Phasing in LED Lighting Technologies: Issues for Near-Term Applications in Asia

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1. EXECUTIVE SUMMARY

TO BE DEVELOPED AFTER REVIEW

(GLOSSARY OF TERMS TO BE INCLUDED)

2. INTRODUCTION

In the last ten years, LED-based lighting products have emerged as a credible, energy-efficient, long-lasting, and low-maintenance alternative for some real-world commercial and industrial applications. The development of LED-based lighting products for residential and commercial-residential applications has also followed quickly, with thousands of products now available on the consumer markets in Asia. Globally, light-emitting diode (LED) based exit signs and traffic signals have saved millions of kWh of electricity and tens of thousands of maintenance hours since their introduction over a decade ago.[1]

LEDs have also generated more stakeholder interest, and new manufacturers seem to be entering the market daily. A number of projections have estimated that LED lighting will gradually replace at least 20% to 35% of incandescent lighting applications by 2020, if not earlier, due to a combination of increased consumer appetite for energy efficiency, and regional and national programs to phase out inefficient lamps.[2]

Although the availability of high-brightness, high quality LEDs – commonly referred to as HB LEDs – still appear to be limited by expert production, this trend seems to be changing, with more fabrication plants for LED "chips" coming "on stream".[3] [4] Along with new production capacity, a new category of LEDs – ultra high-brightness LEDs or UHB LEDs, has been created for the new generation of LEDs, along with a new generation of high-power LED chips (>1W per chip). HB and UHB LEDs are the chips that will be needed for use in high-quality lighting applications.

To obtain the "white" light needed for commercial lighting applications and the familiar "warm white" light desirable by discerning consumers, manufacturers need to either mix UHB LEDs of different color spectra, or use a phosphor coating with a UV or blue LED. Both of these methods require specialized equipment and knowledge, and have the potential to increase costs and reduce overall efficiency of the lighting package. (A primer on LEDs technology is provided in Appendix A of this report).

Nevertheless, the increasing demand for this once unfamiliar product has resulted in some significant changes in how LEDs are made and sold in Asia. These changes include:

- Accelerated LEDs demand and production;
- Increased product availability and variety;
- Production for domestic applications:

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[1] The term "solid-state lighting" is also being used to describe LED-based lighting. LEDs are a sub-category of SSL.
[2] Some of the attention on LEDs can also be attributed to "CFL-fatigue" – the fact that policymakers and other decision makers are convinced that the market for CFLs in Asia and elsewhere is "transformed."
[3] See, for example: "Philips Lumileds Crosses 1 Billion LUXEON LED Benchmark." *Business Wire*, Aug. 4, 2010.
[4] Note that all LEDs require semiconductor "chips" to produce light. These chips require high-tech fabrication similar to computer "chips," or other electronic components.

- Concentration of LEDs manufacturing in regions with low labor and material costs;
- Initiation of a number of national efforts to develop policy and standards for LED-based products; and
- Emergence of specific regulatory and programmatic requirements for LED-based products.

The intent of this report is to provide an overview of LED-based lighting technologies in Asia. It examines the current market, technological issues and barriers to adoption of this technology in order to help policymakers identify opportunities, form program policies, and decisions regarding this new technology. The report provides some background information on the current state of LED technology and market, as well as standards activities and needs around the region. It is not intended to be a primer on this technology, but rather a guide of sorts for those who need to promote, test, and regulate LED-based lighting products. Appendix A contains a brief overview on LEDs for those policymakers who are interested in additional technological details.

While this report broadly applies to the Asia region, the information presented herein focus primarily on China, India, and four countries holding membership in the Association of Southeast Asian Nations (ASEAN) – Indonesia, Philippines, Thailand, and Vietnam. Together, these six nations account for 96 percent of the gross domestic product (GDP) of Asia's developing economies as well as a significant share of the global LED lighting market.

The challenges (and the potential) for LEDs are quite significant, and require actions on the part of policymakers. Specifically, the market trends for LED-based lighting products, especially for consumer lighting in Asia have the potential to resemble the path taken by CFLs not so long ago, with the same tendency towards a "race to the bottom" in terms of product quality, consumer dissatisfaction, and lack of a regionally agreed upon quality standard.[5]

[5] *Confidence in Quality: Harmonization of CFLs to Help Asia Address Climate Change*. US Agency for International Development, Regional Development Mission, Bangkok, Thailand, 2007.

3. THE ASIA MARKET FOR HB LEDS

Globally, the high-brightness LED market grew 11% in 2008, reaching $5.1 billion.[6] However, the market saw a small decline for 2009 due to worsening economic conditions, resulting in an estimated market size of $4.9 billion.[7] While this decline in 2009 affected the more mature LEDs markets such as automotive lighting, mobile phones, and outdoor video screens, other HB LED emerging segments such as backlights for LCD displays in notebook computers and TVs showed continued strong growth.

More importantly, the world-wide LED-based lighting market is projected to continue to grow. In fact, lighting and LCD backlighting are the applications that are seen to be driving the market for HB LED beyond 2010. Over the next five years, the market growth forecast for HB LED is at least at a CAGR (compound annual growth rate) of 24%, and is expected to reach $14.9 billion world wide in 2013.

In Asia, the market for LEDs is rapidly expanding. The exact number is hard to determine, and in fact it is believed to be changing on a weekly basis. According to some data, the total domestic LED applications revenue in China in 2008 was RMB 45 billion (US$ 6.5 billion), which is an increase of 50% over 2007, with the largest applications being architectural illumination and display. In India, the lighting market is worth US$1.5 billion as of 2008, of which LED constitutes 3%, or about US$45 million.[8] Other countries in the region can be assumed to follow the Indian LEDs lighting market, constituting about 2% to 3% of the overall lighting market size. Based on this 2008 information, the current market size in Asia for LEDs can be assumed to be about US$ 7 to 8 billion in 2010, of which lighting constitutes about $US 500 to 600 million and growing.

With respect to HB LED production in Asia, Japan, Singapore, Taiwan and Malaysia have long been major centers of LEDs and LED component manufacturing. Japan accounts for about 44% of world supply in 2008. However, Japan is a relative latecomer in the adoption of LED lighting, as compared to the US, Europe and China. Only recently did a number of companies in Japan enter the market with quality illumination products.[9] A similar situation for LED lighting exists in South Korea, where local interest in lighting has been low until recently. In February of 2010, in an effort to cut carbon emissions and save electricity, the Korean government announced in February that it would be spending $47 million to promote LED-based lighting products.[10]

The most dramatic increase in LED production in the past decade happened in Taiwan and China. The growth in China is encouraged by the Chinese government through the

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[6] Due to intense industry interest in LEDs, the exact size and production numbers can be difficult to come by or to verify. The information presented in this section is a compilation of publically available information, and is used to illustrate the overall size and growth of the industry in Asia.
[7] "High-Brightness LED Market Review and Forecast." Strategies Unlimited, Mountain View, CA, 2010.
[8] Kutty, B. "LEDs will light up your future!" *Dare*, Thursday, 1 May 2008. www.dare.co.in.
[9] Steele, R. "Strategically Speaking: Insights Into LEDs & Lighting. *LEDs Magazine*, October 2009.
[10] Green. M. "Korea Makes New Push for LED Lighting." *Power Integrations*, March 2010.

Ministry of Science and Technology (MST) as well as other agencies.[11] By most estimates, Chinese production of LED-based products (with imported LEDs) currently accounts for a majority of products worldwide, both in lighting and other product categories. Shenzhen is the first city to enter into the LED industry in China, and as of 2009, there are about 1,000 enterprises engaging in LED lighting technology research and development, production and application. It has become the China's largest cluster of LED-based industry.[12]

China has eight other cities focused on LED production, each with its own specialty. Other than Japan, Singapore, Malaysia, and Taiwain, each with significant investments from the start, few other Asian countries have exhibited such significant growth in LEDs production capabilities. India, which is working to leveraging its developed expertise in IT industries to foster LED production, is just now at the beginning of this process.

According to experts, most illumination-grade chips being used in Chinese products are still imported from outside of China currently, from Tier II manufacturers in Korea (LG, Samsung) and Japan (Stanley and others), and from Tier I manufacturers (Cree, Nichia, Osram, Philips, Toyoda Gosei, and Seoul Semiconductor).[13] There are probably several hundred LED packaging firms in China; the highest volume packagers are in Shenzhen and the Shanghai area. In addition to the chip and packaging companies, there are also several thousand LED application companies in China. The exact number is hard to determine, and in fact it is growing almost on an exponential basis.[14]

It is important to note that similar to the personal computer industry, much of the profit in the LED industry is in chip production, with much lower margins in the packaging and application stages. Generally, LED chip production generally accounts for 70% of profits, and LED chip packaging accounts for about 30%. Up to several years ago, the production of HB LEDs was limited to a handful of companies in the US, Japan, Korea, and Europe that hold most of the intellectual properties on LED production processes. This trend is now changing, due to a number of factors, including constraint on production capacity, and the increased interests from both the Chinese and Indian governments in developing their own LEDs chip fabrication capacity and knowledge.

Most of China's current LED industry is in the chip-packaging segment and application development, which are less profitable. However, the Chinese government has been supportive of the industry in helping to expand LED chip manufacturing by offering subsidies designed to bring investment from Taiwan and elsewhere. The Chinese government is willing to subsidize 8-10 million RMB (US$1.2 -1.5 million for each chip

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[11] Stevenson, R. "China's LED production on a growth trajectory," *OLE* July/August 2009. www.optics.org.
[12] In 2009, Shenzhen Municipal Government also issued a series of documents, including the Shenzhen LED industry plan, with the intention to spend more than 200 million RMB in the next three years to boost its LED industry.
[13] Conway, K. LED Consulting, personal communications, September 2010.
[14] Beyond the packaging companies, it has been estimated by some experts that number of companies assembling LED applications in China may reach 10,000 or more.

fabrication machine installation, and this level of incentive has attracted many LED chip makers from Taiwan to set up facilities in China.[15]

[15] Officials from Taiwan based LED companies have pointed out that LED chip production requires high level of technology application and significant experience, and that a massive capacity ramp would not necessarily translate to quality chips that will meet industry standards. In addition, the capacity ramp up will affect pricing, and erode the margins of many small to mid tier LED manufacturers.

4. LED PERFORMANCE AND COST TRENDS

The advances in compound semiconductors used for LEDs follows a trend predicted by *Haitz's Law*. It states that the light output and efficacy of LEDs roughly doubles every 18 to 24 months, and that the future LED performance will likely follow a trend similar to that of the past 30 years. Therefore, not only is the performance of LEDs improving, but the cost is also decreasing, making the technology more cost effective for certain applications.

