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Center for building science News

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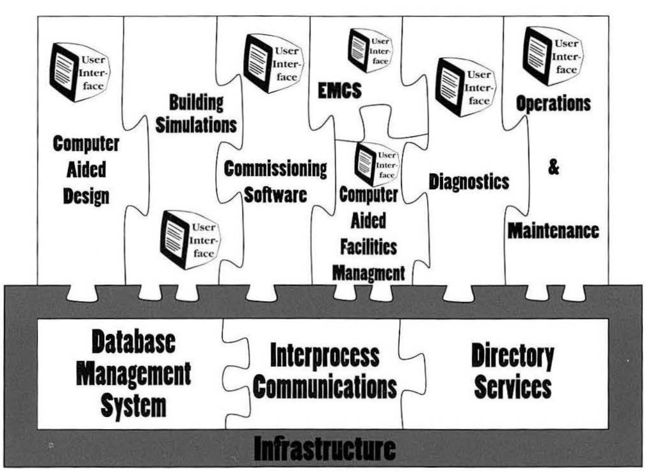
Assuring Building Performance: Creating BLISS

Despite significant advances in building technology and tighter building codes, buildings consume one-third of all energy used in the U.S. at a cost of $200 billion/year. Half of this energy is wasted if one considers the cost-effective measures now achievable. Assuring the highest possible building performance (in health and productivity as well as energy) ought to be a national goal in an increasingly competitive world. Providing designers, builders, and operators with consistent information throughout the life cycle of a building opens opportunities for reaching performance potential. LBL recently initiated an internally funded project to explore these issues, with the goal of creating public-private partnerships to develop workable, cost-effective solutions to assuring building performance.

Commercial building performance consistently falls short of its potential, with costly results to people and institutions. Energy use in commercial buildings accounts for $85 billion per year, more than half of which could be saved if the experience of a few unique, carefully designed and operated buildings could be widely replicated. Occupant health and comfort also suffer in poorly ventilated and conditioned spaces, resulting in lost productivity and a growing incidence of lawsuits.

The goal of the LBL project is to develop and standardize an interoperable set of software tools to correct these problems. The tools will respond to the needs of each phase of a building's life cycle and will be linked by a shared informational infrastructure, the Building Life-cycle Information Support System. BLISS will serve as the backbone of a dynamic data archive for each building. Once the BLISS data archive is established, the marginal cost of supplying additional tools with building data should be small compared to current practice. Interoperable tools that share information should provide considerable efficiencies and cost savings throughout the building life cycle. The tools developed in this project will not be limited to commercial buildings, but because of the existing infrastructure of building operators, computer-assisted design and EMCS, large commercial buildings are the logical first target. The same principles can be applied across the spectrum to single-family residential buildings.



Software tools will link to the BLISS infrastructure

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New Tool for Energy-Efficient Fixtures

Researchers in LBL's Lighting Systems Research Group have been conducting a series of studies on the efficiency of a wide cross-section of CFL fixtures using a newly built apparatus known as a "goniophotometer". 4

Energy and Ventilation Research in Highrise Apartments

Historically, multifamily buildings have been the most neglected building sector for retrofit activity in utility and federal programs, but the last ten years have seen impressive advances in several aspects of improving the energy efficiency of these buildings. 5

Appliance Efficiency Standards, Part 2

Appliance efficiency standards provide a minimum requirement for energy efficiency at the point of manufacture. They seek to overcome market failures—including price distortions, transaction costs, and bounded rationality—which have historically given rise to a gap between observed and attainable product efficiencies. 6

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Creating BLISS

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LBL's early effort will focus on three projects: BLISS, commissioning information tools (CITs), and performance evaluation and tracking tools (PETTs).

Building Life Cycle Information Support System

The goal of this effort is to create a software infrastructure that can be used to share information across disciplines and to link interoperable software tools throughout the building life cycle.

This project has three major elements: 1) to specify the distributed systems software architecture, 2) to build a life-cycle database, and 3) to develop a mechanism to capture design intent. The distributed systems architecture will describe how various building software components will communicate with each other. The building database schema will specify the structure and semantics of the database, providing a common vocabulary for the software components. The data structures will be able to accommodate both object-oriented building descriptions and extensive time-series data from performance tracking tools. BLISS will also be able to capture and represent design intent (goals, specifications, and decisions), a critical set of information that will be updated as the building design evolves. Data on design intent will provide information that is necessary later in the life cycle for successful building commissioning and operations.

Commissioning Information Tools

Commissioning is the process of inspecting and testing a building to ensure that it operates as intended. A cost-effective commissioning process will produce buildings that have lower operating costs while providing a healthier indoor environment that will increase productivity and user satisfaction.

The initial project goals are 1) to develop the conceptual design for a complete CIT, and 2) to develop an operating software module for one building system that is ready for field testing. The software will specify procedures for commissioning, monitoring guidelines, and electronic documentation requirements, along with methods to continue using this information in the operations phase of the building life cycle. The initial focus will be on developing a chiller commissioning module. A new building on the UC Berkeley campus will provide a living laboratory for developing and testing these new tools.

Performance Evaluation and Tracking Tools

The goal of this project is to develop information collection and interpretation systems that allow the building's performance to be continuously evaluated and tracked as part of normal building operation. The first-year effort to produce PETTs will have two elements. The first is development of information resources that describe how the building should perform. This will be accomplished through performance metrics and accessing and updating the design intent and commissioning results inherited from earlier life-cycle phases. The second element will capture how the building does perform, based on real-time data acquired from the building EMCS.

