

The future of lighting: walls of light, LEDs, and glowing trees

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Light bulbs haven't been sexy tech since Thomas Edison's day, but innovation has come to an industry that has seen relatively little of it for a century. Today, the lighting industry is in a remarkable state of flux, and much of it has been driven by government action.

Over the last half-decade, a gradual shift toward more energy-efficient light sources has gathered momentum as nation after nation legislates against the sale of incandescent light bulbs. Venezuela and Brazil started the trend in 2005. Australia and the European Union began phasing out tungsten lightbulbs in 2009. Argentina, Russia, Canada, Malaysia and the United States will have joined the throng by 2014, either by phasing out incandescents outright or (as in the US) by setting minimum efficiency requirements which in effect prohibit most incandescent light bulbs.

With recent data published by the Earth Systems Research Laboratory putting global atmospheric carbon dioxide levels higher than ever, such legislation is certainly timely. Consider the tremendous impact of electric lighting: Department of Energy figures cite electric lighting as responsible for 11 percent of residential and 25 percent of commercial energy consumption in the US. That's *all* energy, not solely electricity.

This is the story of the four main heirs to the incandescent throne—linear fluorescent, compact fluorescent, LED, and OLED—and of the future tech that may one day dethrone these upstarts.

From pocket calculators to living room lamps

The story of the last decade of electric lighting is dominated by the rise of the light-emitting diode (LED). LEDs are members of a new family of solid-state lighting technologies that eschew traditional means of illumination, such as electric filaments or plasma discharge, in favor of electronics. Simply put, LEDs are semi-conductor devices which, when transmitting electrical current, corral electrons into lower energy levels, emitting photons in the process.

LEDs began their commercial life at the outset of the 1970s as humble indicator devices, used in simple displays like the lava-red seven-segment display of Hewlett-Packard's first pocket calculator, the HP-35. Today, LEDs are the diminutive powerhouses of lighting. Commercially available units have broken the killer 100 lumens per Watt (lm/W) luminous efficacy barrier (the "lumen" is the standard unit of luminous flux—useful light output—while "efficacy" is the ratio of light output to power and measures the efficiency of the bulb).

The exponential increase in LED efficacy was identified in 2000 by Dr. Roland Haitz. The Haitz Law, loosely analogous to Moore's Law, predicts a doubling of LED lumen output every three years, with cost dropping by a factor of ten every decade. That year, Haitz predicted that the 100 lm/W benchmark would be broken in 2010. He was right. Rocketing efficacy has allowed LEDs to conquer niche after market niche, from the bicycle headlight to the traffic light, from the emergency light to the desk lamp.

But LEDs have more to recommend them than mere efficacy. Manufacturers' claimed lifespans routinely exceed 50,000 hours—that's the better part of six years continuous illumination. They can now be had in a range of colors, including cyans, magentas, ambers, cool whites, and (recently) warm whites, which was a crucial development LEDs needed to mount a serious challenge in home and office lighting.

High upfront prices have kept LEDs out of many homes, but prices are dropping, and manufacturers believe that LEDs has a bright future in the home. Peter Soares, Director of Consumer Channel Marketing at Philips Lighting, told Ars, "As prices come down, LEDs will be able to replace the more powerful incandescents. It's more a rugged technology, it doesn't have glass or a fragile filament inside, and doesn't have any mercury to worry about at the end of its life. LED will certainly be the long-term winner in the home."

They are also close to taking on exterior lighting. Gas-discharge lamps (particularly metal halide and high pressure sodium lamps) were traditionally the first choice for decorative illumination of building exteriors. These

high-powered pieces of kit, sometimes rated at more than a kilowatt each, are effectively light canons, illuminating entire building façades from the ground. It's a brute-force approach to lighting in defiance of the inverse square law, necessitated by the heft of the lamps and the need to get at them for maintenance.

LEDs provide a lower-energy alternative to gas-discharge, but it's not because they're more efficient (they're not, yet—high pressure sodium lamps reach 150 lm/W). But LEDs can save energy because their size and long life allows them to be mounted on every story of a building's façade. You can light the top floor of a building from close range rather than from the ground, and you don't have to get at the lights every 18 months to replace blown lamps.

