics of saving money on reduced power bills, as well as state and national energy codes that are mandating that buildings need to be lowering lighting power densities (LPDs) through more efficient lighting.

The efficiency of commercially available white LED products has caught up to and passed that of the most efficient traditional technology. Those are bench-top readings in a lab though.

What does it mean out of the lab? To get a real sense of how a user may interact with the technology, it is more realistic to capture the performance of the technology *in situ*. Any optical losses of the fixture, thermal losses, and electrical inefficiencies are factored into the performance. This is “real world” data.



Graph 1: Downlight Fixture Efficacy

The popular, recessed ceiling can fixture serves as a good example of how successfully LED technology has not only arrived, but how it more effectively lights an application than traditional technologies. Graph 1 shows results for recessed ceiling can performance. All the data is taken from independent lab testing.

As a stop-gap technology, the Compact Fluorescent Lamp (CFL) does a good job of improving on the efficiency of a 100 year old technology. LEDs, which are enjoying exponential gains in efficiency on a source level, are already tracking well ahead of fluorescent technology in the application. The performance of the best-of-class LED product gives an additional level of perspective on the future scaling potential for LEDs.

While this serves as an interesting example, the recessed can is an inherently inefficient form factor—especially for some technologies like CFLs. Another fixture type from the commercial environment would serve as a good second data point. The most popular fixture type in commercial application is the fluorescent linear troffer. Let’s see how LED troffer replacements perform against their fluorescent counterpart. We’ll choose a 180’ x 100’ sized room in order to match the size of the average commercial space. Fluorescent and LED lay-in grid luminaires were modeled at a height of 10’. Standard room reflectances for commercial applications, 80-50-20, were used. Independent lab testing data (LM79) data for both fixtures were generated, and a popular light rendering program was used. The horizontal illuminance target of 30FC was set on the work plane. The results are shown in the table below:

Luminaire	Power (W)	Number of Fixtures	Average Illuminance	Max: Min	Lighting Power Density (W/SF)
1’x4’ linear 2 lamp T8 fluorescent Troffer	58	216	37	2.1:1	0.7
LED 2’ x 2’	51	180	35	1.8:1	0.5

Table 1:1 Lighting performance comparison of linear fluorescent and LED lay-in luminaires

Not only was the LED luminaire able to save roughly 30% more energy, it was able to do so using 17% fewer fixtures—saving in fixture installation costs. The LED solution also offered more uniform, voluminous lighting throughout the space. The space with the LED fixture will appear better lit, architectural elements will be better displayed and facial rendering will be enhanced.

Dimmability—the ability to dim lighting is desirable for multiple reasons including special events like a presentation, individual light level preferences and for cost savings. So what are the issues involved? Lighting needs to be dimmed preferably without: a) compromising performance, b) compromising fixture lifetime, and c) the dimming being disruptive. With those concerns in mind, LEDs really become the only technology choice. Can fluorescent lamps dim? Yes, they can, but a look at what happens when they dim compared to LEDs will help build the case for why LEDs are the superior choice.

Fluorescent systems thrive on stasis. It takes an average of 20 minutes for mercury vapor pressure to build within the lamp, and once that pressure is achieved, it wants/needs to remain stable. Frequent switching or dimming the lamp may compromise the integrity of the technology in the following ways:

1. Efficiency—as the fluorescent dims, you lose efficiency. At lower dimming levels, the fluorescent ballast draw represents a greater overall percentage of the power to the point that dimming below 20% of full output saves no energy at all. LEDs, on the other hand, get *more* efficient as they dim, and at no place in the range of 0-100% dimming is the energy savings compromised.

Effects of Dimming on Technology

	Fluorescent	LED
Efficiency	Less	More
Lifetime	Less	More

2. Lifetime—the conversion of energy to electric light in the case of fluorescent technology is a wildly complex process. Heating of the electrodes is critical. Too little heat, you get sputtering; too much heat can lead to evaporation of emissive coating of the electrodes. Lifetime issues are most likely to occur at common, intermediate dimming levels (50-80% range,) where more heating of the electrodes is needed. Additionally, there are issues of switching fluorescent systems on and off from a dimmed state. LEDs, on the other hand, enjoy *greater* lifetime when dimmed and can be frequently switched with no adverse effects.

3. Field Issues with fluorescent dimming systems are well documented[ii] and well understood within the industry. Premature failures, challenges with forward-phase and reverse-phase dimmer compatibility, non-working lamps, severe end darkening, pink lamps and lamps with significantly low output as a function of dimming are just a few of the complaints.