Partnerships

This program cannot succeed without involvement from building-sector partners—as financial sponsors for the next phase of work; as research collaborators; as sources of information where LBNL does not have experience or expertise; and, most importantly, as development partners for the tools and processes in this program. LBNL is actively seeking interested partners to expand this program.

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About the Center

Addressing significant energy-related issues, the Center for Building Science has become an international leader in developing and commercializing energy-efficient technologies and analytical techniques, and documenting ways of improving the energy-efficient technology and indoor environment of residential, commercial and industrial buildings.

The Center is the home of three Energy & Environment Division programs—Building Technologies, Energy Analysis, and Indoor Environment. It serves as a national and international voice for energy efficiency, provides technical support to energy and environmental policymakers, supports and creates institutions and demonstration programs, provides a training ground for students in the energy field, and facilitates transfer of technology and information to the private sector.

Researchers at the Center recognize that despite significant, steady progress since the energy crises of the 1970s, a large potential for energy savings remains to be realized. The Center's interdisciplinary staff studies a wide spectrum of environmental, economic, and technical aspects of energy-efficiency activities, recognizing that energy efficiency is a new and highly cost-effective energy resource.

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News from the D.C. Office

Seminars Explore Energy Policies & Technologies

As part of our effort to communicate with customers and colleagues in the Washington area, the LBNL-D.C. office sponsors a series of breakfast seminars on research and policy topics of current interest. We've held six seminars this spring, each attended by 15 to 25 invited guests from the Department of Energy, the Environmental Protection Agency, the Agency for International Development, nongovernmental organizations, Congressional committee staff, and D.C. staff of other national laboratories.

On March 2, Jim McMahon of LBNL's Energy Analysis Program described LBNL's important contribution to national energy-efficiency standards for appliances. LBNL has provided analytical support to DOE for more than 15 years, contributing significantly to the program's success. LBNL analyses of expected impacts on consumers, manufacturers, utilities, and the environment have improved DOE's understanding of the appliance market and technologies. These detailed analyses will become more valuable to policymakers as some DOE standard-setting shifts to a negotiated rulemaking process. For more information, contact Jim at 510-486-6049 (JEMcmahon@lbl.gov).

Bill Fisk of the Indoor Environment Program presented a talk on March 23 addressing the enormous potential benefit of improving indoor environmental quality in commercial and public buildings. There is considerable evidence that improved indoor environmental quality can reduce infectious diseases, symptoms of allergies and asthma, the symptoms associated with sick building syndrome, and the failures of electronic equipment while enhancing workers' physical and mental performance. The potential productivity gains are on the order of $40 billion per year in the U.S. LBNL is a national leader in laboratory and field research on how to improve indoor environments in an energy-efficient manner. High-quality indoor environments can be attained through a variety of practical, energy-efficient measures, such as better ventilation and air filtration and well-designed lighting. If you'd like more information, you can reach Bill at 510-486-5910 (WJFisk@lbl.gov).

"Sustainable transportation" was the topic of Lee Schipper's seminar on April 26. Co-leader of the International Energy Studies group in the Energy Analysis Program, Lee described sustainable transportation systems as an elusive but critically important goal that involves far more than energy concerns. Transportation has a tremendous impact not only on energy use and pollution, but also on the quality of life in urban and rural areas. This clearly applies to industrial countries, but it is increasingly an issue in developing countries as well. Long-term solutions must be market-based as well as technological. Fuel taxes, "feebates" and other policies that internalize environmental externalities are needed to reduce fuel use and travel growth. Lee sparked a lively discussion of possible market-based pricing policies that the U.S. and other countries could adopt to reduce low-occupancy vehicle use. Contact Lee at 510-486-5057 (LJSchipper@lbl.gov).

Jim Cole, Director of the California Institute for Energy Efficiency, along with Anthony Sebald of UC San Diego and Eng Lock Lee, of Supersymmetry, Inc., presented a seminar on April 28 on CIEE-funded research to improve building energy performance through better diagnostic information and operator feedback. This new collaborative project will explore and demonstrate ways to improve monitoring, data archiving, analysis, and data visualization so that operating problems can be diagnosed quickly and this information can be more usable by building operators. For more information contact Jim Cole at 510-486-4123 (WJCole@lbl.gov).

On May 24, Willett Kempton of the University of Delaware spoke on his recently published book *Environmental Values in American Culture* coauthored by James Boster of UC Irvine. In late June, Alex Bell of LBNL and UC Berkeley led a seminar called "Enhancing the Durability of Automobile Emission Control Catalysts." For details on either talk, call the LBNL-D.C . office at 202-484-0880.

—Nancy Casey-McCabe and Jeffrey Harris

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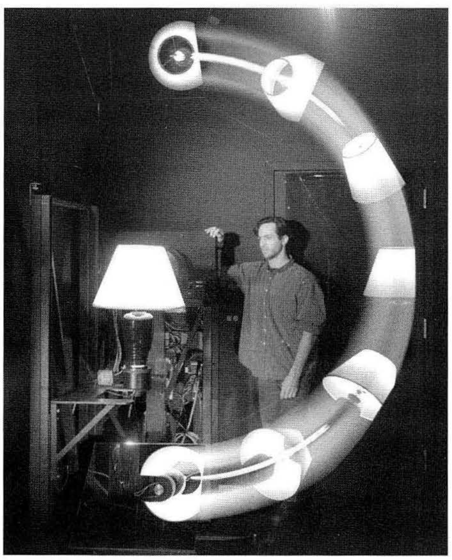
New Research Tool for Energy-Efficient Residential Fixtures

The residential lighting sector represents a significant opportunity for energy conservation because it currently uses inefficient incandescent sources almost exclusively. Compact fluorescent lamps (CFLs) have the potential to transform this market by using one-fourth as much power as an incandescent to provide the same amount of light. While technical advances such as triphosphors and electronic ballasts have addressed issues of color rendition, flicker, and hum, CFLs still face significant market barriers, particularly because of their perceived brightness level in traditional fixture applications. When operated in fixtures originally designed for incandescents, a CFL with total light output equal to an incandescent can appear dimmer because of differences in its light distribution. One type of fixture, the common table lamp, is typically operated for more than 3 hours a day, and thus represents a significant opportunity for energy savings.