It is important to note that this law applies mainly to each single color of LED, but not to white LEDs. This is because the development of white LEDs involves multiple technologies, its performance trends are less predictable than that of single-colored LEDs.[16] However, technology roadmaps maintained by the U.S. Department of Energy in cooperation with manufacturers, show that some white LEDs are bright enough for general illumination applications as of 2010 (Figure 1 below).[17]

Figure 1. LEDs for General Illumination Performance Trends

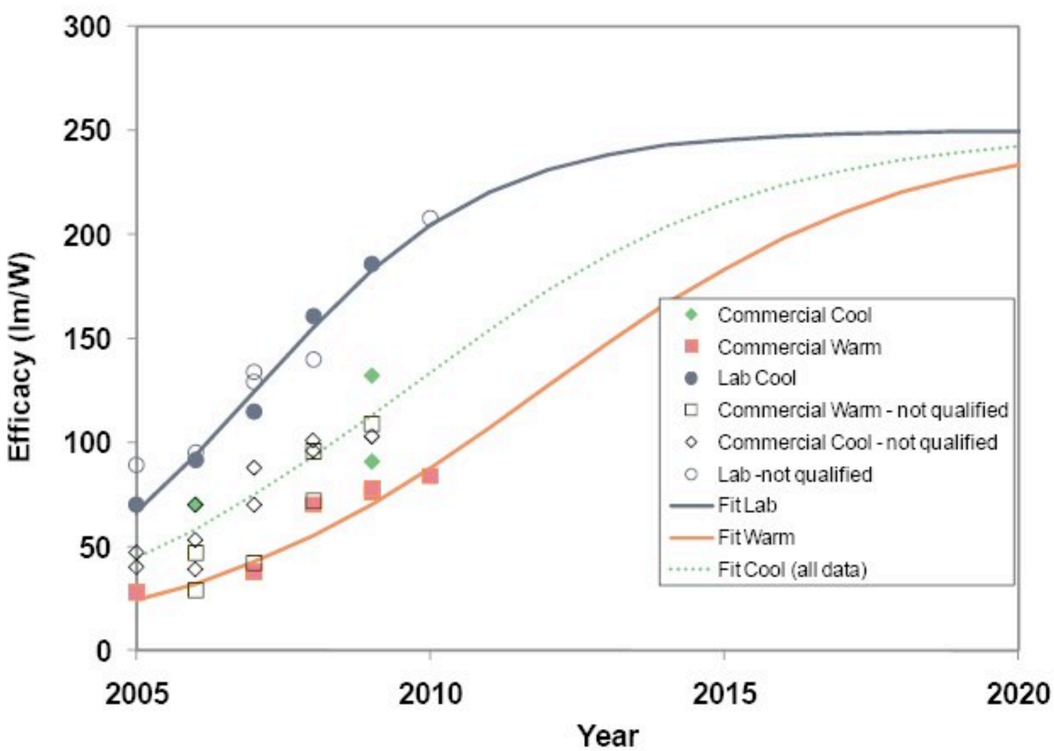


Figure 4.11: White-Light LED Package Efficacy Targets[64], Laboratory and Commercial

Source: US DOE

Note that with the recent progress in price and performance, LED devices are still significantly more expensive than commercial incandescent light bulbs for general illumination. Currently, in the consumer and commercial markets, the price differentials

[16] Appendix A contains a primer on LEDs and white light LEDs

[17] Navigant, 2009.

can be several orders of magnitude. Luminous efficacy of white LEDs is currently better than incandescent and halogen technologies, and has caught up to some fluorescent and gas discharge applications, such as directional lighting for a number of commercial applications, including garage and street lighting.[18] Projections indicate that white LEDs should be able to surpass fluorescent for general lighting during the coming decade. Below, Table 1 illustrates these projections.

Table 1. LEDs Price and Performance Projections

Metric	Unit	2009	2010	2012	2015
LED Efficacy (2580-3710K, 80-90 CRI)	lm/W	70	88	128	184
LED Price (2580-3710K; 35 A/cm2)	$/klm	36	25	11	3
LED Efficacy (4746-7040K, 70-80 CRI)	lm/W	113	134	173	215
LED Price (4746-7040K; 35 A/cm2)	$/klm	25	13	6	2
OEM Lamp Price	$/klm	130	101	61	28

Source: US DOE.

In the market place, the efficacy and cost projections of white LEDs, and are slowly being realized. The breakeven time associated with replacement of a current light source by a LED-based source is a function of how long the lamp operates each day, the upfront cost of the replacement light source, and the cost of the replaced lamp and/or lamp/fixture combination for that particular application. From these perspectives, the LED technology for white light has surpassed the efficacy of the incandescent lamp, but still has a much higher up front cost. The chart below illustrates the relative costs of LEDs currently in the US market.

[18] Note that in applications like area lighting, a direct comparison of LEDs with conventional sources using metrics such as total lumens or lumens/Watt, may not be valid. Rather, the luminaires must be compared based on parametric test results or actual measured performance, taking distribution, uniformity, and other performance characteristics into account.

Table 2. Relative Costs of Directional Lighting

Survey of LED Directional Lamps:

Retail & Online, May 2010, USA (manufacturer data)

light source *	range of values	input power (W)	total light output (lumens)	calculated efficiency (lm/W)	average rated life (hours)	warranty (years)	price (USD)	calculated USD per kilolumen
all types	low	1	35	7	1500	1	$2.73	$4
	high	300	2480	54	50000	20	$80.81	$425
I	low	25	180	7	1500	1	$2.73	$4
	high	300	2480	19	3000	2	$16.27	$19
HI	low	20	490	10	1500	1	$3.32	$6
	high	100	1310	16	12000	4	$15.59	$16
CF	low	5	420	36	2000	1	$30.14	$6
	high	26	1250	54	25000	9	$4.27	$42
LED	low	1	35	25	12000	3	$14.88	$76
	high	16	850	54	50000	20	$80.81	$425

Source: LED Consulting, 2010, Reported in ECEEE.

It is important to note that many comparisons of this type tend to be a simplification. The analysis does not include installation costs of lighting systems, nor are maintenance costs of the incandescent and LEDs systems taken into account. For example, maintenance for a LED system can be virtually non-existent when compared to maintenance for an incandescent system, so that LED lifecycle savings may be larger.

There are also simplifications that make some LED predictions not so favorable. The efficacy of a LED is dependent on the whole system, consisting of the LED chip, the packaging – including the design of the LED package and the heat sink, its power supply and "driver." These components have their own efficiency values and power requirements that are not yet standard in the industry and therefore cannot be predicted.[19]

With regards to LED-based lighting and fixtures, the trend for their penetration is less certain, because it is be more application specific. In the case of CFL and other fixtures with high-efficiency sources, these have made more inroads in the commercial and

[19] While it is reasonable to assume that the semiconductor efficiencies of LEDs will continue to increase rapidly, other components such as heat sinks, optics, solders, may not be able to match LEDs' spectacular gains due to their technological limits.

industrial markets since their introduction in the 1980s, where energy savings and low maintenance characteristics are much more important than others factors, such as first cost or usability (more important in the residential market). This is especially true now in the case of street/outdoor lighting with LED fixtures. Many initiatives have been announced or initiated where LEDs are replacing conventional HID (high intensity discharge) sources.

The insight from the development of fluorescent sources that can be applied to LED lighting products, especially for general and consumer applications is that individual consumers are more particular about product costs and performance. However, other factors such as ease of installation, simplicity, and design, may also play a large part in transforming the market for LED fixtures. The differences in the commercial and residential market preferences, and past penetration patterns of high-efficiency fixtures are pointing towards the fact that LEDs-based luminaires may experience the same path – that of higher penetration in commercial and industrial applications.

5. MEASURING AND REPORTING LEDS PERFORMANCE

LEDs represent a lighting technology fundamentally different than that of the incandescent light bulb or fluorescent light. Measuring LEDs and reporting LED output for use in place of traditional lighting sources actually represents a significant challenge for a number of reasons, briefly summarized here, along with more in depth discussions of LED life and color measurement challenges.

Similar challenges to LED measurement and reporting exist in the classification and application of LED-based lighting products. There are two basic ways lighting is used: *Luminance* applications, where we look directly at the light source, such as in a traffic signal, and *illuminance* applications where light sources are used for illumination, such as in an overhead lamp. In the case of illuminance, a person only sees the light that is reflected from the object—while the object also absorbs some of the light. These are two fundamentally different situations, and each has a corresponding set of measurement methods, tools, and vocabulary that existed before LED-based lighting was a reality.

Directionality

Many traditional light sources (such as incandescent lamps) emit light in all directions. A functional, LED-based package contains a UHB LED chip encased in epoxy with a heat sink, metallic leads, and a light reflector – collectively referred to as "the package." These packages tend to be flat, are typically mounted on a heat sink or substrate, and as a result, the light is emitted hemispherically, rather than spherically. For task lighting and other directional applications, this reduces wasted light. But it remains a challenge for manufacturers to create a device that can compare favorably with the incandescent lamp in terms of light distribution and consistency.

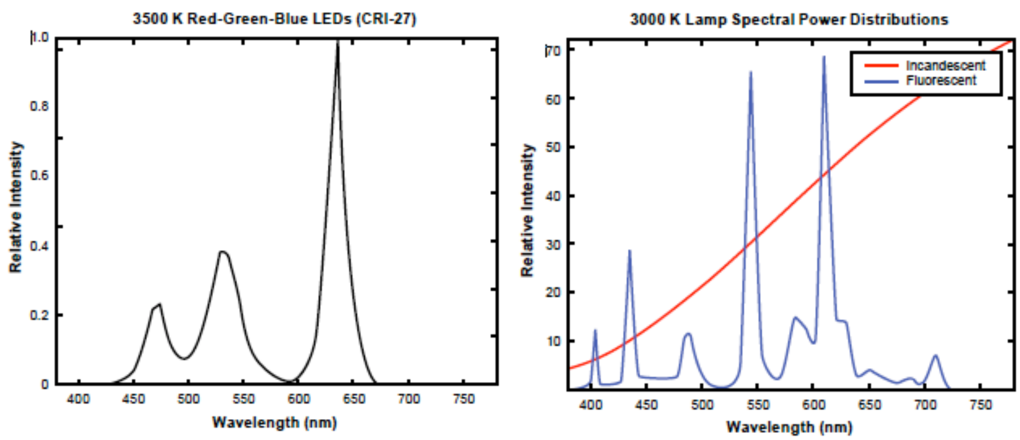
Figure 2. Philips's LED-based A Lamp Incandescent Replacement ("L-Prize" Entry)

Source: My Ton

Light Source Comparison

A variety of color mixing techniques are used to create "white light" LEDs, including packaging UV or blue colored LED with a phosphor, or using complementary colored LEDs that overlap to produce white. Depending on the technique used, the resulting light may appear white, but can have a very different spectrum than traditional sources, especially incandescent lamps. This makes it difficult to directly compare the characteristics of light from a LED source to a traditional source, or even to another LED source. The spectral distribution of a RGB LED is illustrated below, along with the spectral distribution of typical incandescent and fluorescent lamps for comparison.

Figure 3. Examples of RGB LED, Incandescent and Fluorescent Spectral Distributions.



Source: TBD

Color Characteristics (Light Quality)

Lighting designers as well as other evaluators and specifiers of white light are familiar with two descriptors of light quality: *correlated color temperature*, and *color rendering*. Unfortunately, these metrics only work well for measuring color characteristics of conventional light sources, but not entirely useful for LEDs, for reasons described below.

What appears to our eyes as "white" is actually a mix of different wavelengths in the visible portion of the electromagnetic spectrum. Incandescent, fluorescent, and high-intensity discharge (HID) lamps radiate across the visible spectrum, but with varying intensity in the different wavelengths. The spectral power distribution (SPD) for a given light source shows the relative radiant power emitted by the light source at each wavelength. Incandescent sources have a continuous SPD, but relative power is low in the blue and green regions. (See examples above). The typically "warm" color appearance of incandescent lamps is due to the relatively high emissions in the orange and red regions of the spectrum.

Unlike incandescent, fluorescent and other "conventional" sources, LEDs are monochromatic. An individual LED chip emits light in a specific wavelength. This is the main reason why LEDs are so efficient for colored light applications. In traffic lights, for example, the use of colored filters or lenses is actually a very inefficient way to achieve colored light: a red filter on an incandescent lamp can block 90 percent of the visible light from the lamp. This is why LEDs have largely supplanted the incandescent with colored filter systems, but not for general lighting applications.