These points underline the fact that in order to truly capture the value of dimming in the built environment, LEDs are the superior choice. As a purely digital device, LEDs stand in stark contrast to fluorescent in as much as: they not only do not suffer the aforementioned issues as fluorescent when dimmed, they thrive/are best when dimmed.

<u>HVAC Savings</u>—the efficiency gains from using LED product are obvious, yet there are other benefits that come along for the ride. One of those is reduction in the cooling load for the building. The rule of thumb is 1/3rd of the wattage saved for one lighting system to another equals the energy saved in cooling the building as a result of the reduced wattage. Using the example above, we can calculate the equivalent savings for the HVAC by (Wattage of Fluorescent System – Wattage of LED System)/3 or (12,528 W – 9,180 W)/3 = 1,116 W. This is the equivalent of 21 LED fixtures! If one considers the ubiquitous nature of drop ceilings in commercial environments, you will appreciate an additional benefit of the LED systems over fluorescent troffer systems. 90% of fluorescent troffers are static—meaning: they don't allow air flow through the fixture. Considering the fact that fluorescent lamps radiate heat, you have the majority of the 41%[iii] of energy that fluorescent lamps convert to heat radiated down into the occupied space. LED fixtures, on the other hand, conduct heat, and do so in the commercial environment not into the occupied space but into the plenum. This is an additional benefit, albeit one that is much more difficult to quantify, of using an LED system.

<u>Maintenance Savings</u>—the ability of LED systems even by conservative estimates to provide twice the lifetime of competing fluorescent systems can profoundly affect the payback numbers for LED systems. This is an area of considerable debate. Fluorescent proponents are likely to point to lifetime estimates for fluorescent technology of 30,000 even 40,000 hours. They will also point to a lack of data to support the often-cited 50,000 hour estimate for LED. They will then conclude that it is really a wash—no difference in lifetime for the two technologies. So much of these assumptions rely on the application conditions. Let's look at some of the factors that might affect the lifetime of the two systems in an average commercial installation:

- Heat—as mentioned earlier, 90% of fluorescent troffers are static. As a result, heat is trapped in a fluorescent fixture, and heat builds up. The most common fluorescent lamp type, the T8, is designed to operate at 25°C. Heat trapped in the average fluorescent troffer will elevate the ambient conditions in the light fixture to 35-40°C. At these temperatures, not only will the fluorescent emit roughly 10% less light, but it will have a shorter lifetime. LEDs are also sensitive to heat, and in an ICAT rated ceiling can, heat ablation becomes a primary concern. In the average drop-grid environment, however, LED fixtures enjoy advantageous conditions. Temperatures are low, there is lots of airflow, and the system—as long as there is a thermal path from the junction to the outside environment, as a result, should not be taxed.

- Frequent Switching—the position of this paper is that dimming will facilitate tremendous energy savings. In order to compare apples to apples, we need to consider a dimming fluorescent system vs. a dimming LED system. The 30,000 hours metric used by fluorescent manufacturers is based on 12 hour cycle times, and this is not synonymous with the frequent dimming that we are talking about in a high performance building. The frequency of control will greatly reduce the fluorescent lifetime. Additionally, fluorescent lifetime states the time it takes *50%* of a batch of lamps at perfect ambient conditions to fail. LED lifetime, on the other hand, is based on L70 or the amount of time it takes the LED to depreciate 30%. This is hardly the same thing, and you can imagine the side-by-side comparison of an open office, for example, that was previously lit to 30FC at 21 FC for LED—a barely noticeable effect, and one where half of the fluorescent lamps are burnt out. The LED space would be much better lit.

Therefore, even by conservative estimates—if you were to grant dimming fluorescent lamp life of 20,000 hours and you limited LED lifetime to 40,000 hours—you still have a formidable delta that manifests as a greatly reduced operational expense for the LED system. This leads naturally to a discussion of payback.

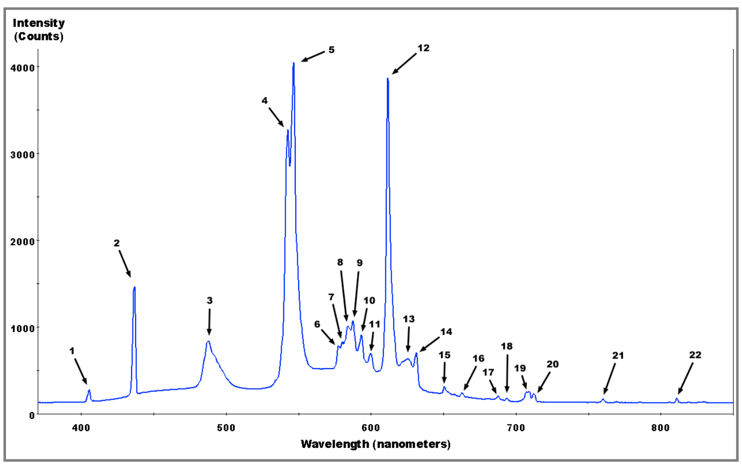
<u>Rate of Return</u>—the supply of commercial LED products is rapidly expanding, and this healthy competition has spurred a drop in cost for the technology. Anyone concerned only with first costs when comparing LED and fluorescent choices in commercial applications will find "low end" fluorescent options that are less expensive than LED offerings. Whether or not they are happy with the fluorescent system is another question. Commercial lighting retrofits or new construction are invariably complex projects and warrant a more robust, second level economic analysis. This analysis will take into account any energy and maintenance savings in addition to the initial capital expense of the system.