Lighting Group researcher Erik Page stands next to the new goniophotometer, shown in a multiple-exposure photo that represents a complete sensor sweep around a table lamp. The lamp is seen reflected in a mirror mounted on a swing arm, aimed at a photocell used for data acquisition.

Researchers in LBNL's Lighting Systems Research Group have been conducting a series of distribution studies on a wide cross-section of CFL fixtures using a newly built apparatus known as a "goniophotometer" (see photograph, left), which can map the amount of light emitted from all angles around a light fixture. The custom-built goniophotometer rotates a large mirror around all angles of a test fixture, allowing light to be reflected from the fixture to a centrally located light meter. The apparatus is fully automated and computer-controlled, enabling researchers to generate highly accurate goniometric light intensity maps of a fixture in less than half an hour. We have collected goniometric data on different light sources (including incandescent bulbs and CFLs of various shapes) operated in standard table-lamp fixtures.

Goniometric results show that CFL orientation plays a significant role in a fixture's perceived brightness. This is illustrated by the chart at right, which shows the candlepower plots of a 100W incandescent, a vertically-oriented 19W triple-tube CFL and a 23W horizontal Circline fluorescent lamp. The plots represent one measurement sweep around the lamp and map out the candlepower distribution in a single vertical plane. Nadir is shown as 0° on the plot and corresponds to readings directly under the lamp, while zenith occurs at 180° and represents readings directly above the fixture. The incandescent lamp in the graph transmits more than 77% of its light straight into the lamp shade (typically in the range from 50° to 140° above nadir). While some of this light is transmitted through or reflected by the shade, much of the light is absorbed, adding to fixture losses. The horizontal Circline lamp sends only 64% of its light into the shade and demonstrates the advantages of focusing output vertically. Horizontally oriented lamps distribute the majority of their flux vertically because of a predominance of horizontal illuminating surfaces. While the incandescent lamp has the larger total bare-lamp light output, the Circline has a much more intense output at the crucial nadir and zenith angles. In effect, fewer total lumens are required to produce sufficient illuminance where it is most needed: at nadir for task lighting and zenith for indirect lighting.

Goniometric results explain why CFLs have traditionally suffered perceived brightness problems. The most common CFLs for table-lamp retrofits have not been horizontal sources that focus flux vertically, but vertical sources that focus flux horizontally. These CFLs direct over 82% of their flux into the shade and suffer associated fixture losses, resulting in a failure to match the lumen output of the incandescent lamps they are intended to replace.

Optimizing fixture geometry and lamp position can significantly increase the efficiency of these CFL fixtures. Ongoing research with the fixture industry seeks to identify and develop efficient source/fixture configurations.

—Erik Page, Michael Siminovitch and Carl Gould

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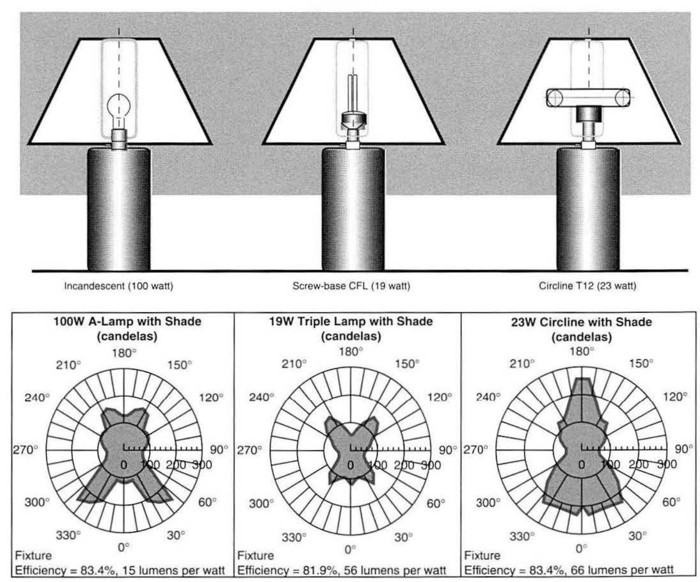

Candlepower plots of incandescent, ordinary CFL, and Circline table lamps

Energy and Ventilation Research in Highrise Apartments:
The Chelsea Public Housing Study

More than 30 million Americans live in multifamily housing. A disproportionate number of them are poor, renters, minority, single parents, and children. While buildings with five or more units account for only 9% of residential energy end-use in the United States, the energy burden—i.e., the percent of household income spent for energy—is several times higher for these households than for single-family households. Historically, multifamily buildings have been the most neglected building sector for retrofit activity in utility and federal programs, but the last ten years have seen impressive advances in improving the energy efficiency of these buildings.