The CRI scale is the metric that has been used to describe the light "quality" of fluorescent and HID lamps for over 40 years. CRI indicates how well light sources render the colors of objects, materials, and skin tones, and is a quantitative "score" of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source. The CRI procedure involves comparing the appearance of a minimum of eight color samples as seen under the light source being tested and a reference light source. The average differences measured are subtracted from 100 to get the CRI. So small average differences will result in a higher score, while larger differences give a lower number.[20] Therefore, light sources that mimic incandescent light or daylight for the eight color samples are, by definition, the ones that will score highest on the CRI.

For LEDs, this measure is not especially relevant because LEDs have very narrow bandwidth emissions, highly dissimilar to the intent of the metric. There are situations with LEDs where the white light generated by commercial RGB LED clusters can be visually appealing, yet the clusters themselves have relatively low CRI values.[21] Because of this, the International Commission on Illumination (CIE) recently recommended that CRI should not be used with white light LEDs.

A new metric to accommodate LEDs and other light sources, tentatively called CQS – the color quality scale, is under development. In the mean time, the US Department of Energy and other organizations involved in LEDs measurements and standards recommend that CRI can be considered as one data point in evaluating white LED products and systems, and it should not be used to make product selections in the absence of in-person and on-site evaluations. Further, CRI may be compared only for light sources of equal CCT.[22]

Correlated color temperature (CCT) – is another metric being challenged by LED-based light sources. CCT describes the relative warmth or coolness in degrees of a light source when it is compared to an incandescing object, such as the sun, or a heated filament. Since LED "white" light can be a combination of several LED light sources, or monochromatic light source and phosphor combination, it is difficult to accurately ascribe CCT.

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[20] If the lamp to be tested has a correlated color temperature (CCT) of less than 5000 Kelvin (K), the reference source is a black body radiator (approximately like an incandescent lamp). For higher CCT sources, the reference is a specifically defined spectrum of daylight.

[21] Similarly, neodymium incandescent lamps (sold under brand names including GE Reveal®, Philips Natural Light, and Sylvania DaylightTM) have low CRIs, but objects illuminated with them appear brighter and livelier when compared with unfiltered incandescent lamps.

[22] This recommendation applies to all light sources, not only to LEDs, as differences in CRI values of less than five points are not significant, e.g., light sources with 80 and 84 CRI are essentially the same.

The most efficient white LEDs at this time emit light of 4500K to 6500K correlated color temperature (CCT). This makes them white to bluish-white in appearance. Some LED luminaire and lamp manufacturers mix LEDs of various color temperatures to reach a target CCT for the array or luminaire, balancing the highest efficacy sources with warmer LEDs, which are less efficient. Color rendering varies according to the make, model, and CCT of the LEDs, but generally is better than high pressure sodium (HPS – usually around 22 CRI) and standard metal halide (MH – around 65 CRI), but somewhat lower than ceramic metal halide (CMH – 80 to 90 CRI). The nominal CRI for neutral (4000K to 4500K) and cool white (5000K or higher) LEDs is typically 70 to 75. In most street and area lighting applications, CRIs of 50 or higher are adequate for gross identification of color.

There are many debates and theories regarding vision and color. Until the advent of a universal, simple way to describe light and color appearance, comparing LEDs to other existing light sources remains a very difficult challenge.

Efficiency

Traditionally, lighting energy efficiency is characterized in terms of lamp ratings and fixture efficiency.

The lamp rating indicates how much light (in lumens) the lamp will produce when it is operated at standard operating conditions (typically at 25 degrees C – room temperature). The luminous efficacy of a light source is then given as the rated lamp lumens divided by the nominal wattage of the lamp, expressed as lumens per watt (lm/w). This is the unit that most lighting users and technical experts are accustomed to using for comparing the relative efficacy of light sources for illumination.

Fixture (or luminaire) efficiency is a function of both the light source (the light “bulb” or lamp) and the fixture, including necessary controls, power supplies and other electronics/ballast, and optical elements. The complete unit is known as a luminaire. The fixture efficiency indicates the proportion of rated lamp lumens actually emitted by the fixture, expressed as a percentage. Fixture efficiency is an appropriate measure for fixtures that have interchangeable lamps for which reliable lamp lumen ratings are available.

However, the lamp rating and fixture efficiency measures have limited usefulness for LED lighting at the present time. This is because the luminaire design and the manner in which the LEDs are integrated into the luminaire have a material impact on the performance of the LEDs inside the luminaire.

Thus, depending on what is under consideration, the resulting efficacies can vary. In addition, most LED lighting systems are composed of many discrete components, therefore the losses in these components also need to be measured accurately in order to calculate overall efficacy, not just of the LED chips. The specific points of potential energy waste in an LED system can include:

- Materials losses: Defects in the crystal structure of the LED chip can lower the light output.

- Internal losses: Some photons cannot escape from the LED chip; they convert back to heat energy.

- Thermal losses: As the temperature at the p-n junction internal to the LED chip rises, its light output declines.

- Encapsulant and optical element losses: The materials in sealants, optical layers and lenses must be carefully matched to the spectrum of the chip to allow as much light as possible to pass through these layers. If phosphors are added, they must also be "tuned" to maximize the light emission.

- Solder or other contact losses: Poorly soldered or bonded components resist the flow of electricity, and convert it to heat energy, compounding any thermal issues in the device.

- Controllers, drivers, transformers and other power supply component losses: Each of these devices can have its own power demand, and contribute to the system efficiency.

- Luminaire: The LEDs are usually integrated with one or more conventional luminaire components, such as reflectors, housing, or lenses, each of which has loss potentials.

Reliability
LED chips have a significant advantage over other sources in reliability. Traditional light sources with filaments and electrodes will burn out sooner if switched on and off frequently. In incandescent lamps, the tungsten filament degrades with each hour of operation, with the final break (causing the lamp to "burn out") usually occurring as the lamp is switched on and the electric current rushes through the weakened filament. In fluorescent and HID lamps, the high starting voltage erodes the emitter material coating the electrodes to the point of failure. LED life and lumen maintenance is unaffected by rapid cycling. However, the electronics, or "drivers" must be designed to take advantage of this characteristic, and need to be considered as part of LED performance and quality metric – see the discussion of rated life, below.

Life
One of the most remarkable qualities of the LED technology is that it has a long rated life – up to 50,000 hours or more, compared to about 40,000 hours for the best linear fluorescent lamps.[23] Another quality of note is that LED chips do not burn out in the same

[23] In general, the life of a conventional lamp is defined and published by the ANSI/IES and IEC/CIE to be the time at which 50% of the test lamp population burned out. The use pattern that lamps are subjected to depends on the typed of lamp being tested. For example, incandescent lamps are required to operate

way that conventional sources do. Instead, their lumen output decreases over time, although other components can suffer catastrophic failure, which can lead to the LED chips becoming non-functional. Conventional lamps also have some light output depreciation over the course of their life, which varies according to the types of lamp (Table 3, below). These percentages are not taken into account when lamps are rated for longevity. Depending on the application, the lamp may require retirement before the end of its life because of decreased light output.

Table 3. Rated Life and Lumen Output for Various Light Sources[24]

Light Source	Rated Life (hours)	Lumen Maintenance @50% rated life	Lumen Maintenance @ 100% rated life
Incandescent	1,000	90%	78%
Tungsten-halogen	2,000	97%	93%
Metal Halide	15,000	80%	65%
Fluorescent (med load)	20,000	85%	75%
High Pressure Sodium	24,000	90%	72%
Mercury Vapor	24,000	75%	65%

The rate of degradation of the LEDs happens based on a number of factors. These factors include: the quality of the LED chip, the design of the LED package, and the design of the LED system. The most important factors here are heat dissipation within the LED, and the long-term performance of the associated electronics, or "drivers". A quality chip without appropriate heat removal, for example, is going to degrade much faster than a properly driven, properly cooled LED chip. Similarly, a quality chip associated with a short-lived or low quality driver also will not perform well over the long run. Further, life testing for LEDs is impractical due to the long expected lifetimes, and the current rapid pace of development. Even with 24/7 operation, testing an LED product for 50,000 hours would take 5.7 years. Furthermore, products under testing would be obsolete by the time they finished life testing due to the fact that technology continues to develop and evolve.

A life testing procedure for LEDs has been proposed by the Illuminating Engineering Society of North America (IESNA) based on the idea of "useful life," or the point in time at which the device's light output has declined to a level that longer meet the needs of the application. For example, for general ambient lighting, the level might be set at 70% of initial lumen output. Useful life would be stated as the average number of hours that the LEDs would operate before depreciating to 70% of initial lumens. The leading HB LED manufacturers have begun using the L70 language, stating that their white LEDs "are projected" to have lumen maintenance of greater than 70% on average after 50,000 hours when used in accordance with published guidelines.

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continuously at their specified voltage until they burn out, whereas fluorescent lamps are operated under controlled conditions cycling 3 hours on and then 10 minutes off until they burn out.

[24] Data adapted from the IESNA Lighting Handbook: Reference and Application, 9th edition (2000) by the authors in the publication: N. Narendran, J.D. Bullough, N. Maliyagoda, and A. Bierman, "What is the Useful Life for White Light LEDs?," Rensselaer Polytechnic Institute, Troy, NY, 2001. Abstract available at http://www.lrc.rpi.edu/solidstate/SSLPublications.asp.

Controls for LEDs

Unlike incandescent lamps, which are universally dimmable with inexpensive controls, fluorescent and HID sources present a number of challenges in this regard. In general lighting applications, only CFLs with a dimming ballast may be operated on a dimming circuit; and HID sources require specialized electronic ballasts for any degree of dimming. Dimming ballasts for commercial (specification)-grade fluorescent systems is readily available and effective, although at a substantial price premium. Further, all of these sources usually do not perform well over a wide (1% to 100% light output) dimming range like incandescent lamps.

LEDs themselves have advantage over fluorescent and HID sources in that they can be dimmed over a wide range. However, the challenges to dimming LED-based devices are in the electronics, or "drivers." Like in the case of fluorescent and HID commercial applications, LED-based dimming systems can be available and effective at a cost. In the case of general lighting, LEDs face a similar challenge to dimmable CFLs – they need to be compatible with a wide range of dimmers currently in use. It can be difficult for manufacturers to adequately test the compatibility of their products with the variety and technologies used in dimming incandescent lamps (including halogen).

Eye Safety

The vast majority of LEDs are completely safe and do not represent any hazard to the human eye. However, as the radiant output power of individual LED chips and multi-chip LED arrays continues to increase, there is also growing concern over the increased potential risk of eye damage. High-powered LEDs can cause a thermal heating effect in proportion to the power density of the radiation, which can result in tissue damage to the retina, similar to exposure to laser sources. Shorter wavelength radiation emitted by some LEDs can cause a photochemical effect in the retina, changing the chemistry of the cells, and UV at shorter wavelengths can cause damage to the cornea and/or the lens.

One ongoing issue with LED safety is the problem of whether to classify an LED as a laser or a lamp – both have merits and both present problems, depending on how the LEDs are arranged and used. Lasers and LEDs can cause a thermal heating effect in proportion to the power density of the radiation. At shorter wavelengths below 400 nm, UV light is largely absorbed by, and can cause damage to, the cornea and/or the lens.