More importantly, LEDs have allowed architects to literally cast their buildings in a new light, every few seconds if necessary, by means of dynamic color changes. Arrays of individually dimmed red, green, and blue LEDs can be programmed to fade between any colors in the spectrum.



The Peace Bridge between Buffalo and Fort Erie uses some 700 RGB LED color-change lighting fixtures
Philips Lighting

The benefits of LEDs in architectural lighting are overwhelming. It's this foothold that has seen the LED become a mainstream illumination technology, with architects rightly ignoring the warnings of engineers initially skeptical of manufacturers' lifespan claims. Buckingham Palace, the Cristo Redentor and the Yas Hotel in Abu Dhabi are three high-profile examples of decorative LED lighting, though each admittedly has the budget to cope with the increased initial outlay for LEDs. Projects like these give the LED serious sex appeal.

Estimates value the world LED lighting market at \$15.4 billion in 2011. That's 10 percent of lighting's market share, up from 5 percent in 2010. Helped by the phasing-out of incandescent bulbs, LEDs are projected to take 16 percent of the total lighting market by 2013. Naturally, lighting's innovators are ahead of the curve. Lee Dryden, a spokesman for Osram, told Ars that "in the last fiscal year, we made around 20 percent of our sales with LED-based technologies".

But to gain further ground, the LED has to knock off the reigning champ in commercial interiors like offices, universities, and hospitals: the venerable fluorescent light. Despite Haitz's Law and the sense of inevitability it gives to LEDs, fluorescent lighting is mounting a serious defense of its entrenched position.

The benefits of a low upfront cost

Excited vaporized gas is a funny thing; it emits ultraviolet light that's useful for illumination only if you stick some luminescent phosphor in its way. But it's a much more efficient way of converting electrical energy into light than making tungsten extremely hot (as in incandescents), and fluorescent proved dirt cheap to operate. It wasn't expensive to buy, either.

Until very recently, unless one exhibited a flagrant disregard of electricity bills, fluorescent was the only viable choice for the workplace, and the perception of fluorescent lights as flickering, green-tinged "sick building syndrome"-inducing tubular horrors is well out of date. Magnetic control gear (the means of regulating the flow of current through the tube) has been superseded by electronics, all but eliminating flicker. Triphosphor tubes emit light in red, green and blue spectra, emitting white light so workforces no longer appear to be suffering from outbreaks of communal nausea.

Modern T5 fluorescent tubes exceed 100 lm/W efficacy, putting them neck and neck with current LEDs but at a fraction of the initial outlay. One pro-LED piece of marketing we came across claims that, due to LED's lifespan, the 10-year cost of ownership for a commercial LED fitting is just over half that of the fluorescent alternative. Crucially, though, it admits that the initial outlay of the "average" fitting is nearly \$300 for LED but under \$100 for fluorescent.

Peter Soares of Philips Lighting argues that the "very economical" pricing of fluorescents combined with good performance and relatively long-life (now up to 40,000 hours, according to Soares) creates a "tough hurdle" for LEDs to overcome in office lighting. Still, he predicts that LEDs will "eventually supplant linear fluorescent fixtures due to the promise of greater energy savings and even longer life".

In the home, too, fluorescent lighting is the initial winner in the efficiency drive—usually the "compact" fluorescent format that replaces traditional light bulbs in lamps and overhead fixtures. A 2011 report by the Clinton Foundation showed production of CFLs in the US has exploded from 20 million lamps in 2003-04 to 255 million in 2009-10, spurred by demand for energy-efficient home lighting.

But without a serious technological breakthrough, fluorescent lighting is merely holding out against the inevitable. All else being equal, if VantagePoint's prediction that the cost of LED lighting will tumble 90 percent by 2015 proves accurate, the dominance of LED lighting both at home and at work would seem assured. But all is not equal. In the workplace, at least, the LED's ascendancy is far from certain because its solid-state cousins—the OLEDs—are on the march.

Photograph by Philips Lighting