Consumer LED Lamps: Industry, Technology and What's Next

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LED Lamps: What Are We Talking About?

- For use in **residences, by consumers.**
- Wherein the light source is **one or more** light-emitting diodes (**LEDs**). Typically these are **blue-emitting LEDs** that are packaged with **yellow-emitting phosphors**, to create what we see as **white light**.
- Meant to be operated on **mains power**, and, where previously the consumer used a lamp of the **A-line** ("light bulb") or **G-line** ("globe") type.
- Where previously the light source would have been: incandescent (I), halogen incandescent (HI) or compact fluorescent lamp (CFL).

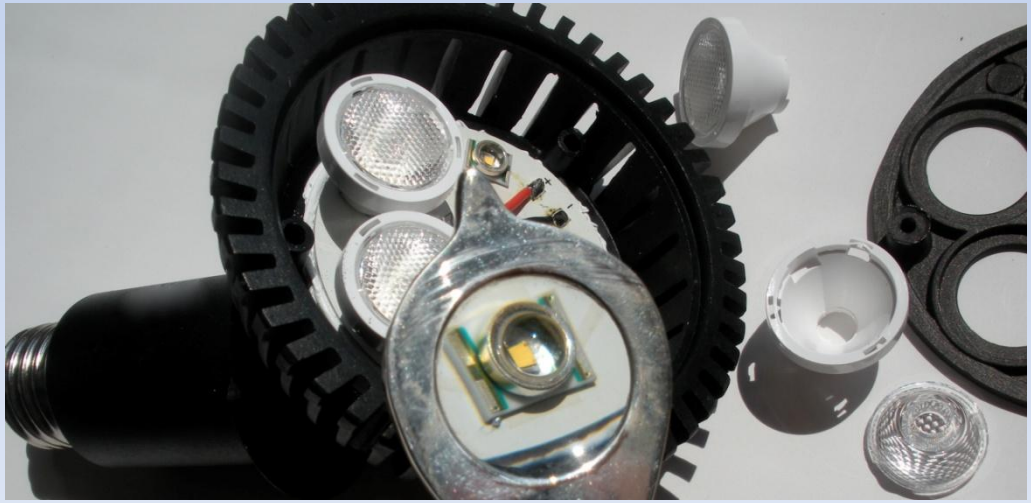
LED Lamps: What's Inside?

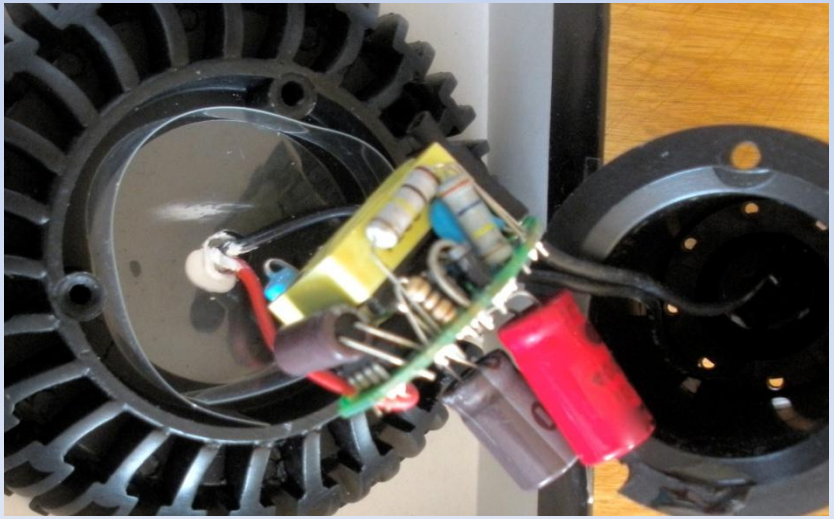
Light source: LEDs, in a package, or, mounted on a circuit board.

Optics: phosphors in silicone gel, or, in a plastic lens; micro-structured lenses for beam pattern control; reflectors.

Electrical/electronics: circuit board; AC to DC transformer; circuit driver; feedback loops & sensors; controls (on/off; dimming).

Thermal: conductive adhesives; heat sink.