In general lighting for commercial application, a realistic rule of thumb when comparing LED to traditional fluorescent systems, is that specification-grade LED offerings cost 20-30% more than specification grade fluorescent alternatives. Once a Life Cycle Cost Benefit Analysis (LCCBA) is performed, however, taking into account the effects of dimming for energy efficiency, maintenance saving and tax effects of depreciation, payback for LED systems can range from 6 months to 3 years. Considering the longer paybacks for other, more mature energy efficiency technologies such as wind and solar, this is indeed good. And as the cost of

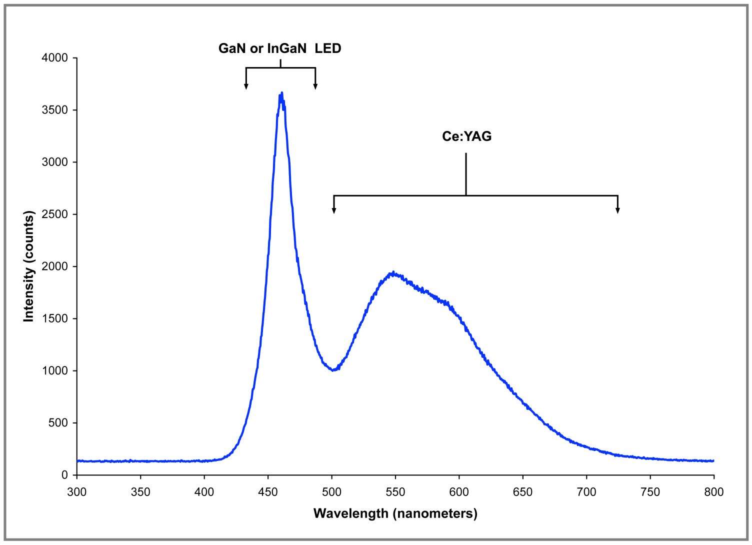
LEDs and other components continues to come down, the payback numbers will collapse to less than one year. At the point that the payback comes in under the time of one business cycle, there will be massive disruption. This is the reason that market analysis performed by Philips Lighting predicts that by the middle of the decade 50% of all commercial spaces will be lit by Solid State Lighting sources[iv] and by the end of the decade it will be north of an 80% adoption rate.

LEDs can Provide Enhanced Color/Light Quality over Traditional Sources

Quality of Light is among the most important things that consumers care about[v]. The perception of LED technology with regard to color has been a result of first experience with cheap LED flashlights or inferior-quality screw-based lamp replacements. Not only do people not have to sacrifice light quality with LEDs, the light quality can be enhanced through the use of LEDs. First, let's talk about the quality issues that plague fluorescent technology. Then we'll talk about the ability of LEDs to offer a higher quality of light.



Studies reflect that people have an unfavorable impression of fluorescent lighting[vi]. A typical complaint is that they are "unfriendly" using descriptors like "harsh" when describing the quality of the light. The graph below shows the spectrum of a typical fluorescent lamp. There are two significant things to note. First, the jagged nature of the peaks in the spectrum of the typical lamp are very unlike the more uniform and tapered spectrum of daylight. Secondly, the largest peak in the fluorescent spectrum takes place in the green area of the spectrum. Fluorescent lamps benefit from the green component. The human visual system is more sensitive to light in the green spectrum which translates to efficiency. Unfortunately, green light is bad light from a quality white light perspective. Green light makes skin tones look sickly. The heavy green spike makes surroundings look poorer and more dingy than a well-balanced spectral distribution.



The spectrum of the average white phosphor-converted LED on the other hand is smoother than that of the fluorescent light. It mimics the spectrum of daylight more closely, and it is immune from the heavy spike in green that you will find in interiors lit with fluorescent technology.