Figure 1. *The Margolis Apartments in Chelsea, Massachusetts, was designed in 1973 and is typical of high-rise construction from that period. This USHUD project is the site of ventilation and infiltration measurements to improve comfort and energy performance.*

A new book, *Improving Energy Efficiency in Apartment Buildings,* by John DeCicco, Rick Diamond, Sandy Nolden, and Tom Wilson, funded by the U.S. Department of Energy and the Energy Foundation and to be published by the American Council for an Energy Efficient Economy in early 1996, documents much of this work. It is the result of collaboration by practitioners and researchers active in multifamily retrofit research. One area that continues to block retrofit efforts has been our lack of understanding of how ventilation and infiltration occurs in these buildings. Unlike single-family buildings, where our knowledge of ventilation and infiltration has benefited from such tools as blower doors and tracer gas measurement, the more complex configurations of multifamily buildings challenge our ability to measure and model the air flows and their resulting energy costs.

We have been working for the past two years at the Margolis Apartments (*Figure 1*), the site of a collaborative venture among DOE, HUD, the Boston Edison Company, and the Chelsea Housing Authority, to demonstrate energy-efficient retrofits of public housing as part of a utility DSM Program.

We made a series of visits to the building in which we performed ventilation and air-leakage measurements using tracer gases and blower doors to determine the performance of the energy-saving retrofits and to determine if adequate levels of ventilation for air quality were being met throughout the building. Following these measurements, we modeled the air flows in this building using the computer simulation program COMIS, which allowed us to understand the complex air flows under different weather conditions.

Our findings to date illuminate the asymmetric nature of the air flows in highrise buildings. Depending on the side of the building and the height above the ground, the unit may be under- or overventilated (*Figure 2*). We have also been studying the relative importance of the stair towers and elevator shafts and how they interact with both the mechanical and natural ventilation in the building. One disturbing finding is that the designed mechanical ventilation often performs poorly, both in exacting a greater energy penalty and in not providing adequate ventilation.

We plan to continue our study of ventilation in highrises by looking at additional buildings and making recomendations for both retrofits and new construction. One goal of this research is to develop protocols and guidelines for measuring and improving ventilation as efficiently as possible.

—Rick Diamond, Helmut Feustel, and Darryl Dickerhoff

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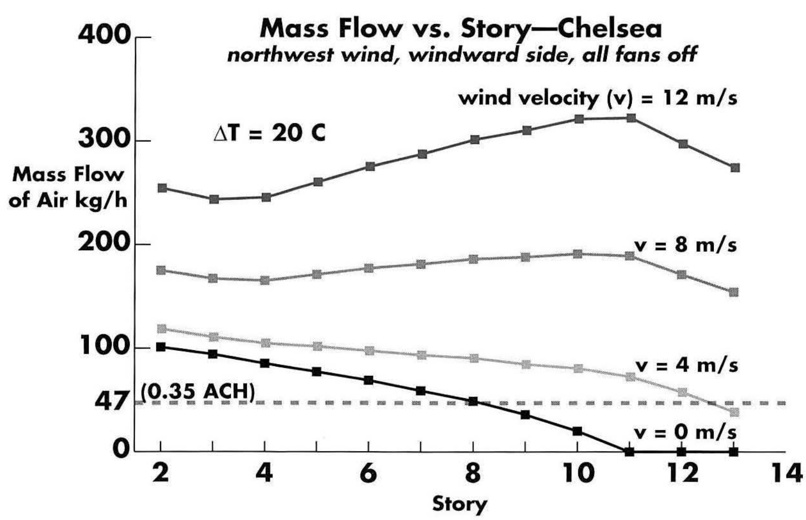

Figure 2. *A simulation of the air flows in the Margolis Apartments under different wind speeds. The model shows that even apartments on the windward side of the building are not receiving sufficient outside air (according to ASHRAE Standard 62, see dashed line) during periods of low windspeed.*

Appliance Efficiency Standards

Part 2 of 2: Policy process and consumer gains

Part 1 of this article (*CBS News*, Spring 1995) discussed LBNL's role in setting federal appliance efficiency standards and presented an overview of the net national benefits of standards. Here, we examine the broader policy context for appliance standards and consumer benefits.

Policy Context

Appliance efficiency standards provide a minimum requirement for energy efficiency at the point of manufacture (or import). These standards seek to overcome market failures—including price distortions and transaction costs—that have historically given rise to a gap between observed and attainable product efficiencies. In this way, appliance standards complement information programs, utility DSM and other incentive programs, and research on new technologies in improving energy and economic efficiencies.

The process of developing standards has evolved since the 1970s, with increasing participation by manufacturers and other interested parties in the early stages of the analysis of standards updates. This extensive participation promotes a standards process grounded in the best information, including proprietary data. Continued discussion between manufacturers and environmentalists, supported by objective analysis, reduces disagreements and helps resolve or bound uncertainties in the data.

The policy process has been especially inclusive for refrigerators—the product for which standards have been most successful. California set the first standards for refrigerators in the late 1970s. These standards were superseded, however, when national efficiency requirements were set in 1987 affecting refrigerators made in 1990. An updated standard, which became effective in 1993, further improved the efficiency of new refrigerators by 15%. A recent consensus agreement, if enacted into law, will improve refrigerator efficiency by another 25% for 1998 new units. This most recent consensus standard was the result of two years of active negotiation among industry representatives at the Association of Home Appliance Manufacturers, environmental advocates at the Natural Resources Defense Council, efficiency analysts at the American Council for an Energy Efficient Economy, and utility and regulatory representatives from the New York State Energy Office, the California Energy Commission, Pacific Gas and Electric, and Southern California Edison.

In energy terms, an average new auto-defrost refrigerator with top mount freezer in 1972 used about 2000 kWh/yr. A new unit in 1990 used about 900 kWh/yr, and in 1993 about 690. In 1998, a new unit will consume less than 500 kWh/yr.

