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Illuminating Changes

Conventional lightbulbs may soon be obsolete

Janet Raloff

The first of two parts on lighting's environmental and human impacts

In a remote mountain community of Mexico's Sierra Madre, people are tending fields, cooking meals over open fires, and field-testing light-emitting electronics woven into colorful swaths of fabric. Depending on how a person folds or hangs one of the hand-towel-size pieces of cloth, it serves as a cordfree wall light, table top reading lamp, or hanging lantern.

Sheila Kennedy's team at Kennedy & Violich Architecture in Boston designed the solar-powered lamps, which depend on light-emitting diodes (LEDs). The researchers' goal: a safe, clean, rugged, and long-lived alternative to kerosene and candles for the world's 1.6 billion people living in homes without electricity. However, the biggest appeal of LED lighting for the world's poorest communities may be its low cost relative to those liquid fuels, notes Evan Mills of Lawrence Berkeley (Calif.) National Laboratory. His analyses indicate that without subsidies, 2-watt battery-powered lamps using white-light LEDs (SN: 7/16/05, p. 43: Available to subscribers at

Light-emitting diode-lit sconce showcases solid-state technology. Although many engineers expect solid-state alternatives to render bulbs obsolete in the next couple of decades, some are still working to cut the heavy energy and environmental costs associated with traditional lighting.
Lighting Research Institute

http://www.sciencenews.org/articles/20050716/bob10.asp) could pay for themselves in a year or less.

Other scientists are looking for ways to save lighting costs for people throughout the industrial world. In the United States, for instance, $55 billion worth of electricity—some 22 percent of the nation's total—goes annually to light homes and businesses. That sum is roughly equivalent to the output of 100 large power plants. Pollution associated with the energy needed for lighting is also large: Annually, about 450 million tons of carbon dioxide and 3 million tons of smog-generating nitrogen oxides and

sulfur dioxide.

These numbers are pushing a massive government, industry, and academic effort to shrink lighting's economic and environmental footprints. Some of the movement's low-tech strategies would simply reduce how long and intensively existing lamps burn. Promising far bigger payoffs are solid-state technologies: computer-chip-like LEDs and eventually more-exotic, organic light-emitting diodes (OLEDs), which might someday be fashioned into glowing films applied to walls and ceilings. Such semiconductor devices would be far more efficient than incandescent bulbs or even fluorescent tubes.

Kennedy predicts that electric illumination is poised to undergo a dramatic metamorphosis from a "bulb culture" to a society that sees by the "digital light" of semiconductors.

Bulb boosters

Throughout the developed world, homes and office buildings flood people with artificial daylight at all hours. Yet most of that lighting depends on technological dinosaurs.

Thomas Edison commercialized the incandescent bulb—a glass-encased, glowing filament—in 1879. The technology had been under development, at that point, for nearly a half-century. Fluorescent lamps—glowing tubes of mercury vapor—evolved in the late 1890s. Both types of lamp provide reliable, fairly pleasing illumination, but they carry high costs.

WIND POWERED. A photo composite of the New York skyline and an architectural model shows how LEDs could illuminate the ceiling on a landing for East River ferries serving Manhattan. Electricity generated by windmills at pier's end would be stored in batteries until needed to power the lighting. New York City agencies commissioned the plans.
Kennedy & Violich Architecture

Incandescent bulbs, including halogen types, are energy hogs: Typically emitting as light only 5 percent of the energy they use, they convert the rest to heat. Because incandescent bulbs are cheap, their light can seem less expensive than a fluorescent tube's. However, incandescents put out only 15 to 20 lumens per watt, less than one-quarter the output of fluorescent tubes. And an incandescent lasts only about 750 hours, some 8 percent of the typical fluorescent tube's life.

Many programs are developing technologies to make existing lighting systems more efficient. Among the simplest are devices that dim the fluorescent ceiling fixtures in offices when daylight is strong. These systems "have been around for a long time, but the market for them has remained small because they've been costly," notes Stephen Johnson of the Lawrence Berkeley National Laboratory.

Dimming each fixture has required extra wiring and a special, high-cost ballast, the gadget that controls voltage to a fluorescent light. However, engineers have recently developed wireless systems for signaling fixtures fitted with dimmable ballasts.

Powerweb Technologies of Media, Pa., has teamed with GE Lighting Systems to offer one such system.

It not only saves energy by dimming fluorescents when daylight is abundant, notes Powerweb President Lothar E.S. Budike Jr., but can also dial back the lights' output to take advantage of the hour-to-hour fluctuations in rates that utilities charge for power.