6. NEAR-TERM OPPORTUNITIES FOR LED LIGHTING

It will be only a matter of time before LED-based lighting will be one of the mainstays in the residential, commercial, and industrial markets. In the near term (one to three years), LED-based lighting products will first see specific application in the commercial and industrial arenas before finding their way into more mainstream and residential applications. Even with the recent pace of product development, Asia's residential market will not see large adoption of LED products within this near-term timeframe (other than for the novelty factor) due the combination of first cost and availability of quality products. The exception may be in the off-grid (DC) lighting market, where investments are being made to replace kerosene and other inefficient and polluting light sources in rural Asia.[25]

Non-Residential/Non-General Lighting Opportunities

Areas where LED-based lighting products will likely to make a significant impact in the near-term are: outdoors and roadway lighting, transportation-related functions, and architectural application, based on current costs and energy savings potentials.[26] ECO-Asia's review of the majority of available data on actual, documented cases regarding installation of LEDs in comparable applications that can be verified with performance test data, shows that:

- LEDs are generally yet not cost-effective in indoor, general/ambient applications, especially in retrofit cases.
- LEDs are most cost-effective in situations where they are displacing a traditional light source in an application with high duty-cycle, in a new-build situation – these include new area, parking, or new street and outdoor lighting installations, as well as decorative and signage lighting.
- Available performance and cost data show that LEDs are not yet ready to displace the best fluorescent applications – the linear fluorescent T8 or T5 lamps for general lighting.[27]
- Available "best in class" LEDs are now comparable to incandescent and halogen in some applications, but LEDs have yet to surpass CFLs in cost-effectiveness for general lighting situations, especially in most residential applications.[28]

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[25] See, for example "'Lighting for All' Scheme to Bring Clean Energy to 50 Million Asians" Asian Development Bank (ADB) and The Energy and Resource Institute (TERI) press release, 29 October 2010, New Delhi, India. Also Lighting Africa at: www.lightingafrica.org.

[26] Note that architectural applications are likely to be new application areas and not replacement or refurbishment of existing uses.

[27] http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lightfair7_mccullough-caliper2.pdf

[28] The latest round of US DOE CALIPER testing of LEDs replacement for IR reflector halogen applications shows that LEDs do not deliver similar center beam candlepower (CBCP) yet.

LEDs will continue to make additional impacts in areas such as traffic signals and signage. These areas are briefly elaborated further below. However, it is important to note that LED products have the potential to be "disruptive" and may find other niches that are not in these broadly outlined categories. This is because these products are entering the market at different entry points, and may or may not be limited to their traditional distribution channel for their product categories and applications.

Traffic Signals

LED traffic signals offer a huge potential for energy savings and maintenance efforts over incandescent lamps. Traffic signal retrofits take advantage of the colored nature of the LED light by replacing the incandescent lamp and colored filter combination. The luminous efficacy of the LED system far exceeds that of incandescent lamps in this application. LED traffic signals save between 80% and 90% of the electricity of conventional incandescent signals. As a result, there have been many success stories from incandescent to LED conversions by energy conscious agencies and municipalities around the region. At this time, many of the traffic signals in large cities have been converted. For example, Singapore has replaced all of its incandescent traffic light with LEDs in an initiative that began in the 1990s. However, the proportion of overall traffic signals replaced is believed to be small, and the efforts have not reached many second and third-tier cities.[29]

LEDs traffic signals also hold a significant maintenance advantage over existing incandescent systems. They can last 5 to 10 times longer than conventional signals (up to 50,000 hours), and therefore pose little or no maintenance requirements. This means reduced safety risk for the work crews as well as reduced maintenance costs incurred by the municipality, city, or agency responsible for the operation and maintenance of the signal. In addition, where installed, battery backup systems for important intersections can illuminate LED signals for much longer periods of time than they can illuminate incandescent signals in the event of a power outage.[30]

Currently, the most significant barrier to LED traffic signals' market penetration is their initial cost, which is considerably more than incandescent traffic signals. An incandescent traffic signal lamp costs on average, about US $2 to US $2.50, excluding reflector and

[29] The Clinton Climate Initiative is working to reduce climate impacts in the world's top 40 cities, and includes LEDs promotion.

[30] To illustrate, a 68-light intersection (4 lanes) with incandescent signal lamps consumes about 6.8 kilowatts, while the same intersection, configured with LED signals, consumes a tenth of that amount, or 680 watts. This has the potential to lengthen battery run time by a factor of ten, moving a system from being able to run 15 minutes to a system that would be able to run for over 2 hours. Other advantages of such low power consumption include the ability to reduce system and back-up battery size, thereby decreasing purchase and/or maintenance or battery replacement costs as well.

cover. LED traffic signal modules costs vary, but they can cost about many times more than the incandescent unit. For example, a red LED signal can range from US $50 to US $100, and a green LED module may cost twice as much.

Exit Signs

Exit signs found in some commercial buildings still use incandescent lamps, and each sign can consumes about 30 to 35 kWh annually. LED-based exit signs currently use about one-tenth of the energy required by incandescent lamps, about half as much as fluorescent ones, and can last much longer than both. The luminous efficacy of the LED system far exceeds that of incandescent lamps (and CFLs) in these types of applications. Like traffic lights, new and retrofit exit signs also take advantage of the colored nature of the LED light, replacing the need for incandescent lamps or CFL and colored filters, and can save between 80% and 90% of the electricity of conventional incandescent exit signs, and about 50% of CFL-based signs.

Because of their energy saving potential, LED exit signs were the focus of a number of utility programs in the US, and are now well established in the market. The introduction of the US EPA/DOE ENERGY STAR® Exit Sign program in 1996 further enhanced the market acceptance of LED exit signs in the US, and established a set of performance specification for these products that can be adapted for Asia. In the US, the Energy Policy Act of 2007 requires that all new exit signs meet the ENERGY STAR requirements.

Transportation

Shipping and aviation facilities rely on colored light sources as guidance signals. Conventional installations rely solely on incandescent lamps. These incandescent lamps have varied lifetimes, ranging from 2,000 hours up to 8,000 hours. Due to their locations and applications, the use of incandescent lamps can be a major maintenance burden. In addition, since these incandescent lamps are filtered to achieve particular colors suitable for aviation, shipping, and roadway needs, most of the input power is wasted.
There are hundreds of airports as well as ports and shipping facilities in operation in Asia, with many more under development or being upgraded that require markers, numbers, signs, and other high duty-cycle lighting tasks related to transportation indicators.[31] The wholesale replacement of incandescent transportation-related lighting with more energy efficient and longer lasting LED units can result in significant energy and maintenance savings for shipping and aviation facilities, most of which are struggling to meet the rapidly growing transportation demands of this region. Table 4 presents possible savings in these applications.

[31] "Asia Pacific region to develop 350 new airports over a decade, with more than USD100 billion in investments." Frost & Sullivan, Jakarta, Indonesia, 12 Nov 2010.

Table 4. Typical Intersection and Airport Lighting Use

	Traffic Signal Per Intersection			Aviation Per Airport - One Runway			
Lamp Location	**Ball**	**Turn**	**Pedestrian**	**Approach**	**Touchdown**	**Centerline**	**Edge**
# Lamps Required	24	2	8	96	180	120	70
Incan. Watts/Lamp	150	125	125	375	60	120	120
Subtotal (Watts)	3,600	250	1,000	36,000	10,800	14,400	8,400
LED Watts/Lamp	15	10	15	56	9	18	18
Subtotal (Watts)	360	20	120	5,400	1,620	2,160	1,260
Savings (Watts)	***3,240***	***230***	***880***	***30,600***	***9,180***	***12,240***	***7,140***
Total Savings (Watts)			**4,350**				**59,160**

Source: Ecos Consulting, 2005.

Commercial Signage and Architectural Building Decoration

Many signs are on 24 hours per day, and most typical architectural decorative lighting tends to be on at dusk and remain lit past midnight – Shanghai, China is a typical example of this new mode of operation. A variety of LED products are now available for new or retrofit commercial signage and architectural lighting that could further reduce the electrical load, even for neon and fluorescent signs, especially during peak hours. These include the following:

- *Color Wash floodlighting* for variable color on interior and exterior walls in entertainment venues, and other high profile building facades.
- *Channel Lettering replacement* products from a variety of manufacturers.
- *Replacement Neon* polycarbonate tubing puts LEDs into a package that looks like a neon tube typically used for architectural neon accents on buildings and in entertainment venues.

Retail Food and Beverage Refrigeration Case Lighting

Another retail area where LED lighting has the potential to excel is in refrigerated coolers and freezers of grocery markets. Currently, this market segment is dominated by fluorescent lighting. LEDs have inherent characteristics that are much more suitable for this particular application. They are more efficient at directional illumination, not adversely affected by cold temperatures, and may not require as much space. Other LED advantages include lower maintenance and imperviousness to frequent switching, and they can be "tuned" to highlight particular colors in the products on display. In addition, LEDs can also reduce the amount of heat introduced into the display space when compared to fluorescents, yielding secondary savings at the compressor level.

A number of well known manufacturers, as well as newly established LED manufacturers have introduced refrigerated case products in the past year, with test and full-scale installations taken place in the US and elsewhere, including China.[32] However, fluorescent manufacturers are aggressively moving to keep their dominance in this market – several manufacturers have introduced cold-cathode fluorescent (same technology used in displays and LCDs) illumination systems for coolers, as well as more efficient systems based on T-5 fluorescent lamps. While these new fluorescent systems may promise incremental energy savings, LEDs can still offer important advantages over many of them, including lower maintenance and lower possibility of in-case lamp breakage.

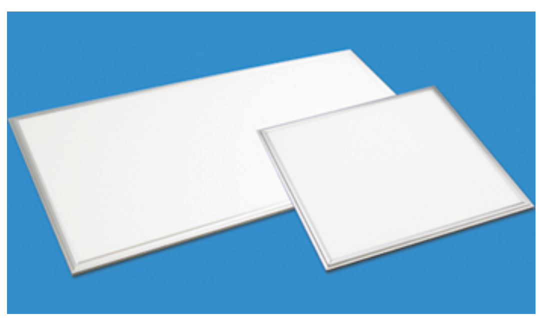
Area Lighting

The area where LED-based lighting has gained the most attention and traction in the shortest length of time is area lighting – both indoor and outdoor public spaces, and parking lots, as well as street lighting.

With respect to indoor lighting, the distinction needs to be made between a retrofit device (such as an LED-based lamp made to fit into an existing incandescent socket, or a LED tube lamp made to replace T8 linear fluorescent tubes), of which there are many, and not all of them well executed, versus a new lighting fixture designed from the start to take full advantage of LEDs characteristics such as directionality and controllable or "tunable" light characteristics.[33] Manufacturers have been introducing a number of innovative systems to effectively and efficiently light areas with LEDs. Examples of these systems include the Cree LR24, and the MaxLite Flat LED panel, shown in figures X below. Products of this type are slowly gaining awareness in the US and Europe architectural circles and may be cost effective in new facilities.

Figure 4. LEDs for Area Lighting

Cree LR24 (Source: Cree)



MaxLite LED Panel (Source: MaxLite)

With respect to outdoor lighting, LED-based products have made significant progress in establishing themselves as credible alternatives to HID, induction, fluorescent and other traditional street and outdoor light sources in terms of performance and design. Cities and

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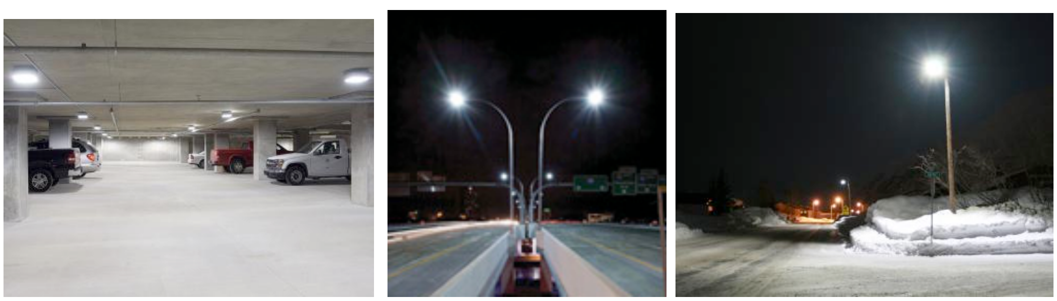
[32] For example, "Wal–Mart Uses GE LED Refrigerated Display Lighting to Save Green" GE press release, Cleveland, OH, USA. Accessced on 18 Nov 2010.
[33] An example of this would be a LED-based reflector lamp versus a lighting system such CREE's LR6 downlighting fixture.

municipalities around the world from Europe to Asia are racing to test and install LED street and public lighting.