Consumer Savings

For American consumers, energy-efficiency standards translate into dollar savings every time utility bills come due. Looking at refrigerators alone, the average consumer can expect to save about $140 over the 19-year life of a top-mount auto-defrost refrigerator meeting existing standards versus one only meeting initial federal standards (savings in 1993$ discounted at 7% real). Purchasers of models meeting the 1998 consensus standard can expect further savings. Moreover, market data indicate that refrigerator prices have not increased, and that consumer choice has not been restricted as a result of standards.

Adding savings from other appliances meeting federal efficiency requirements only increases the level of consumer gain. Table 1 gives a snapshot of annual energy consumption and cost savings for a list of typical home appliances. Values in the middle column are for appliance models meeting standards set in the National Appliance Energy Conservation Act of 1987 (NAECA).

Table 1. Annual energy consumption and cost comparison

Appliance	1990 stock average annual energy use (kWh)	1994 new unit annual energy use (kWh)
Refrigerator-freezer	1220	670
Freezer	1010	500
Clothes washer[1]	890	670
Clothes dryer (electric)	930	830
Dishwasher	620	500
Room air conditioner	970	830
Gas water heater	300 therms	270 therms
Gas furnace	610 therms	530 therms
Total Annual Energy Use:	5640 kWh 910 therms	4000 kWh 800 therms
Total Annual Costs: ($0.082/kWh & $0.69/therm)	$1,090	$880

[1]Includes electricity consumed in heating water in an electric water heater

The importance of the story told by these figures is that, as time passes, the U.S. stock of appliances will consume far less energy, even as their features and numbers increase. In this way consumers and the environment both benefit from federal appliance efficiency standards.

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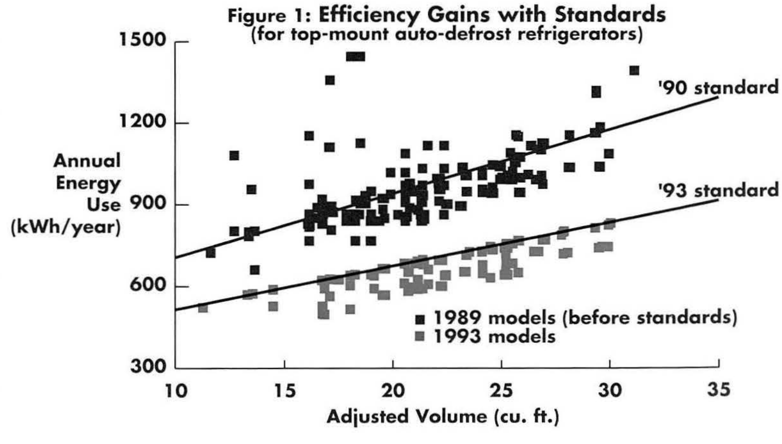
Figure 1: Efficiency Gains with Standards (for top-mount auto-defrost refrigerators)



The Bidirec ional Radiometric Scanner

Center Research Facilities

Saving energy in buildings is increasingly a matter of balancing different efficiency strategies. A building uses less cooling energy during the summer when it has specially coated windows that reduce solar heat gain. But a building with increased daylighting and lighting controls uses less lighting energy throughout the year, suggesting that buildings can harvest significant energy savings with windows that transmit most of their incident visible light. During the winter, solar heat gain through windows also contributes to maintaining a comfortable indoor temperature. But the amount of energy that gets through is determined by the effect of the window plus any shading device, such as a venetian blind—classified as a complex fenestration system.

This complicated interplay of factors requires researchers to have an accurate method of measuring the solar heat gain of any window system, which can include shades, blinds, drapes, and a variety of glazings, tints, coatings, and glass thicknesses. Scientists in the Building Technologies Program developed a solar heat gain scanner to improve research on fenestration systems and to develop a universal rating system for fenestration solar heat gain.

The device, essentially a scanning gonioradiometer, consists of a fixed source of light and a sample mounted on a plane that rotates about a fixed vertical axis relative to the source. The sample also rotates about an axis that is perpendicular to this plane (see photo). An optical collection system is mounted on a semicircular arm that rotates about a vertical axis through the center of the sample. The three elements of this detector system are a collecting mirror, an integrating sphere, and a pair of sensors. Radiation is collected by the mirror and focused onto the entrance of the integrating sphere, which contains a radiometric and a photometric sensor. The sensors collect data on both the wavelength and intensity of radiation coming from the test sample. The data are then amplified and sent to a computer to be recorded.

Joseph Klems and colleagues have been using the scanner to develop a method of calculating solar heat gain that is more reliable than older, calorimeter-based methods. Using the old technique required testing the complex window system in every possible configuration—for example, every possible orientation of its venetian blinds—a prohibitively expensive procedure.

The radiometric scanner measuring the solar optical properties of complex glazings in shading systems.

The Center researchers are testing a faster, simpler way to measure solar heat gain. During the 20-minute procedure, the detector system measures the radiation distribution over the outgoing hemisphere by continuously moving over the detector's vertical arc, which in turn steps through the horizontal outgoing angles; when the outgoing scan is completed, the sample plane is rotated 15° and the measurement repeated for another incident angle. For most systems, characterization over six incident angles is sufficient; for very complicated systems it may be necessary to repeat the 20-minute measurement for multiple rotations of the sample within its plane.

This work is sponsored jointly by ASHRAE and the U.S. Department of Energy, with the goal of establishing a standardized method for measuring solar heat gain analogous to the National Fenestration Ratings Council U-value method. The results to date suggest that this radiometer-based approach provides results at least as accurate as and considerably faster than calorimetric-based methods. Although still under development, the scanner facility can be used in collaborative work with outside organizations; when development is completed, the scanner should be available for privately-funded studies.