LED Industry Status: Demand

- **Demand for illumination products is increasing;** they should exceed 10% of overall blue chip demand in 2012.
- Global LED chip leaders completed extensive build-outs of their **manufacturing facilities**.
- **Yields will improve,** lowering the per-chip cost for illumination-grade packages.
- Smaller manufacturers and start-ups have difficulty competing as large manufacturers clear out inventory. This may lead to **industry consolidation.**

LED Industry Status: Focus on Illumination

- **Illumination-grade LED packages: more difficult to make** than LED packages for displays. Must conform tightly to specifications, and, they may use multiple LEDs within each package.
- **China** invested heavily in LED chip manufacturing. Manufacturers must focus on quality control to get past the initial start-up of their production lines.
- Much of China's initial output of LED chips will be for displays & outdoors, not for indoor illumination. **LED lamps made in China for export often use blue chips imported from Europe, USA & Japan.**

LED Industry Status: Moving Toward Ecosystems

- LED **ecosystems** are clusters of companies, facilities and personnel that develop expertise in anticipating demand, designing and manufacturing just-in-time deliveries of products to customers. Often government supports research and funding for ecosystem development.
- Examples of **existing LED industry ecosystems** are the Optics Valley in Korea; LED-industry-related companies in Chinese Taipei; and, Silicon Valley in California. Singapore is the global center for Philips' chip manufacturing. Penang, Malaysia has a strong ecosystem for LED packaging.
- China is shifting toward funding more robust ecosystems and supply chains for LED packaging and LED lighting products.

LED Lamp Assembly

- **Hand-assembled** on small lines.
- LED lamp manufacturing requires many electronics, thermal and optical component **suppliers** nearby, to meet customer orders for rapid assembly and delivery.
- Extensive **testing facilities** are needed, too. Most lamps are tested for 24 to 48 hours before packing & shipping, to identify early failures.

LEDs Require Test Equipment & Quality Assurance at Each Step of Manufacturing

Images: Civilight Shenzhen Semiconductor Lighting Co., Ltd.

Technology Status and Forecast: Lumen Output & Lamp Efficacy

- LED chip, package and lamp **roadmaps** differ significantly.
- Industry has excellent record of achieving **laboratory milestones**; getting better at bringing high-efficacy lamps to market.
- Overall lamp quality varies considerably by country, due to **consumer protections** (or lack of them!)
- **Illumination-grade** chips and packages remain difficult for any but the leading manufacturers to produce consistently, in high volume.

Technology Status and Forecast: Lumen Output & Lamp Efficacy

- All components in the lamp must be **optimized as a SYSTEM** to take best advantage of the LEDs. The best LED chips won't perform well without an appropriate circuit driver.
- Examples: **If the chips are not driven properly** and they get too hot, the wavelength emitted shifts to blue, and will not fully energize the yellow/red phosphors. This leads to lower light output and lower efficacy.
- The **weakest link** in the system determines the LED lamp's performance. Often this is the circuit driver; seldom is it the LED.

LED Lamps: Different Than Previous Light Sources

Light Source	CCT: Correlated Color Temperature	CRI*: Color Rendering Index	Lamp Efficacy (lumens/ watt)
Incandescent	2700-2800	100	5—17
Halogen-incandescent	2775-4400	98—100	11—24
Compact fluorescent**	2400-6500+	70—92	35—70
LED***	2400-6500+	70—95+	15—90+

Sources: Manufacturers literature, online catalogs, literature reviews.

* *CRI may be replaced by a new metric, "color quality scale" (CQS)*

** *Requires special handling: contains mercury.*

Technology Status and Forecast: Lumen Output, Lamp Efficacy & Lighting Quality

- **Technical developments to improve lamp design and quality:**
  - Higher efficacy LED chips → less bulky heat sinks.
  - Higher voltage LEDs → increase lamp efficacy.
  - More consistent binning and use of multichip packages → increase light output.
  - Feedback loops → improve lumen maintenance and reduce color shifts.
- **High quality circuit drivers** and assembly line **QA** are most important for assuring quality to the consumer, because LEDs seldom fail. More often, the circuit driver or a solder joint fails, causing the LED lamp to fail, too.