LED-based street and area lights have many advantages over conventional sources. The most important is that they are not a point-source like high-pressure sodium or metal halide, and therefore the available luminous flux, or total amount of light, can be more evenly distributed and controlled. This characteristic allow designers to aim individual LEDs in the light fixture for optimal distribution and precise cut-off, allowing them to achieve the performance of HPS or MH with a smaller lumen package, thereby reducing energy consumption in the process.[34]

This is one category that has also seen the most innovation and adoption so far. Furthermore, it has yielded a number of valuable lessons and cautionary tales for the early adopters. In the US, a number of high-profile test installations jointly conducted by the US DOE and various partners have helped to compile significant performance and cost data on a range of products.[35] US DOE's test installation reports – called GATEWAY Demonstrations – can be found at their website, as are full parametric laboratory test results of products used in these demonstrations.[36]

Figure 5. Installations of Indoor and Outdoor LEDs Lighting Demonstrations in the US.



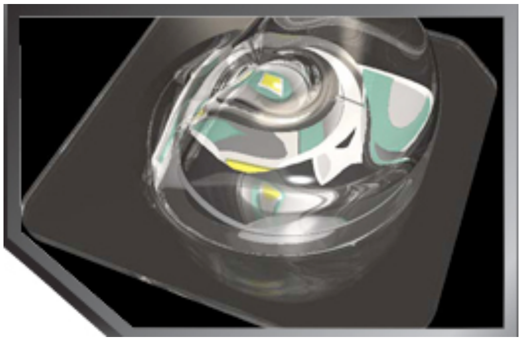
Source: US DOE and Cree.

Figures 6 and 7 below, illustrate how one manufacturer has taken advantage of LEDs' unique characteristics in their design process and applied them towards street and area lighting. Figure 6 shows the actual LED module with a reflector and lens system that can use to precisely direct the light output of individual LEDs. Figure 7 shows the array of these LED modules installed in a "bar" that can be used in a modular basis. In this design, a number of light bars can be combined to reach the total lumens as well as the distribution pattern desired for a particular luminaire or application.

[34] Note that in applications like area lighting, a direct comparison of LEDs with conventional sources using metrics such as total lumens or lumens/Watt, may not be valid. Rather, the luminaires must be compared based on parametric test results or actual measured performance, taking distribution, uniformity, and other performance characteristics into account.
[35] For example, see: http://blog.mlive.com/grpress/2008/08/led_lights_fail_to_illuminate.html; or, http://www.punchng.com/Articl.aspx?theartic=Art201011250185978

[36] http://www1.eere.energy.gov/buildings/ssl/gatewaydemos.html

Figure 6. LED Lens & Reflector System



Source: BetaLED, Inc.

Figure 7. A Modular LED "bar"

7. LED STANDARDS DEVELOPMENT OPTIONS FOR ASIA

As discussed earlier, the facts that LEDs are a fundamentally different new light source, and the characteristics of LEDs may not be adequately described by current metrics, combine to pose a challenge to those who must set standards for this new technology. In addition, the fact that the standard setting process can be slow, while industry progress is advancing at breakneck pace, and the challenge compounds: by the time a particular standard can be developed for LEDs, the technological advances may have rendered some performance parameters inadequate. Thus, the standard development process for LEDs may need to be designed so that it can handle more product diversity and innovation, as well as accounting for uncertainties in the pace of development.

The ECO-Asia team conducted a survey on technical standards, national regulations, testing and labeling requirements, and other performance and quality requirements that address LEDs available for sale in Asia. While this report broadly applies to the Asia region, the data presented focus primarily on China, India, and four countries holding membership in the Association of Southeast Asian Nations (ASEAN) - Indonesia, Philippines, Thailand, and Vietnam. Together, these six nations account for 96 percent of the gross domestic product (GDP) of Asia's developing economies as well as a significant share of the regional LEDs market. The results are summarized below in Table 5. Additional details regarding specific standards and categories are further discussed in this section and summarized in Appendix B.

Table 5. Overview of Standards Activities in Asia

Country/Region	LEDs Std Activities?	Specific Application Category Under Development	Responsible/Lead Organization
Brunei	None	None	Energy Division of PM Office
China	Task Teams formed	Street, devices, lamps	CNIS, others
Hong Kong	Task Team formed	None	EMSD
India	Task Team formed	Street lighting, off grid	BIS
Indonesia	Testing standards being developed	LEDs for solar homes	DGE&EU, NSI
Japan	A number of standards have been published	See Appendix B	JELMA, JIS
Malaysia	Under consideration	Not yet decided	Standards Malaysia
NZ	Yes, Task Team formed	Street lighting	EECA
Philippines	2010 Designated for LED standards	Modules/General Safety	BPS
Taipei	A number of standards have been published.	See Appendix B	BSMI
Thailand	Under development	LED modules	TISI
Vietnam	No	NA	VSQI

With respect to LEDs standards development globally, there are a number of efforts underway to help define LEDs. Most notable are the efforts by in Europe by EC EU

Ecodesign initiative and the US Department of Energy's Solid-State Lighting Commercialization Support, based on its five-year plan to accelerate adoption of energy efficient lighting. US DOE's effort has assisted in the development or coordination of a number of LEDs-related standards, which also form the basis for other standards being developed in the region:

- ANSI C78.377-2008, Specifications for the Chromaticity of Solid-State Lighting Products: Specifies recommended chromaticity (color) ranges for white LEDs with various correlated color temperatures (CCTs).

- IES LM-79-2008, Approved Method for the Electrical and Photometric Testing of Solid-State Lighting Devices: Specifies a standard test method for measuring the photometric properties of SSL devices, allowing calculation of luminaire efficacy.

- IES LM-80-2008, Approved Method for Measuring Lumen Depreciation of LED Light Sources: Specifies a standard method for measuring the lumen depreciation of LEDs, allowing calculation of LED lifetime.

- IES RP-16 Addenda a and b, Nomenclature and Definitions for Illuminating Engineering: Provides industry-standard definitions for terminology related to solid-state lighting.

- IES G-2, Guideline for the Application of General Illumination ("White") Light-Emitting Diode (LED) Technologies: Provides lighting and design professionals with a general understanding of LED technology as it pertains to interior and exterior illumination, as well as useful design and application guidance for effective use of LEDs.

- NEMA LSD 45-2009, Recommendations for Solid-State Lighting Sub-Assembly Interfaces for Luminaires: Provides guidance on the design and construction of interconnects (sockets) for solid-state lighting applications.

- NEMA LSD 49-2010, Solid-State Lighting for Incandescent Replacement—Best Practices for Dimming: Provides recommendations for the dimming and design of screw-based incandescent replacement solid-state lighting products.

- NEMA SSL 3-2010, High-Power White LED Binning for General Illumination: Provides a consistent format for categorizing (binning) color varieties of LEDs during their production and integration into lighting products.

- UL 8750, Safety Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products: Specifies the minimum safety requirements for SSL components, including LEDs and LED arrays, power supplies, and control circuitry.

In addition to the European and North American standards covered above, there are also a number of safety standard that are applicable to LEDs. These include:

- IEC 60825-1, Safety of laser products - Part 1: Equipment classification and requirements. This standard was developed by the International Electrotechnical Commission and has been adopted in Europe as EN 60825-1. This standard is commonly known as the Laser Safety Standard but also covers LEDs, and treats them as lasers. Note that LED products sold in the EU must be tested according to 60825-1.

- EU General Product Safety Directive. This directive requires that all consumer products for sale in the EU should be safe. The Directive does not reference 60825-1 but manufacturers have used use this standard to help define "safe." It is important to note that different EU member countries have various guidelines (rather than directives) covering laser and LEDs: no laser or LED pointer can be above Class 2, and that all LEDs in children's toys must be Class 1.

Japan has also developed a number of LEDs-related standards, including the following:

- TS C0038 – (Pub.2004-11-20)(Expire 2011-05-19) – Photobiological safety of lamps and lamp systems;

- JIS C8121-2-2 (Pub. 2009-03-20) – Miscellaneous lampholders Part 2-2: Particular requirements – Connectors for printed circuit board based LED-modules;

- JIS C8152 – (Pub. 2007-07-20) – Measuring methods of white light emitting diode for general lighting;

- JEL 311 – (Pub. 2006-03-22) – General Rules for Photometric Method of White LED Lighting;

- JIS C 8153 – (Pub. 2009-03-20) – DC or AC supplied electronic control gear for LED modules – Performance requirements;

- JIS C8147-2-13 – (Pub. 2008-10-20) – Lamp controlgear – Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules;

- JIS C8154 – (Pub. 2009-03-20) – LED modules for general lighting – Safety specifications;

- JIS C8155 – (Plan 2010) – LED module for general lighting service – Performance requirements;

- TS C 8153 – (Pub. 2007-07-20; Expire 2010-07-19) - White light emitting diode devices for general lighting – Performance specifications;

- JIS C 8156 – (Plan 2010) – Self-ballasted LED – lamps for general lighting services by voltage >50V – Safety specifications;

- JIS C 8157 – (Plan 2011) – Self-ballasted LED lamps for general lighting services – Performance requirements.

Taiwan (Chinese Taipei) already published several LED device/product standards. These are listed below:

- CNS15233: Fixtures of roadway lighting with light emitting diode lamps – outdoor;

- CNS15247: Test methods on light emitting diode components and modules (for general lighting service) for normal life -- other;

- CNS15248: Methods of measurement on light emitting diode components for thermal resistance – other;

- CNS15249: Methods of measurement on light emitting diode components for optical and electrical characteristics – other

- CNS15250: Methods of measurement on light emitting diode modules for optical and electrical characteristics – other.

8. SUMMARY AND RECOMMENDATIONS

It is important to note that LEDs will not displace all other light sources. Rather, it will be one of the mainstays of energy efficient lighting. The versatility of incandescent lighting for many tasks, as well as with over a century of investments and development of all things lighting centering around this light source, means that its legacy will not be easily or quickly changed.[37] In addition, developments in the existing light sources have not stopped.[38] Thus, the future of energy efficient lighting will require that each light source be used to their best advantage.

Nevertheless, in order for LEDs to achieve their potential for energy efficiency and widespread adoption, and used to their best advantage, it is clear that policies and standards need to be developed for LEDs. As discussed earlier, LEDs represent a fundamentally different, new light source, and the characteristics of LEDs may not be adequately described by current metrics, combine to pose a challenge to those who must set standards for this new technology. In addition, because it may not be possible to apply any of the current standards towards new LEDs, new standards have to be developed or updated for almost every application categories to insure that LEDs characteristics are taken into account.

For one standards-setting agency, having to address a number of lighting standards – from indoor to outdoor lighting – in the near term can be a daunting prospect. However, many standard agencies across the Asia region will need to update their lighting standards library to accommodate LEDs in the near future. Adding to this situation is the fact that the standard setting process itself is a slow and resource intensive one, and the prospects can become overwhelming. The one factor that can help this situation: many governments are keen to develop their domestic LED industry, or to improve their energy efficiency, or both, and may be willing to direct resources into this particular area – if such a case can be made. There are also other initiatives underway, including compliance with RoHS, that also need to be taken into account.