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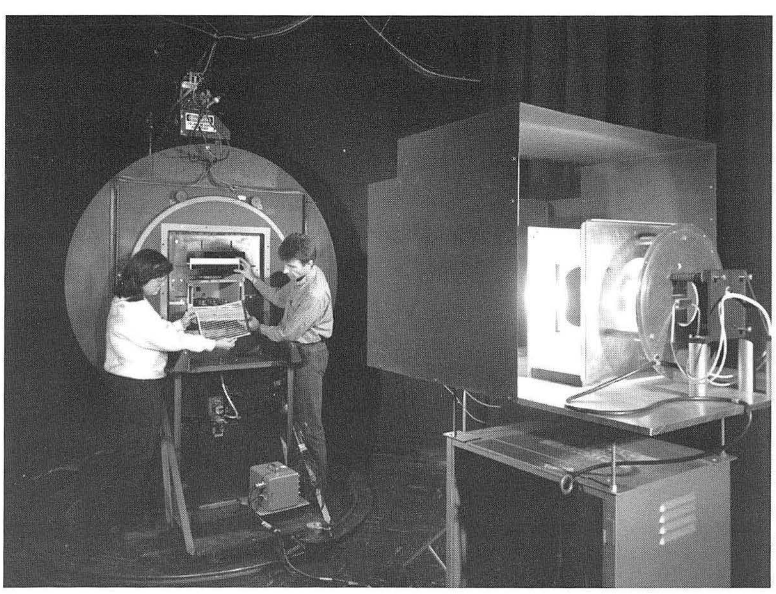

Liliana Beltran and Konstantinos Papamichael (Building Technologies Program) prepare a sample for testing in the scanning radiometer.

Sources

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Energy Efficiency and Renewable Energy Clearinghouse

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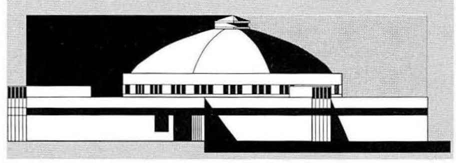
About Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of these nine laboratories, LBNL is located in the hills above the campus of the University of California, Berkeley.

With more than 3,000 employees, LBNL's total annual budget of about $250 million supports a wide range of unclassified research activities in the biological, physical, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, LBNL has had nine Nobel laureates. The Center for Building Science is one of 12 centers at LBNL.



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Center for building science News

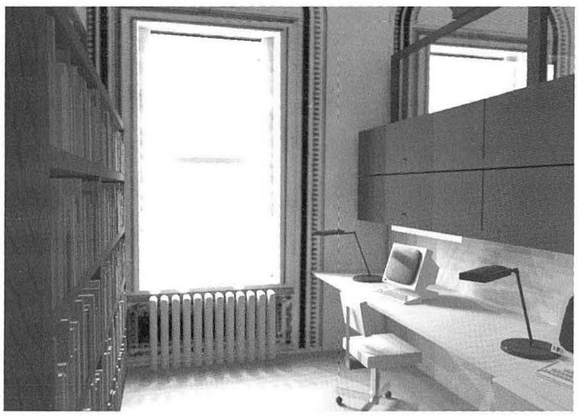
LAWRENCE BERKELEY LABORATORY ENERGY & ENVIRONMENT DIVISION • SPRING 1995

FEMP at LBL

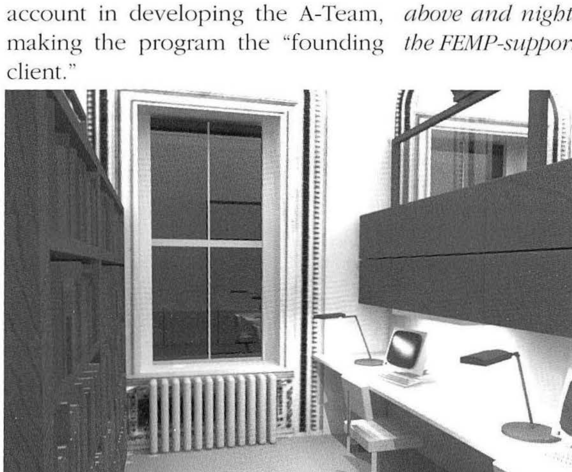
DOE's Federal Energy Management Program is "operations central" for coordinating the federal effort to reduce its own energy use. FEMP plans to use 30% less energy by 2005 then it used in 1985 and conserve water as well. Director Mark Ginsberg has transformed FEMP into a visible resource for federal energy reduction efforts. It helps agencies implement effective programs of their own by creating partnerships, leveraging resources, transferring technology, and providing training and support.

Lab Support Role

FEMP relies on three national labs—LBL, PNL, and NREL—to provide strong technical support, such as expertise in energy technologies; protocols, tools, and guidelines necessary for the program's information base; and effective dissemination programs. The labs also play direct field-support roles by coordinating demonstration projects. FEMP sought LBL's expertise in advanced building technologies, analysis capabilities, and the newly formed Applications Team (*CBS News*, Fall 1994). FEMP's needs were taken into account in developing the A-Team, making the program the "founding client."



These photorealistic RADIANCE simulations of a retrofitted Old Executive Office Building workspace (daytime above and nighttime below) are part of LBL's efforts in the FEMP-supported Greening of the White House project.



Support Activities

LBL's support activities fall into two categories: (1) for the FEMP knowledge base, developing an "infrastructure" of underlying methods, protocols, guidelines, techniques, models, and the means for their dissemination; and (2) designing, coordinating, and managing demonstration projects to motivate the widespread adoption of FEMP's concepts for saving energy. These are implemented in four program areas:

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Appliance Efficiency Standards

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In 1987, the National Appliance Energy Conservation Act established the first national standards for refrigerators and freezers, furnaces air conditioners, and other appliances, and established a schedule for possible updates. The national economy benefits by about $1000 for every federal dollar expended on this program.