Achieving good color quality is not easy. While phosphor technology continues to improve dramatically, commercially available LEDs with superior color quality has become the domain of a small number of Tier 1 suppliers. Luminaire manufacturers who use Tier 1 suppliers pay a premium to make that quality part of their value proposition. As the public becomes more educated about these issues, they will demand the higher color quality, stability and efficiency that is part and parcel with quality components. Fortunately, new labeling programs such as the *Lighting Facts* labeling program from Energy Star Lighting are helping to educate the market on lighting quality and performance for LED fixtures.[vii]

Additionally, as the public becomes more aware of the link between lighting and productivity[viii], there will be a natural demand for higher quality LEDs. This can be extended lastly to the capability of controls. Individual control over lighting in work environments is highly preferred. Add to this the enormous energy saving potential, and you see a need for automatic controls in the office. Automatic lighting control can eliminate energy waste by minimizing the lighting when it is not needed. That takes extreme precision and nuance. A robust system needs to take into account the wide range in individual preference and need for lighting at any one moment. It needs to have a network of data to utilize, and in order not to be de-commissioned it must disappear into the background and do its job quietly without being seen.

LEDs are Safer

Over 1M fluorescent lamps will be disposed of in 2011. What becomes of those lamps? If they end up at a municipal incinerator, 90% of the mercury will be released into the atmosphere. One study on disposal of fluorescent lamps was blunt in its assessment: “Short of dumping broken lamps into lakes, this is the worst possible way to handle the mercury content in fluorescent and HID lamps[ix].” What happens to mercury is that it bio-accumulates up the food chain, and, as such, is a potent nuero-toxin that can harm both humans and animals. LEDs, on the other hand, are free of mercury and relatively benign. As a longer-life product, there is a greatly relieved disposal burden vs. brittle, commodity-grade fluorescent troffers, which need to be replaced on average every seven years.

There are an Increasing Number of LED Luminaire Choices

The pace of new LED fixture options has also accelerated over the last five years. The early market for LEDs fixtures included a limited selection of LED downlights, screw-based lamp replacements, undercabinet "pucks" and LED linear fluorescent replacement lamps for use in fluorescent troffers. These early fixtures meditated more on making the technology palatable to the public instead of designing around the strengths of the technology. In the case of the linear lamp replacements, the DOE[x] called out serious application issues with the product and warned the public against their use. Since 2006, however, there has been rapid growth in new LED fixture options, formats, and competitive options for general lighting. Today, there are literally hundreds of task, cove, track, sconce, and downlight LED fixture formats for practically every conceivable application. There are LED luminaires in 2'x2', 1'x4', and 2'x4' "lay-in" formats, as well as newer LED slot and linear pendant options to compete broadly across all applications with fluorescent lighting in commercial spaces. These new offerings are coming from both the major lighting brands as well as Solid State Lighting specialist firms.

Conclusion

LEDs offer some clear advantages versus other lighting technologies and are here to stay. The only question is: how quickly will the adoption rate be? If industry predictions hold true, the upsurge in LED fixture specification for commercial applications will be exponential in the next five years. This model is predicated on the simple and predictable scale of technological improvements in performance, quality and value of LED systems. It is a given. What nobody understands clearly is how the other attributes and features will contribute to the growth and adoption of LED technology. With baby boomers reaching retirement age, Light and Health, a burgeoning field in lighting research, becomes an important area of interest to the industry. LEDs are uniquely capable of activating the circadian system vs. traditional technology, and, therefore are well positioned to be the go-to technology here. Worker productivity is another area of interest. The cost of lighting an office is a fraction of the cost of salaries, so even small increases in productivity due to lighting are both highly valuable and justified. LED Luminaires in conjunction with sophisticated controls are a great way to improve office workers' sense of well being by enhancing the environment. This leads, in turn, to higher productivity. Thanks to the unique nature of LED technology, the future of lighting will be rapidly evolving and exciting. In the meantime, it is good to know that LED products that draw on a host of attributes such as long life, ease of controls, efficiency, and user friendliness already exist and are a compelling option for any commercial interior application today. The future is now for LEDs.

[i] National Center for Energy Efficiency and Conservation (NCEEC) 2011

[ii] NLPIP, Dimming T8 Fluorescent System Problems, 2006

[iii] IESNA Lighting Handbook (Rea)

[iv] Philips Lighting, Analyst Day Presentation, 9/24/2009

[v] EcoPinion: Lighting the Path Forward, Survey Report, Issue 10, March 2011

[vi] *Increasing the Market Acceptance of Compact Fluorescent Lamps (CFLs),* Lighting Research Center, 2003

[vii] For more information on the Lighting Facts labeling program, see http://www.lightingfacts.com/

[viii] McCloughan *et al*., 1999

[ix] Lighting Futures, Volume 3 Number 2

[x] US Department of Energy *Application Series: Linear Fluorescent Replacement Lamps*