Technology Status: Comparing LED to Incandescent Lamps

Range of Results, U.S. DOE CALiPER Testing*	Incandescent	Halogen-Incandescent	LED	*Consumer's View of LEDs*
Number of Models	**7**	**5**	**26**	**--**
Input Power (W)	**55 to 101**	**71 to 98**	**1 to 14**	***Great!***
Initial Efficacy (lm/W)	**7 to 17**	**11 to 24**	**16 to 97**	***Great!***
CCT (K)	**2491 to 2854**	**2805 to 3020**	**2643 to 7272**	***Buyer Beware!***
CRI	**99 to 100**	**84 to 100**	**49 to 93**	***Buyer Beware!***
Initial Light Output	*Predictable*	*Predictable*	*Varies*	***Caution!***

Results in rows 1 to 5 published by U.S. DOE CALiPER, July 2006 to October 2011.
Accessed November 2011 at: http://www1.eere.energy.gov/buildings/ssl/caliper/default.aspx
*NOTE: Opinions in row 6 and column 4 are those of the author, not of U.S. DOE.

Q: When does 43W = 60W?
A: Only when you buy light bulbs!

October 2011, USA Reality Check: LED Lamps in a "Big Box" Do-It-Yourself" Retailer

Initial light output (lm)	Input Power Demand (W)	Claiming to Replace (W)	Useful Life (hr or yr)	Warranty (Years)	Retail Price (USD)
240	7	25	25,000 hr 15 yr	6	14.97
240	5	25	25,000 hr 15 yr	6	24.97
450	8	40	50,000 hr	5	19.97
470	8	40	22.8 yr	6	21.97
510	8	40	23 yr	--	17.97
800	12.5	60	22.8 yr	6	24.97
850	13	60	25,000 hr	5	23.97
950	13	60	25,000 hr 23 yr	5	25.97

Inaccurate Performance Claims: What to Do?

- Require a **label or tech data sheet** with standardized test info for lamps (not just for LEDs).
- Conduct **outreach** to inform manufacturers and distributors of standards. Offer **recognition** for best performance. Example: Multi-million USD “L-Prize” awarded to Philips in August, 2011.
- Conduct **random testing. Publish the results.** Institute a third-party appeal procedure, but reserve the right to impose reasonable penalties for violations of the law.
- **Require “no-questions-asked” return or warranty terms** from manufacturers, distributors or retailers. Inform buyers of their legal recourse if the warranty is not honored.

“Best” Applications for LED Lamps*

- **Depends** on level of lighting sophistication in the home.
- **Essential lighting services:**
  - **Indoors:** (safe mobility and good orientation; face-to-face communication; fine-motor tasks such as reading, preparing food & grooming; extended work and leisure hours; aesthetics of the home)
  - **Outdoors:** (sense of security; safe mobility and good orientation; wide-area communication; enhance use of space during dark hours.
- ***Linear LED** lamps may eventually be suitable, but for now linear fluorescent lamps have higher light output, higher efficacy and lower cost.

Applications for LED Lamps in Residences

- Consider the **occupants' needs** for lighting services, available LED features & each room's **average hours of lighting use.**
  - **Outdoors:** thresholds; outdoor security.
  - **Indoor**s: kitchen, ambient and task; stairwells; tasks (especially reading, assembly and other fine tasks).
  - **Outdoors and indoors:** Any directional lamp application where the lamp is close to the illuminated surface; or, where the lamp is operated 12 to 24 hours per day.
- **Controls reduce wasted hours of lighting energy.** Choose LED lamps that are compatible with:
  - Occupancy sensors
  - Dimmers
  - Timers

LEDs: Changing the Lighting Industry

- LED lighting is more like other **consumer electronics,** no longer the exclusive domain of lamp companies.
- Consumer electronics companies **don't know much about illumination,** but are invading the territory of lamp companies.
- Therefore, **lighting manufacturers must "get savvy"** about manufacturing and marketing consumer electronics.
- **"To do list":** update consumer psychographic profiles, put more emphasis on social marketing, increase direct and online sales, and, better understand how to communicate life-cycle costs and benefits.

LEDs: Changing the Lighting Industry

- **LED lamps will become far more efficient** (system-level), but will require a more integrated manufacturing community to deliver quality at reasonable cost.
- Eventually, **disposable lamps will disappear!**
- Instead, we will have dedicated **LED luminaires,** and, **LED lighting systems** that are embedded in building and furniture infrastructure.


Thank
You!

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APEC LED WORKSHOP: *POLICIES TO PROTECT AND EDUCATE CONSUMERS*

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