FEDERAL LABORATORY AFFILIATES CCST

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FOCAL POINT

LAWRENCE BERKELEY NATIONAL LABORATORY

Helping to Energize the California Economy

With one of the world's largest economies, on par with that of Italy, California is also one of the biggest energy consumers. Since over half its energy supply originates beyond its borders, the state is particularly vulnerable to any increase in the prices of oil, natural gas, and electricity—as recent experience has demonstrated all too clearly. But California leads the nation in its efforts to reduce the energy consumption of buildings, appliances and industries, thanks largely to the innovative work of scientists and engineers at the Lawrence Berkeley National Laboratory. Ever since the Arab oil embargo and the ensuing energy crises of the 1970s, they have been addressing these issues with cost-effective solutions that save Californians billions of dollars annually in avoided energy costs. And new efforts are underway to help convert the solar energy blanketing the state into useful fuels and electricity.

Aerial view of the Los Angeles basin at night, demonstrating the huge energy consumption for lighting (photo courtesy of UCLA Department of Astronomy).

Berkeley Lab began to examine energy consumption in buildings during the mid-1970s, when particle physicist Arthur Rosenfeld organized a workshop to bring together architects, engineers and scientists with significant energy expertise. They soon recognized that buildings consume about one-third of the primary energy and two-thirds of the electricity used annually in the United States. "We realized we had found one of the world's largest oil and gas fields," recalled Rosenfeld. "The energy was buried, in effect, in the buildings of our cities, the vehicles on our roads, and the machines in our factories."

In 1975 Rosenfeld founded the Energy Efficient Buildings (EEB) program at Berkeley Lab to help "mine" the vast energy supply available in residential and commercial buildings by dramatically reducing the huge amounts of it they were wasting. An early outcome of this work was the 1977 establishment of the Title 24 building codes in California requiring energy-efficient measures in new residences, such as dual-pane windows and insulated walls and roofs. The standards are based on computer simulations done at Berkeley Lab indicating that these highly cost-effective measures would pay back the added expenses of implementing them in just a few years.

In the late 1970s and early 1980s, researchers in the EEB program began to develop innovative new technologies that would soon begin to have dramatic impacts on energy savings in buildings. This research led, for example, to the low-emissivity (or "low-E") window coatings used in dual-pane windows, often known as "smart windows," that permit desirable daylight to penetrate but retard unwanted heat transmission in the form of infrared, or thermal, radiation. Now standard building practice, the use of low-E windows blocks this