Sulfur Lamps—The Next Generation of Efficient Light?

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Sulfur lamps are a revolutionary new light source that efficiently provide a spectrum of light similar to solar radiation. They are long-lived and maintain their efficiency and light output over their entire lifetimes, unlike conventional sources whose outputs typically diminish by 75%.

An Inexpensive CO Passive Sampler

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Indoor Environment Program researchers are developing an inexpensive CO passive sampler designed for large-scale indoor surveys in cooperation with The Quantum Group of San Diego. The technology could also be adapted as an occupational hazard sensor or as a residential warning system.

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FEMP at LBL

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Energy-efficient procurement. Jeff Harris and others in E&E's Washington Project Office have been identifying "off-the-shelf," cost-effective, energy-efficient products to encourage their purchase through standard or innovative procurement channels (*CBS News*, Fall 1994, p. 3). They are also developing strategies to use large-volume federal purchasing to acccelerate the commercialization of more advanced "state-of-the-shelf" technologies. One of the effort's major accomplishments was implementing the Federal Procurement Challenge, a voluntary, governmentwide commitment inaugurated by a White House ceremony.

Design assistance. FEMP is working to remove a major stumbling block for facility managers—not knowing how to define and design a project successfully—by providing design assistance. E&E's Rick Diamond is coordinating LBL's effort to develop information guidelines on specific subjects (e.g., window films) that discuss the issues, pitfalls, recommended courses of action, product vendors, and additional sources of information. Another design assistance project is to evaluate existing energy resource centers, established by utilities to support customers in DSM programs, to determine what is most useful to the federal sector.

Advanced technology demonstrations. These include performance measurement and accelerate acceptance by the federal community. LBL's Francis Rubinstein and Steve Selkowitz are helping design and implement lighting and windows technology demonstrations.

Measurement and verification. Energy Savings Performance Contracts with third parties are an important way of providing necessary capital for facility retrofits. Energy service companies make their profits from a share of the energy and cost savings streams. Recent work by Steve Kromer in the Energy & Environment Division's Washington D.C. office, and now Brad Gustafson, is establishing for those contracts a sound financial basis for both parties through measurement and verification protocols that reliably measure pre- and post-retrofit performance.

Projects, Projects, Projects

Highly visible success stories are a major FEMP strategy, and LBL, with significant involvement of its A-Team, is working on the following:

Presidio. The transition of the Presidio of San Francisco from the U.S. Army to the National Park Service provides a major opportunity to design and implement a comprehensive energy performance upgrade, in keeping with the NPS's intention to develop the Presidio into a community of tenants and activities supporting sustainable development. Last October, during the transition ceremonies, DOE and NPS signed an agreement giving FEMP responsibility for providing technical support.

The A-Team's Dale Sartor spent a year on assignment at the Presidio, where he developed a comprehensive energy plan for the site and negotiated a major DSM contract with Pacific Gas & Electric Co. to provide funding for the energy overhaul and a role for LBL in coordinating the effort. Early efforts involve site energy audits and the design and implementation of a measurement and verification data backbone. The first retrofit projects will include buildings housing the Gorbachev Foundation and the Tides Foundation, along with parts of the Letterman medical research complex. They will also demonstrate how such projects can be financed through Energy Savings Performance Contracts.

Greening of the White House. LBL was part of an audit and design strategy team tasked with retrofitting the White House and adjacent Old Executive Office Building. Specialized audits of lighting and windows and design recommendations followed, based in part on analysis performed with the RADIANCE model, as shown on page 1 (also see *CBS News*, Summer 1994).

FEMP's efforts have already reduced federal energy costs by half a billion dollars in two years, and these numbers can be improved substantially. California's large federal presence and progressive utilities make the state a major FEMP regional target, and LBL expects to play a large role in helping FEMP meet its goals.

—*William Carroll*

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About the Center

Addressing significant energy-related issues, the Center for Building Science has become an international leader in developing and commercializing energy-efficient technologies and analytical techniques, and documenting ways of improving the energy-efficient technology and indoor environment of residential, commercial and industrial buildings.

The Center is the home of three Energy & Environment Division programs—Building Technologies, Energy Analysis, and Indoor Environment. It serves as a national and international voice for energy efficiency, provides technical support to energy and environmental policymakers, supports and creates institutions and demonstration programs, provides a training ground for students in the energy field, and facilitates transfer of technology and information to the private sector.

Researchers at the Center recognize that despite significant, steady progress since the energy crises of the 1970s, a large potential for energy savings remains to be realized. The Center's inter-disciplinary staff studies a wide spectrum of environmental, economic, and technical aspects of energy-efficiency activities, recognizing that energy efficiency is a new and highly cost-effective energy resource.

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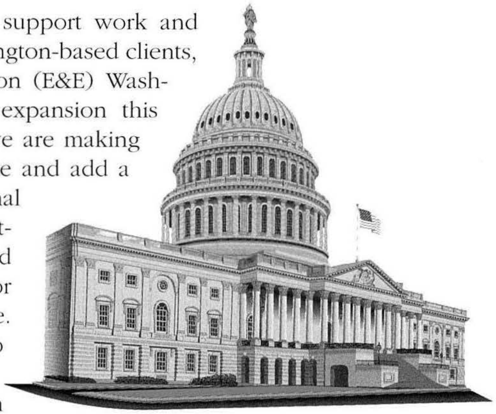
News from the D.C. Office

Expansion



With a growing amount of project support work and increasing contacts with our Washington-based clients, the Energy & Environment Division (E&E) Washington Project Office is preparing for an expansion this spring. Two years after the office opened, we are making plans to more than double our present space and add a second meeting room, as well as additional demonstrations of efficient lighting, daylighting, and office technologies. The expanded space will be located either on a different floor of our current building at 1250 Maryland Ave. SW or in another building equally close to DOE headquarters.