Daylight is incorporated into a fluorescent-lighting system developed at Oak Ridge (Tenn.) National Laboratory. Two sun-tracking rooftop mirrors pipe light into a building via more than 100 acrylic fibers. Each fiber can deliver about 400 lumens, comparable to the light from a 30-watt incandescent bulb, notes David Beshears, one of the developers.

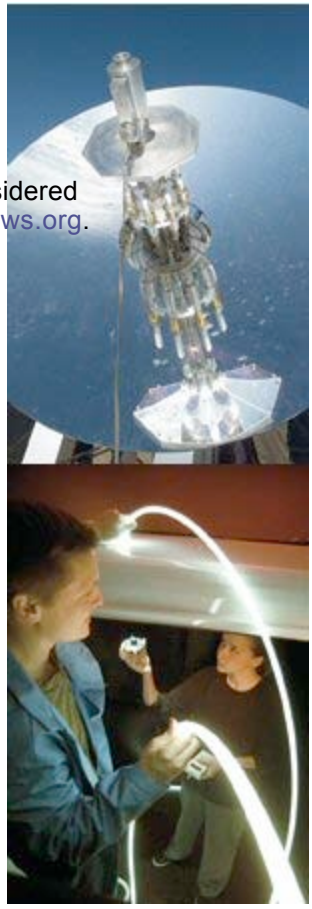
Inside the building, bundles of fibers feed their light into solid acrylic rods. These resemble long fluorescent lights and sit alongside fluorescent tubes in ceiling fixtures. When the sun shines, the acrylic tubes glow and photosensors dim the rods' fluorescent neighbors.

"In a typical facility, we're collecting about 100,000 lumens," Beshears says. However, he adds, light losses—such as a 3 percent drop per meter of optical fiber length—generally restrict the system's useful output to about 50,000 lumens. To limit such losses, the designers don't recommend sending fibers more than one full floor below the rooftop.

Although a commercial version of a 126-fiber system might cost $24,000, Beshears says, Wal-Mart, jewelry and furniture stores, offices, and government buildings have expressed interest. Especially attractive, he adds, is the sunlight-hued illumination the rods put out. The Oak Ridge team is field-testing the lighting system in stores and offices in several cities.

Lighting tasks

Many engineers share Kennedy's view that within a decade or two, most current lighting strategies will be as antiquated as the vacuum tube radio. They expect solid-state technology to expand from its current use of LEDs in flashlights, auto taillights, and novelty gear to widespread illumination.



Even though they're still being improved, LEDs are already in the efficiency range of fluorescent tubes, and researchers predict that they'll ultimately deliver about 150 lumens per watt in commercial applications throughout a projected lifetime of at least 70,000 hours.

Smaller than a fingernail, these solid-state devices directly convert about 20 percent of the incoming electrical energy to light. They dissipate the rest as heat, although they don't become hot to the touch. Application of a voltage to these devices causes the electrons inside their receiving section to become highly energized. Some electrons then jump across a junction into an adjacent segment of the device, in the process radiating light. The energy required for electrons to cross the junction determines what color they emit.

LEDs' small size doesn't limit their applications because many can be grouped for high-intensity applications, and optical enhancements can broaden their emissions into beams of various widths. Depending on how they're grouped and their spectral outputs, LED lamps can also be designed to vary their color whenever—and to whatever hues—users choose.

Such solid-state lighting holds the prospect of huge energy savings, says James R. Brodrick, who manages the Department of Energy's $19 million LED-and-OLED-development program. Among DOE's goals: LEDs that produce at least 150 lumens per watt in commercial units. "That's pretty ambitious," Brodrick says. The agency has a 20-year time line for bringing to market such a product.

Nadarajah Narendran of Rensselaer Polytechnic Institute's Lighting Research Center in Troy, N.Y., notes that owing to new optical enhancements developed in his lab for LEDs, "we're now getting between 80 and 100 lumens per watt."

HYBRIDIZED. Sunlight collected by the large mirror (top) is focused into a smaller one above it and then reflected down through a rooftop opening into a bundle of optical fibers. Routed to ceiling fixtures (bottom), the fibers light up an acrylic rod that's placed between fluorescent tubes. When the sunlight and fibers are bright, the fluorescent lights cut their output. Boles/ORNL

LEDs might have their first major impact not in whole-building illumination but rather in task-light niches better suited to their small size. Johnson says that analyses by his Berkeley lab indicate that "you can probably reduce your [overhead lighting] by at least 50 percent when you have good-quality task lighting." In commercial buildings, he says, that might translate into "very substantial energy savings."