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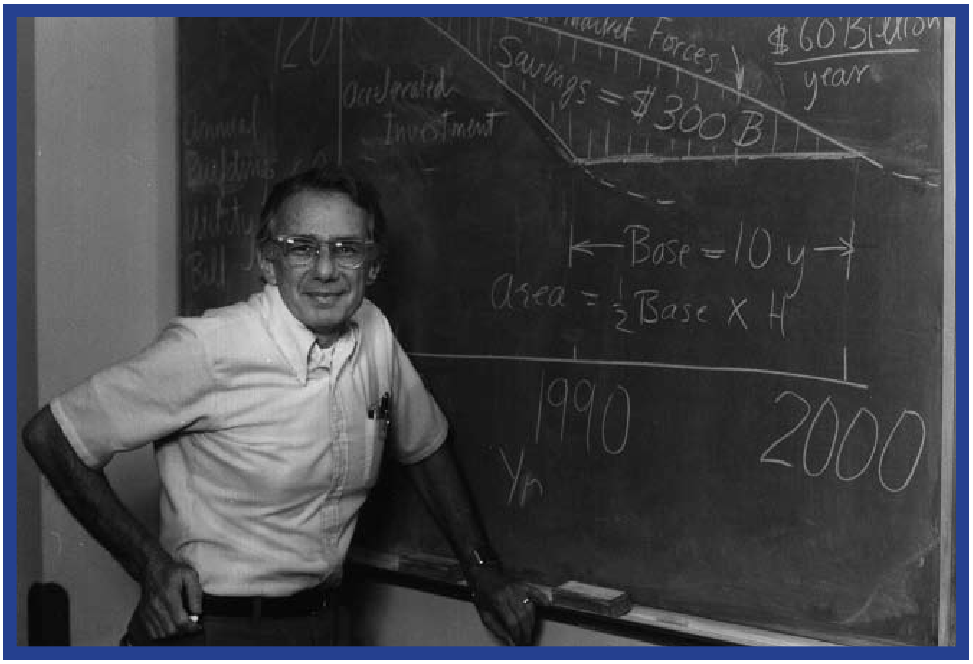
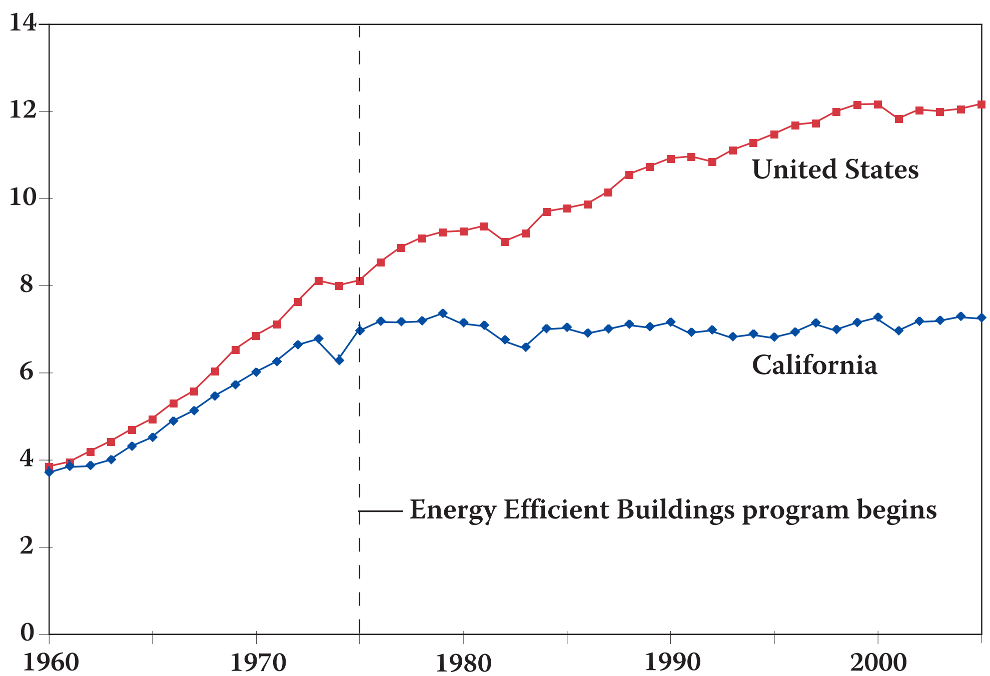


Berkeley Lab's Arthur Rosenfeld at the blackboard, summarizing the enormous potential that exists for energy savings in buildings and appliances.

heat flow right where it is most severe. Another important energy-saving technology pioneered at Berkeley Lab is the solid-state ballast, which permits fluorescent lights to operate at higher frequencies where they can be up to four times more efficient. This work led in the 1990s to compact fluorescent light bulbs, which are steadily replacing incandescent sources—a technology dating back to Thomas Edison—in homes and offices.

Berkeley researchers also attacked wasteful energy usage in home appliances—especially refrigerators, which had soared to an average 1,800 kilowatt-hours per year by the mid-1970s. Using advanced refrigeration technology and energy-consumption standards pioneered by EEB workers, this figure has been slashed to less than 600 kwh today, a savings of more than $120 per year for Californians who buy new refrigerators. These and other Berkeley-inspired appliance standards have been enshrined in the U.S. Department of Energy's "Energy Star" efficiency ratings for home appliances. The total statewide cost savings due to these standards and to the Title 24 building codes is now estimated at $4 to 5 billion annually, according to the California Energy Commission, of which Rosenfeld has been a long-standing member.

In the mid-1980s, researchers led by Hashem Akbari began investigating what they call "cool colors" for roofing materials, specialized coatings that reflect substantially more—some 20 to 30 percent—of the solar radiation striking them back into space than do normal roofs. These coatings reflect most of the radiation in the invisible infrared portion of the sun's spectrum, but they appear much the same as ordinary roof colors to human eyes. By absorbing substantially less radiation, roofs with these specialized coatings lower the temperature inside buildings and thus the electrical power consumed for air-conditioning. If installed in large numbers, such "cool roofs" will eventually reduce urban air temperatures on hot summer days, which would also help to retard smog formation in such areas as the Los Angeles basin. Berkeley Lab researchers are working closely with many companies in the roofing business, including about 30 in California, to hasten adoption of this inexpensive technology in roofing materials.