Thus, for policymakers, standards-setting bodies and agencies across the region, an immediate standards and policy "triage" of sort is required for LEDs. Based on ECO-Asia's review of the majority of available data on actual, documented cases regarding installation of LEDs in comparable applications that can be verified, policymakers and standard setting agencies may wish to focus on the following application areas for LEDs initially:

- **Area, parking, street and/or outdoor lighting**: This is a high-interest area, and policy support for standards may be easily obtained. However, standards for these application areas can be very involved, as related standards such as pole height,

[37] Consider the pace of T12 to T8 tube lamp replacement world-wide, or magnetic to electronic ballast for tube lamps.
[38] For example, the "super CFL" and other coated and halogen IR reflector lamps have made significant progress in efficacy.

distribution, illumination levels, etc. may also need to be revisited, adding to the time required;

- **Traffic lights and transportation-related signals**: These are high-duty applications, and can yield significant savings both in energy and maintenance costs, even if they are not as visible as other applications. Changing transportation and traffic-related lighting may also require code or regulation changes in addition to changes in standards.

- **Signage and architectural applications**: Similar to traffic and transportation-related applications, these are high-duty cycle, and are also increasing in number as more commercial buildings are being built and retrofitted around the region.

- **Off-grid lighting applications**: This is an application that has gained significant interest in recent years, as a new generation of low-wattage LEDs are starting to meet some basic rural lighting needs. These have the potential to serve a large percentage of Asia not yet connected to the grid. Like street lighting, complementary standards will be needed, such as charging and battery capacity, for example.

As noted, LED products have the potential to be "disruptive" and may find other niches that are not in these above broadly outlined categories, and may or may not be limited to their traditional distribution channel for their product categories and applications. In addition, the lessons learned from the introduction of CFLs indicate that while consumer-orientated LED products (such as incandescent lamp replacement) are not yet cost effective, a number of steps, including quality standards, must be put in place soon for consumer products to protect early adopters from exaggerated claims and products with dubious performance and reduce the risks of these products "poisoning" the market.

Finally, there are a number of considerations that policymakers in Asia may wish to consider when considering the growth of LEDs:

- **Roadmap for LED-related policies**: Policymakers will require a roadmap for LED categories for standard setting, regulation and promotion based on industry development progress and potential impacts to guide their decisions. Policymakers may also want to consider a regional, on going effort to coordinate on a regional roadmap for LED categories based on the potential impacts in terms of energy savings and costs. This will allow a continued "triage" for standards and regulation development that can allow policymakers and standard setting agencies to keep pace with the industry.

- **A regional effort on LED standards and labeling**: A regional effort towards harmonization of standards and labeling for LEDs can help to speed up adoption of quality LED-based products and reduce the overall efforts needed around the region. Currently, there is no recognized set of common quality criteria for LED-based products in place across Asian consumer or commercial markets. This presents an opportunity for harmonization of quality standards that can help to reduce confusion, speed up adoption, and to send the right economic message to suppliers and developers of quality LEDs in Asia.

- **Quality is essential**: A hard learned lesson from the introduction of CFLs into the Asian markets was low-quality products can undermine energy-efficiency policies and efforts to mitigate greenhouse gas emissions. High-level policymakers need to recognize that the prevalence of low-quality LED products in the market will again constitute a significant barrier to the full realization of energy-efficiency policies. Given that first costs for new LED-based products are much higher than CFLs (on a per-unit basis), it is imperative that public and private investments should be made as wisely as possible.

- **Use available regional institutions**: Currently, many countries focus their standards on energy efficiency and energy performance and do not explicitly incorporate other quality criteria into their standards. Therefore, an initial step for the regional harmonization process can begin by identifying some common performance characteristics for LEDs that can insure energy, light output and lifetime performance to provide a minimum level of product quality in the market. There are three regional initiatives that can serve as suitable vehicles for such a regional effort:

    - **The Asia Lighting Compact –** ALC, based in Singapore, is a regional, independent, public private partnership whose mission is to promote standards harmonization, product quality, and adoption of energy efficient lighting. It has worked with regional stakeholders to develop a set of quality standards for CFLs in Asia.

    - **The Regional Center for Lighting –** RCL, based in Sri Lanka, is a technology hub for lighting in Asia. RCL's mission is to advance sustainable lighting and make it affordable to improve the well-being of the citizens and the countries within the region. It is developing a technology and knowledge portfolio and laboratory capacity.

    - **Lites.asia –** lites.asia stands for Lighting Information and Technical Exchange for Standards. The objective of lites.asia is to facilitate a greater involvement by Asian / APEC countries in the development of IEC standards. This should result in standards which are more appropriate for regional needs, thus enabling Asian / APEC countries to adopt IEC specifications with minimum local variations.

A combined, coordinated effort by these organizations can help advance both the technology roadmap and standards harmonization for the region. They can also work together to arrive at the recommended performance and quality categories, as well as recommended product categories, test methodologies, data sharing plans, etc. suitable and acceptable for all agencies and stakeholders in Asia.

- **Develop guidelines for municipalities**: Currently, many municipalities and agencies are in the throes of "LEDs-fever." They are determined to make investments in LEDs at all cost, or are confused by misleading performance and lifetime claims when carrying out cost-benefit analyses. One possible approach to address this issue is to develop an one-page guide for evaluating LEDs and product claims that officials and agencies can use to screen out dubious products. A follow up step would be to seek support for a regional municipal public lighting organization, whose purpose is to disseminate information regarding best practices in public and municipal lighting for agencies in the region.

- **Develop guidelines (and labels) for consumers**: Similar to the many municipalities and agencies, consumers are also blinded by exaggerated and unverified claims of performance and quality. As a result, low cost consumer products are appearing in many markets without any oversight or recourse for consumers. This remains a preventable disaster. Energy or consumer agencies can work with a recognized regional organization on product quality – such as the Asia Lighting Compact – to develop a consumer guide and/or a label to help consumers choose quality products. This guide can use common descriptors of performance and quality for consumers around Asia, and can help prepare the market for quality products.

APPENDIX A
A PRIMER ON LEDs

Note: The materials used in this section were taken from a number of sources (to be documented).

1. COVERAGE

Light emitting diodes were invented in 1969, and represent the first fundamentally new lighting technology since the gas-discharge lamps. LEDs bring many advantages to electric lighting, the most notable advantages being energy efficiency and extremely long service life. Other characteristics of LEDs can include:

- The size of a LED system is often smaller in profile than that of other lighting systems.
- The performance of LED systems, like fluorescent lamp systems, declines if heat builds up.
- If various colors are mixed within a system, and the system lacks circuitry to balance the light output as temperature varies, the overall color appearance of the light output may shift.
- The life of LED systems, like any other system, is determined by the duration of the shortest-lived component.
- LEDs typically have fast 'on-times' in the order of 60 nanoseconds (vs. 10 milliseconds for incandescent lamps)

The LEDs covered in this report is limited to LED-based lighting products. To date, this includes LEDs that emit visible and ultraviolet energy.[39] This report focuses only on the so-called *high brightness LEDs* (HB LEDs) and *ultra-high-brightness* LEDs (UHB LEDs), although there is no standard industry definition of the HB LEDs or of UHB LEDs. This report does not cover the wide range of solid-state lighting (SSL), which includes lasers and *organic light emitting diodes*, or OLEDs.

2. BACKGROUND

Materials in electric and electronic applications are classified into three groups according to their *conductivity*, a property that describes how easily current flows in the material:

- *Conductor* – in conducting materials such as copper and gold, electric current flows with virtually no resistance.

[39] Sometimes UV emitting semiconducting chips are coated with a phosphorescent layer that emits light in the visible spectrum when it is exposed to UV light. Ultimately, the user sees visible light. This technique is sometimes used to produce white light.

- *Insulator* – in materials that are opposite of a conductor, like plastic and rubber, virtually no electric current is able to pass.

- *Semiconductors*. Semiconductors are materials in between the two conducting extremes. They are solid, crystalline materials that are more conductive than an insulator but less conductive than pure conductors.

Creating LEDs from Semiconductors

By layering semiconductor materials that have different levels of conductivity, material scientists can produce a *diode*. A diode is a valve-like device through which electrical current flows in one direction and is blocked from flowing back in the other direction. More specifically, by applying a voltage difference across two distinct layers of the diode, current flows through the material. *Light emitting diodes*, or LEDs, are special types of diodes that convert electrical energy into light through a phenomenon called *electroluminescence*.

The physical explanation for LEDs is as follows: the flowing current in a LED excites electrons in one semi-conducting layer to a high-energy state. These excited electrons then combine with "holes," or places in the material where there are a lack of electrons. This combination of electron and hole allows the electron to settle into a lower energy state and emits a photon, or "light packet." The photons that are emitted from this recombination make up what we perceive as light from the diode.

Photons that are produced from this recombination process in LEDs typically have nearly identical energies. Consequently, each LED emits light that falls within a narrow bandwidth. This bandwidth is determined and limited by the materials with which the LEDs are made. This band can be produced in the visible range of the electromagnetic spectrum, but also in the infrared and ultraviolet through the use of different semiconductors. It is the narrow bandwidth in the visible light range that causes the light from LEDs to appear monochromatic.

Manufacturing the LED Wafer

Like other semiconductors, each LED consists of extremely thin, "sandwiched" layers of materials that typically are compounds formed of two to four elements. These thin layers are brittle and must be either created on or transferred to a more durable rare earth metal, such as sapphire, gallium, or indium. These materials function as a *substrate*; their crystalline structure is selected to be compatible with the compound semiconductor materials.

Precise amounts impurities, or *dopants,* purposely introduced to the semi-conducting layers of an LED determine the electrical properties of the compound materials. By doping layers differently, different colors and efficiencies of LEDs can be achieved. Some doping processes are well known and established (such as the process that produces red LEDs), while others are in earlier stages of development.

The creation of the thin layers that make up the LED involves many carefully designed and controlled steps and additional materials, including some toxic gases. The processes for creating LEDs require cleanrooms and sophisticated controlled-system equipment, similar to the processes used for creating other semiconductors. The most common processes for creating the newest generation of LEDs are molecular *beam epitaxy* (MBE) and *metalorganic chemical vapor deposition* (MOCVD).

Unlike the semiconductors used in computer processing and memory chips, however, LEDs are far more difficult to fabricate. They cannot be produced on large "wafers" (wafers are sliced nodules or boules of ultra pure semiconductor materials "grown" under controlled conditions in laboratories). Most LED wafer substrates are four or six inches in diameter or smaller, due to the challenges of growing defect-free boules, and the brittleness of the materials.

LED wafers that pass quality control criteria are further processed to create individual LEDs. Layers of conductive metals and photoreactive films are applied and then etched in geometric patterns to create the basis for microscopic circuits. Optical materials can also be applied and shaped at the wafer level of production. The result is a gridded matrix of individual LEDs with the required shapes and layers. Wafer size and composition are important economic and process factors because they limit the number of individual LEDs that can be produced from one wafer.