Office-furniture makers might lead the way, he says, by designing products suitable for LED task lights. For instance, low-voltage electric strips under a desk shelf might enable a worker to plug in a small, flexible-necked LED light wherever it's needed.

Luxo of Elmsford, N.Y., is introducing the first high-intensity LED desk lamp. A cluster of three bulbs drawing a total of 9 watts of electricity—from a traditional wall outlet—will deliver diffused illumination equivalent to a 40-watt halogen light bulb.

The relatively expensive lamps will be marketed as alternatives to the high-intensity desk lamps used in hospitals and other places where desk lighting is needed 24 hours a day, says Sam Gumins, the company's chief executive officer. In those situations, "you're looking at 7 or 8 years of nonstop use before the [LED] lamps have to be replaced," whereas halogen bulbs can burn out as often as once a month.

He adds that the LEDs are cool even while lit, so they're safer than hot-burning incandescent halogens. Gumins claims that the long-lasting LEDs will make up their cost difference within 4 years of day-and-night lighting.

Some developing nations are already pioneering solid-state home lighting. Since 1997, the Light Up the World Foundation has outfitted some 14,000 homes in 12 countries—including Ghana, Peru, and Nepal—with rugged task lamps. The group, based at the University of Calgary in Alberta, has designed battery-powered LED lamps for use in some the world's most remote spots, regions that would otherwise depend on "flame lamps" of kerosene and candles.

In areas without electricity, a family now spends up to 20 percent of its income for kerosene, says Mills. After an initial investment in an LED lamp, lighting costs could drop to almost nothing—for years—he notes. Including the costs of the lamps, current LED technology would cost these people far less than flame lamps do.

Mills adds, "It's plausible that over the next decade we'll see many more households using LED lighting in the developing world than in developed countries."

Living with light

When Narendran and his family recently built a new house near Troy, N.Y., the lighting expert found that he was unprepared for the question, "Where will you put your lights?"

That experience led Narendran to think about divorcing lighting from electrical outlets and hard-wired fixtures. Over the past 2 years, his research team has come up with a scheme for flexible illumination that's possible only with LEDs.

His research center now showcases several rooms, each with a grid of low-voltage wiring covering the ceiling and walls. LED-lit sconces, pendants, or panels are built into tiles that can be snapped into place anywhere on the rooms' surfaces. Electrical contacts on the back of these lighting tiles connect to the power grid.

Computerized controls contain an address for each tile and so can turn individual units on and then adjust their brightness and color.

Repositioning a light requires simply snapping its tile into a new location. The system also accommodates other electronic appliances, such as wireless speakers and flat-panel television screens.

WEAVE-AND-GLO. Mexican villager is illuminated by LEDs woven into a swatch of cloth to create a flexible solar battery-powered lamp. S. Richins/Univ. Michigan

"All leading lighting and LED manufacturers are working with us," Narendran says, "so we've been able to transfer technology from the lab to the field very quickly. That's why we are very optimistic that something like this will catch on."

He says that affordable room-lighting systems based on the research center's model could be on the market within 5 years.

After that, Narendran says, look for tiles coated with plastic-wrap-thin OLEDs that cover walls and ceilings "like sheets of glowing paper." Indeed, Narendran anticipates, with the proper programming, such OLED panels could "display or change a wallpaper design at the touch of a button."

As with her fabric-lighting experiment in Mexico, architect Kennedy is pushing the envelope further, to where "light can begin to take on the material characteristics of ... those things into which it's embedded," she says.

In one case, Kennedy and her colleagues have integrated LEDs into yarn that could be woven into wall coverings or furniture, she says. The project is still experimental because the lighted fabric needs to be made more rugged and more easily washable. The product would be a step up from the Mexican fabric lamps.

All these low-voltage, LED devices can divorce lighting from a centralized power grid. Most can use energy from solar cells, wind systems, or batteries. Indeed, Kennedy says that the seminomadic Mexican people participating in the field test especially like this flexibility.

Some members of that community have urged her group to extend the technology to build lights into other objects and make warming blankets for infants. Such LED-lighting innovations exemplify, says Kennedy, the emergence of a new design trend: "lighting that lives within materials."

Next week: Better understanding of how the human body responds to certain wavelengths may improve health and productivity.

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