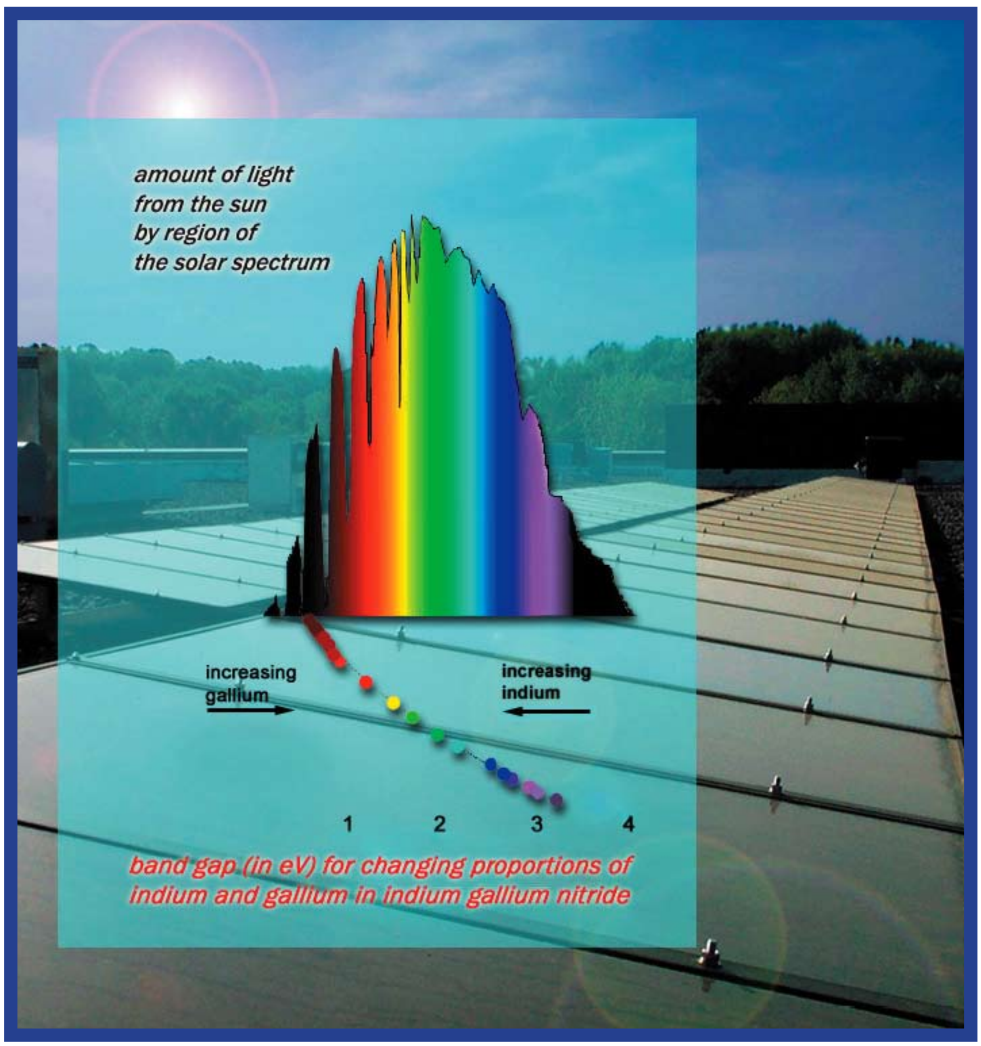


Annual per-capita electricity usage, in megawatt-hours per person per year for customers in California and the United States. While the national average has continued to climb steadily, California electricity consumption leveled off completely after 1975, when Berkeley Lab's EEB program began (Source: California Energy Commission).

Even better than reflecting the sun's energy would be to trap and convert it into electricity, but doing so economically requires cheap, efficient and rugged photovoltaic cells—a goal that has long eluded solar-energy enthusiasts. During the past decade, researchers at Berkeley Lab led by Wladek Walukiewicz have been studying various semiconductor alloys composed of the elements indium, gallium and nitrogen in ongoing efforts to make high-efficiency solar cells and light-emitting diodes (LEDs). A great advantage of this approach over silicon-based cells (which reach efficiencies of 10 to 20 percent), is that cells made of indium gallium nitride can potentially convert over 50 percent of the solar energy hitting them into electricity. The Berkeley Lab researchers achieve such high efficiencies by depositing several ultra-thin layers of the compound, each containing a different proportion of indium and gallium, onto a substrate. The interfaces between these layers convert different portions of the solar-energy spectrum—from the infrared through the visible—into electricity. That way, most of the available solar energy can be used, not just a small part of it.

But indium gallium nitride has its own peculiar problems, including a large number of crystalline defects and a tendency of the layers to crack during deposition, which Walukiewicz and his group have been addressing. An earlier resolution of this cracking problem in LED manufacturing, achieved in a cooperative-research program with Hewlett-Packard, Inc. and the Xerox Corporation, helped promote the formation of the San Jose high-tech startup Lumileds, now a division

Windows heat test at Berkeley Lab, comparing the heat flow through a standard window and that through a dual-pane window with low-emissivity coatings.