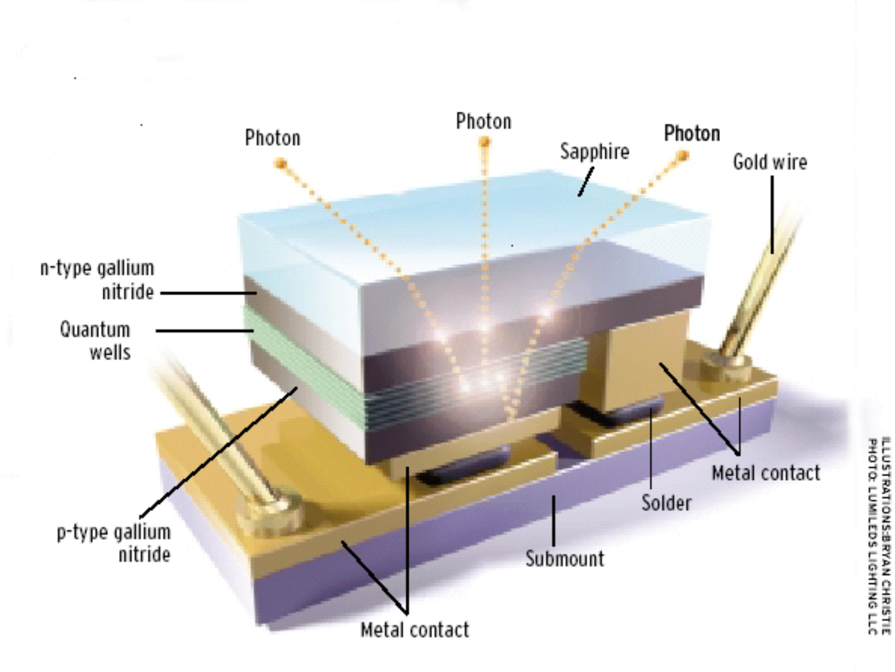
Creating the LED Package

Once the microscopic circuits are in place, the individual LEDs are then separated (known as "die"). The LED wafer itself is not a functional light source, however. Once the die pieces are separated, there are several more steps to create the functional circuit and efficient emitter known as a *package*. The LED die can be placed inside reflective cups, or coated on some planes with highly reflective material. Metal leads are attached to one or more surfaces of the LED. These are usually made of gold. Sometimes the die pieces are encased in a highly transmissive material, usually an epoxy. The encasing material can be molded into an optically desirable shape, laser-shaped, or deposited in a fine film.

The final steps in manufacturing LED packages are as critical to performance as all of the preceding steps. The brightest LEDs to date are carefully shaped in three dimensions to allow as much light as possible to exit the device. In addition, most of the high-brightness LEDs making the news today incorporate either a *thermal heat sink*, or a means of direct attachment to a thermal heat sink. Thermal heat sinks help maintain the temperature of the LED, which is critical because higher temperatures adversely affect the quality and quantity of light emitted from the package. The heat sink can be a metal such as aluminum, copper, or a conductive ceramic material. High temperatures can permanently affect the performance characteristics of a LED, shortening its useable life span, lowering its light output, and shifting the color of light that is emitted.

Although less energy is wasted as heat in the most advanced LEDs compared to incandescent lamps, LEDs still generate significant thermal output despite the fact that they tend to be very low power devices. A *high brightness LED* without an appropriate heat sink would become very hot to touch. The heat build-up internally in the diode causes mechanical failures as the disparate materials inside the device expand at different rates, causing physical stress. For instance, the gold lead wires can snap, or the epoxy encapsulant can expand, tearing apart the nearby components.

Figure 8. Diagram of an LED package.



3. "WHITE LIGHT" FROM LEDS

Unlike conventional light sources, most of which emit some version of white light and must be filtered to produce colored light, LED sources are inherently colored light sources (due to their narrow photon bandwidth). The compound semiconductor materials determine the spectral power distribution (or color) of the light that is emitted from a LED.

Currently, there are a number of major material systems are used for high brightness LEDs, with a number of experimental prototypes using other material systems under development and testing.

- AlGaAs (aluminum gallium arsenide): the red end of the visible spectrum (longer wavelengths, low energy)

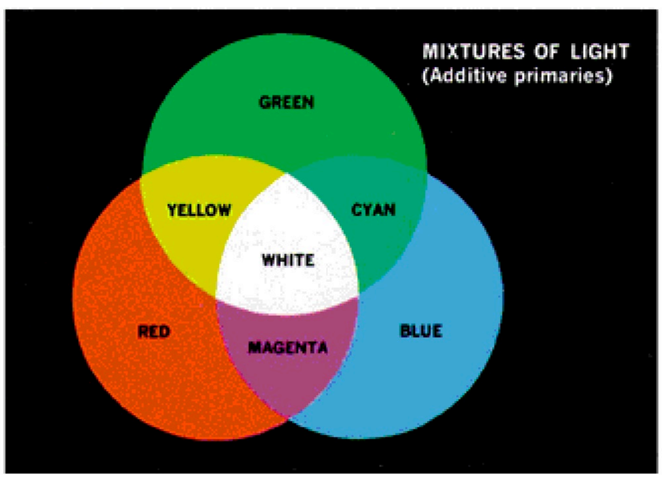
- AlGaInP (aluminum gallium indium phosphide): red-orange-amber-yellow portion of the visible spectrum (mid-wavelength, middle energy)

- AlInGaN (aluminum indium gallium nitride): theoretically spans the visible spectrum, with the exception of some gaps in green; however, it is primarily used for the green-blue end of the visible spectrum, and ultraviolet (short wavelengths, high energy)

As discussed earlier, LEDs chips also vary in *color purity,* that is, how pure the color of light is, versus how close to white the light might be. LED die from a single wafer can vary in dominant color and also in color purity. Manufacturers sort LEDs chips into *bins* by both of these characteristics. This expensive process is reflected in the price of the die: bins with the least variation are most costly.

Using LEDs to Make "White Light"
When white light passes through a prism, it is split into component colors, making some version of a "rainbow." Mixing two colors that are opposite each other in a color space, such as blue and yellow, creates *binary* white light. Also red, green and blue (RGB) can be mixed together to make white light. Regardless of the technique used, the relative amount of energy of each color must be balanced to create the perception of a neutral white; otherwise the result appears "cool," closer to the blue end of the spectrum or "warm," closer to the red end of the spectrum (Figure 9).

Figure 9. Color Mixing Chart



Source: Navigant, 2007.

A variety of color mixing techniques are used to create "white light" LEDs. The more colors of light that are represented in a white light, the more satisfying the result may be, because human vision has evolved in the very broad spectrum of daylight. The most common ways of creating white light with LEDs are:

- Placing discrete red, green and blue LED die close enough to each other to create the impression of white when viewed directly. Some large video display walls are composed of millions of units, like pixels, of colored LEDs.

- Placing discrete red, green and blue LEDs inside a device with a diffuser, so that viewers only see the "blended" light.

- Encapsulating a blue or ultraviolet LED in a layer of phosphors. The phosphors are excited by the short wavelength radiation, and then emit light in longer wavelengths, such as yellow and red. The blue LED/phosphor solutions are less efficacious than the discrete RGB systems.

LED manufacturers are struggling to create LED light sources that mimic more conventional sources such as incandescent and fluorescent lamps.

Phosphor Technology
The production of phosphor based white light LEDs are limited not only by the progress of the LED technology, but also of the progress of the phosphor technology.[40] Phosphors must be 'tuned' two ways. They must be tuned to accept a certain wavelength of excitation light, or the light that 'pumps' the electrons in the phosphor to higher energy levels. Secondly, the phosphor must be tuned to release a certain emission light, or light that is produced as a result of the electron falling from the pumped-up state to a lower energy state. The tuning of these two parameters is achieved by changing the chemical structure of the phosphor specific to white light applications.

Other factors important to consider with phosphor technology include: degradation rate of the phosphor compared to the other phosphors and the LED and the emission efficiency. Phosphors degrading at different rates can lead to a change in color temperature and color rendering over the lifetime of the LED. A phosphor with too short a lifetime would limit the lifetime of the LED. The emission efficiency of the phosphor is important so that the ratio of output of the different colors is appropriately balanced.

3. PRODUCING LED LIGHTING SYSTEMS

LEDs must be incorporated into an integrated system in order to be used in most lighting applications. At a minimum, the system contains LEDs, a *circuit* (either on a board, or formed of wires), a *thermal heat sink*, a *driver/power supply* that connects the circuit to the source of electricity and modifies it to meet the particular LEDs' operation requirements. The entire system must be taken into account when comparing input power demands, because other components in the system, such as the driver, have their own added requirements.

LEDs are direct current (DC) devices, so the use of alternating current (AC) requires additional components. The driver is analogous to the ballast in conventional fluorescent systems. The newest, highest power LEDs require sophisticated electronic drivers. Usually a LED system includes some type of housing or support, and often it includes reflectors or lenses to direct or diffuse the light. Beyond these basics, there are myriad LED systems marketed or assembled from components, and very few standards available. There are however, two basic types of systems:

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[40] Although there are currently white LEDs on the market that are a blue LED with a yellow phosphor, these do not have the necessary color rendering characteristics to be used for most lighting applications.

- Chip on board (COB) and surface-mount type (SMT) LEDs are mounted on the surface of a circuit board. The board can either be rigid or flexible. The system can be very small, with many die packed densely into a small area to function as a point source. Or, it can cover larger areas or long lengths, with the LEDs spaced to achieve particular light distribution patterns.

- LED modules, clusters or "lamps": These systems have discrete LED packages soldered into place in more conventional circuits, such as LED holiday lights and LED neon sign replacement kits. Some LED-based lighting devices are designed for use in conventional screw-base or pin-base sockets; they have all the system components integrated into a single product.

4. LED PRODUCTION AND THE ENVIRONMENT

Highly toxic and controlled substances are used to manufacture LEDs and other electronics in the semiconductor industry. For example, ammonia, arsine, nitrogen and phosphine gases are used in the fabrication process, and stored in bulk on-site at LED chip fabrication facilities. Dust from the sawing or scribing of chips can contain toxins or potential toxins.

However, LEDs are manufactured in clean rooms like other semiconductors, so much of the exposure to humans would be limited by processes put in place similar to that of other semiconductor manufacturing practices (which is governed by local environmental laws). The wafer and chip fabrication processes are highly energy-intensive, as are the mining and refining of the precursor metals (gallium and indium) and rare earth phosphors (for white LEDs). Unlike most gas discharge lamps, no mercury is contained in LEDs.

Assembly of LED lighting systems is also similar to that of other electronics devices. Much of it is automated, and involves soldering of components onto etched circuit boards. Lead solders are commonly used, but lead-free solders are an alternative. Depending on environmental regulations in place at the manufacturing plant's location, highly volatile solvents may be used to clean finished circuit boards. Much like the computer industry and, increasingly, the lighting industry, LEDs, components, and LED lighting systems are manufactured in Asia, particularly in Malaysia and in Taiwan and China, as well as India.

LEDs last longer than the light sources they may replace, but as noted, the lifespan of the LED system, including the housing, may be more or less than conventional sources, depending on the types of components used. Due to the smaller size and lighter weight of LED lighting systems, they have a lower volume and weight than conventional systems (except for the heat sink components, which can be made of aluminum and tend to be large and heavy).

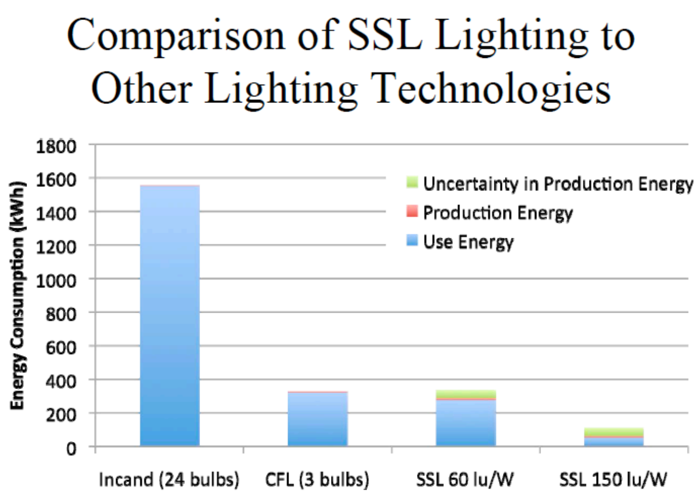
If the system has integral components, the entire device would have to be disposed of at end of useful life. The use of thermo-bonded plastics and metals may make it difficult to separate components for reuse or recycling. Older red LEDs are likely to contain small amounts of arsenic – a potent toxin. Many new LEDs contain no arsenic, but they do contain gallium and indium, about which little is known of possible health and environmental effects.