Various proportions of indium and gallium in the semiconductor alloy indium gallium nitride absorb different parts of the solar spectrum corresponding to different "band-gap" energies as measured in electron volts (eV). Thus a solar cell made with multiple layers of this alloy can convert more than half the sun's energy into electricity.

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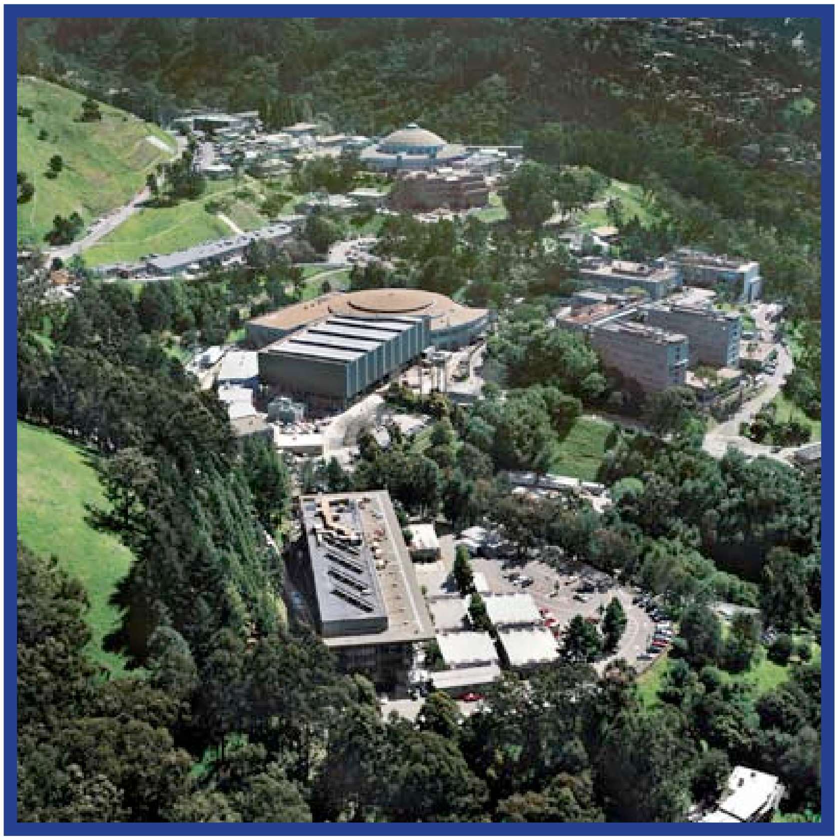
of Philips Electronics. One of the world's leading LED manufacturers, Lumileds holds a large share of the burgeoning multi-billion dollar market for high-efficiency solid-state lighting. These high-brightness LEDs have been rapidly replacing incandescent and fluorescent bulbs for everyday uses such as traffic signals and the backlighting of flat, liquid-crystal video displays—and are about to make major inroads into the markets for automobile headlamps and general lighting of homes and offices.

In 2005 Berkeley Lab initiated the Helios Project, a multidisciplinary research initiative that brings together specialists in nanotechnology, synthetic microbiology and other disciplines to address the conversion of sunlight into electricity, hydrogen, ethanol and other biofuels. Project director Paul Alivisatos figures that manufacturing solar cells economically will almost certainly require applications of nanotechnology—say, by growing semiconductor nanocrystals in vats before assembling them into large sheets. Helios Project researchers are also seeking higher-efficiency methods to transform solar energy bound up in switch grass, rice hulls and other crop wastes into useful ethanol and hydrogen by mimicking the biological digestive processes performed by bacteria found in the guts of termites. This highly innovative research could lead to cellulose-converting enzymes that can be manufactured and employed in large quantities.



Aerial view of Lawrence Berkeley National Laboratory. Most of the Lab's R&D efforts in energy efficiency occur in the group of buildings in the foreground, home of the Lab's Energy and Environmental Technologies Division.

Any of these approaches, if successful, would allow Californians to begin large-scale harvesting of what is by far the state's greatest indigenous energy source—the sunlight falling upon it daily. And that would allow it to do so without adding significantly to the overabundance of atmospheric carbon dioxide widely considered responsible for global warming. Led by its new director, Nobel laureate Steven Chu, Berkeley Lab has redoubled its long-standing efforts to research and develop such "carbon-neutral" energy sources. As he notes, "Energy is the single most important problem that science and technology must solve in the coming decades."

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