A recently released study conducted by Carnegie Mellon University's Green Design Institute provided the following summary:[41]

- LED processing currently appears to be a small contributor to overall life cycle energy consumption of SSL lamps.
- Materials for the lamp, especially heat sink, are a significant contributor to the overall environmental impact of LEDs lighting systems.
- Designs are expected to reduce material needs as heat sink designs are optimized to reduce cost;
- Opportunities to reduce overall life cycle energy consumption if these materials can be recovered (i.e., takeback or recycling systems implemented);
- Current estimates of energy for manufacturing is small compared to current use energy, life cycle energy is comparable to other competing technologies.
- Product dependent – results could be different for different SSL applications.

Figure 10 below, contains a comparison of energy use and production energy for incandescent, CFL, and LED technologies.

Figure 10. Energy Use and Production Energy for Selected Light Sources.
Source: Carnegie Mellon University



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[41] "Solid-State Lighting Life-Cycle Assessment." By Deanna H. Matthews, Mary Ashe, Paulina Jaramillo, H. Scott Matthews, Francis C. McMichael, Christopher L. Weber, Green Design Institute, Carnegie Mellon University, 2009.

APPENDIX B. ECO-Asia LEDs Standards Survey Results

No.	Question(s)	Response(s)									
		Brunei	Hong Kong	Indonesia	Japan	Malaysia	New Zealand	Philippines	Chinese Taipei	Thailand	Vietnam
1	What standards development activity on LED does your organization do or has happened/is happening in your country? Please provide us a copy of the standard if you have.	None at the moment.	N/A (According to the development background of HK lighting industry, the HK lighting industry still follows EN and BS EN standards. Currently, there is no new released local and regional LED related standard. Because the demand from the market and the industry, Hong Kong government is starting to form the task team for solving these standard related issues.)	Major Laboratory for Energy Technology (B2TE-BPPT) conducts performance test of LED for Solar Home System application. The test is done based on standard testing for general lamps	TS C0038 – (Pub.2004-11-20)(Expire 2011-05-19) – Photobiological safety of lamps and lamp systems; JIS C8121-2-2 (Pub. 2009-03-20) – Miscellaneous lampholders Part 2-2: Particular requirements – Connectors for printed circuit board based LED-modules; JIS C8152 – (Pub. 2007-07-20) – Measuring methods of white light emitting diode for general lighting; JEL 311 – (Pub. 2006-03-22) – General Rules for Photometric Method of White LED Lighting; JIS C 8153 – (Pub. 2009-03-20) – DC or AC supplied electronic control gear for LED modules – Performance requirements; JIS C8147-2-13 – (Pub. 2008-10-20) – Lamp controlgear – Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules; JIS C8154 – (Pub. 2009-03-20) – LED modules for general lighting –	Early discussion by the Technical Committee on Lighting, Lamps and accessories to consider developing national standards related to LED	EECA carries out the Government program to develop minimum energy performance standards (MEPS) and labelling requirements for products. For LED's - Review of current/draft LED standards in other APEC economies to develop harmonised methods of Testing.(EECA is aware that there is potential for improved standards in the area of LED lighting. They are an internationally traded product, mostly imported into New Zealand making harmonisation of standards important to ensure good consumer choice and low costs of compliance.)	The Philippines has programmed for 2010 the development of a national standard for safety specifications for LED modules for general lighting and a national standard for performance requirements for self-ballasted LED lamps for general lighting services. The Philippines will review IEC 62031 (LED modules for general lighting -Safety specifications) & IEC/PAS 62612 IEC:2009 (E) (Self-ballasted LED-Lamps for general lighting services-Performance requirements for possible adoption as national standard. The Bureau of Product Standards (BPS) has recently convened its technical Committee on Lamps and Related Equipment to start the standard development process for LED products (This was triggered with requests from various sectors. The scopes of related existing Philippine National standards do not include LED.)	Taiwan already published several LED device/product standards. Below listed the progress of the LED standards. Published standards: CNS15233: Fixtures of roadway lighting with light emitting diode lamps -- outdoor CNS15247: Test methods on light emitting diode components and modules (for general lighting service) for normal life -- other CNS15248: Methods of measurement on light emitting diode components for thermal resistance -- other CNS15249: Methods of measurement on light emitting diode components for optical and electrical characteristics -- other CNS15250: Methods of measurement on light emitting diode modules for optical and electrical characteristics -- other Under Review Optics measurement method for LED lighting system -- Indoor & outdoor Environment and reliability testing method for LED devices -- other Fixtures of flood lighting with light emitting diode lamps -- Indoor & outdoor Optical and electrical characteristics measurement method for LED chip -- other Drafting Fixtures of T-Bar (Ceil mounted) with light emitting diode lamps -- indoor Quality testing method for LED chip Accelerated life testing method for LED chip --other Thermal resistance measurement method for LED chip -- other ESD testing method for LED device Power supply measurement method for LED lighting system --other Environment sustainability testing method for LED lighting system – indoor & outdoor Accelerated life testing for LED device and module --other	We are developing standard for LED modules for general lighting- Safety specifications by adopting IEC 62031. No copy of the standard is available because it is in Thai language only.	None yet
2	If there is, in what category (e.g. indoor lighting, outdoor lighting, others – please specify specific application area: street lighting, automotive, etc.) is it and in what stage is it in the standards development?	None at the moment.	N/A The explanation was described as above. Now the stage for standard development is at the beginning stage.	Application of LED for SHS (mainly indoor lighting) and Street lighting application using PV as power source.	We are in charge of general lighting field only, not automotive etc. And we, JELMA etc, focus into the standards of measurement, Light source safety and performance.	Not decided yet	Domestic Street Lighting	Currently in the process of deliberating the possible adoption of IEC 62031:2008- LED Modules for General Lighting- Safety specifications and its normative references. (The next meeting has been scheduled on 14 April 2010. The scope will be decided during the deliberation process.) The proposed national standards shall cover LEDs for general lighting applications as well as Christmas lights using LEDs. We are in the initial stage of standards development. Timeline is to finish the development of the LED standards within 2010.		For general lighting. Committee Draft (CD) stage.	
3	Which organization in your country is taking the lead and who are the other organizations involved in the standards development?	The Energy Division at the Prime Minister's Office fully supported by the Department of Electrical Services at the Prime Minister's Office, Construction Planning and Research Unit at the Ministry of Development and the Department of Mechanical and Electrical Works, Public Works Department in promoting and the adoption of Standards specifically for Electrical and Electronics Equipment/Appliances/Products.	In Hong Kong, Hong Kong government's departments in charge the standards development. Each department will focus on its own professional field. Now following departments and organizations are involving in this task: 1) EMSD;2) HyD; 3) OFTA; 4) ITC; 5) ASTRI (ITC funded); 6) HKPC (ITC funded).	National Standard Body; Technology Application and Assessment Agency; Directorate General of Electricity and Energy Utilization; Electricity Certification Service (LMK)	Japan Electric Lamp Manufacturers Association (JELMA), Japan Luminaires Association (JLA), Illuminating Engineering Institute of Japan (IEIJ), 3 drafting organizations, are in charge of Japan Industrial Standard (JIS). We basically intend to harmonize with IEC standard etc as international standards.	STANDARDS MALAYSIA as the National Standards Body and SIRIM Bhd which is responsible for managing the Technical Committee on Lighting, Lamps and accessories	EECA is the Government Authority & Regulator tasked with managing products regulated under the Energy Efficiency (Energy using Products) Regulations. Performance standards cited in these regulations are usually developed (or adopted from international standards) in conjunction with DCCEE (formerly DEWHA, Australia) as well as industry stakeholder groups.	The Bureau of Product Standards (BPS under the Department of Trade and Industry in partnership with other government agencies.(Other agencies include the Department of Health with respect to food, drugs, cosmetics, devices and substances; the Department of Agriculture with respect to products related to agriculture.) Standards development is led by the Bureau of Product Standards (BPS) under the Department of Trade and Industry (DTI). In the case of energy standards and labeling, the development process is handled jointly by DTI-BPS and DOE-ERTLS. This is done through the Technical Committee approach. In particular, BPS TC 4 on Lamps and Related Equipment which will develop the standards for LED is composed of representatives from BPS, DOE, stakeholders, and PELMATP. PELMATP is the acronym for Philippine Efficient Lighting Market Transformation Project, a project of DOE. BPS TC Chair comes from the private sector.	BSMI/MOEA is the lead. BOE/MOEA and DOIT/MOEA are involved.	Thai Industrial Standards Institute (TISI) and Department of Alternative Energy Development and Efficiency (DEDE). TISI is responsible for safety and performance standards, but DEDE is responsible for energy efficiency standard.	- Vietnam Standards and Quality Institute; - Technical committee related to lighting equipment
4	Are there other existing and/or planned programs/initiatives that pertain to the promotion of LEDs (i.e. replacement) in your country?	None at the moment.	In Hong Kong, the Hong Kong government funded projects to evaluate the feasibility for deploying LED streetlamp technologies/products in Hong Kong. Now, HyD, ITC, and ASTRI are involving in this project. Besides, ASTRI also started the 'Green Hong Initiative' since 2009.	LED is already introduced by Market. The Government has no specific program on LED yet.	Yes. There is a collaborating group with above 3 JIS drafting organizations and National Institute of Advanced Industrial Science and Technology (AIST), Japan Commission Internationale de l'Éclairage (JCIE) , Japan LED Association(JLEDS).	No information	EECA is a signatory to the international ENERGY STAR programme. It is possible that an ENERGY STAR LED standard would be suitable for use in the New Zealand market to endorse high performing products.	The Philippines does not have any program yet for the promotion of LEOs. however. we have some initiatives on LED application under the Philippine Energy Efficiency Project, in particular the retrofit of Baguios Burnham Park lamp posts at the lagoon area traffic lights in three major cities. and lighting for some households in off grid areas. The Philippines will closely monitor and evaluate the aforementioned LED applications under the PEEP.	BOE lunched a 3- year program (2009~2011)to replace all incandescent traffic sign by LED traffic sign. BOE lunched a LED street lamp demonstration project to set 47 LED lamp demonstrate site.	There are no activities, programs and initiatives in the present	No, but Vietnam is considering program for promotion of LEDs. There is a national objective program on saving and conservation energy.
5	Can you provide more information/web links or contacts familiar with these activities/programs/initiatives?	-	http://www.astri.org	-	Yes, I can do some. Also I would ask you to provide more informations about you and your these research result as soon as possible.	No information	http://www.eeca.govt.nz/; http://www.eeca.govt.nz/standards-and-ratings/energy-star	Department of Energy (DOE) at www.doe.gov.ph. (DOE is the lead agency in the implementation of the Philippine Efficient Lighting Market Transformation Project (PELMATP).	BOE/MOEA: http://www.moeaboe.gov.tw/ DOIT/MOEA: http://doit.moea.gov.tw/doiteng/ BSMI/MOEA: http://www.bsmi.gov.tw/wSite/mp?mp=2	-	www.vsqi.gov.vn