The Project office was established in Spring 1993 to enhance the Division's capabilities and performance by:

- Maintaining close contact with DOE and other Washington-based clients to help us better understand their needs and desires and transmit this information to E&E researchers and management.
- Working to help LBL staff design and manage projects that respond effectively to our clients—often in close cooperation with other labs.
- Participating directly, through LBL staff based in the Washington Project Office, in carrying out LBL projects that benefit from closer interactions with DOE Headquarters and with other agencies in Washington.
- Transmitting to existing and prospective clients information about LBL's technical capabilities and the results of recent and ongoing research.

The Project Office provides logistics support to LBL personnel who are in Washington either for short visits or on extended assignments. Located within walking distance from DOE and the Washington offices of five other national labs, the office also demonstrates some of the energy-efficient lighting and equipment technologies developed at LBL or supported by LBL analyses.

When it started in 1993, the Project Office was staffed with two LBL employees and an office manager. We expected to have room for three to four years' growth. Instead, our success in supporting Berkeley staff while in Washington, and in identifying projects that benefit from close proximity to DOE and other sponsors, has all but filled the available office space within two years. Recent project additions include international energy-efficiency projects in developing and industrial countries, analysis of energy-efficient federal and state purchasing, and measurement and verification of energy savings in federal buildings. Other LBL programs are also considering plans to conduct policy analysis and related activities through the Project Office.

Significantly, the LBL Director's Office, in consultation with other divisions, has decided to follow the lead of the Energy & Environment Division and participate in staffing and managing the expanded Project Office—with a broader mission of representing all LBL Divisions. As a result, we hope to see many more people from LBL—and their colleagues and guests—taking advantage of our expanded facilities beginning this summer.

—Jeff Harris

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Appliance Efficiency Standards

Part 1 of 2

In the National Energy Policy Conservation Act (1978), Congress required DOE to set energy-efficiency standards for 13 residential appliances if technologically feasible and economically justified. In 1987, the National Appliance Energy Conservation Act (NAECA) established the first national standards for refrigerators and freezers, furnaces, air conditioners, and other appliances and established a schedule for possible updates. It was supported by manufacturers largely because it eliminated disparate state standards. The legislation was also supported by environmental and consumer groups, received broad bipartisan support in Congress, and was signed into law by President Reagan. Subsequent amendments added fluorescent lamp ballasts, and the Energy Policy Act of 1992 (EPAct) added lamps (incandescent and fluorescent), small electric motors, office equipment, and plumbing products.

LBL's Role

The Center's Energy Analysis Program has been a contractor to DOE since 1979 and the prime contractor for engineering and economic analysis of appliance standards since 1982. Currently about 25 people work on this project, including six scientists. LBL's role is to provide economic and technical analysis of alternative standard levels in support of the DOE, which selects the standard levels that ultimately become law.

The analysis of appliance standards includes:

- Engineering analysis: What design changes could save energy, and how much energy? The analysis includes using manufacturer and other researchers' data, developing or modifying simulation models (e.g., for thermal performance of a refrigerator, air conditioner, or water heater), calculating energy savings, and researching manufacturing costs.
- Economic analysis: What are the national impacts from the perspectives of consumers (net effects of increased equipment price and decreased energy expenditures), manufacturers (units sold and profitability), and utilities (lost revenues, but deferral of new capacity)? The analysis includes forecasting models for energy used in U.S. residential and commercial buildings through 2030, financial models of prototypical manufacturers in each industry, and estimates of reduced energy sales and of deferred requirements for new power plants.
- Environmental analysis: By how much will CO_2, SO_2, and NO_x emissions be reduced?

Analytical Results

Appliance standards have beneficial economic and environmental effects. The projected economic effects of standards to date (including original legislation and updates) include the following:

- The national economy benefits by about $1000 for every federal dollar expended on this program.
- Consumer benefits exceed costs by about 2.5 to 1. For residential appliances, the net present value (the benefits that result for consumers after subtracting the extra cost of more efficient appliances from the total energy savings) is $53 billion (1990$, discounted at 7% real) projected from 1990-2015 from the NAECA standards and its updates on refrigerators and freezers, washers and sryers, and dishwashers.
- For lamps, the net present value of the standards in EPAct is $56 billion (1990$, discounted at 7% real, 1995-2030).
- Proposed rules, including those applying to ballasts and water heaters, if finalized, will save consumers an additional $66 billion (1990$ net present value at 7% real, 1996-2030). Public comments on these proposals are being analyzed, and new proposals for other appliances are expected in 1995.

The results from NAECA and updates that have already become law, and not counting EPAct or proposed rules will be:

- Cumulative energy savings (1990-2015) of 23 Quads, equivalent to 1.4 years of U.S. residential energy use.
- Deferred electricity generating capacity by 2015 equivalent to 21 GW, equivalent to 42 500-MW power plants. Proposed further standards could defer another 37 GW.
- Reduced environmental impacts (1990-2015) approach 400 million tons of carbon, 3.3 million tons of NO_x, and 5.0 million tons of SO_2, amounting to 2% of total U.S. emissions.

The second part of this article, to appear in the summer issue, will explore the policy context of appliance standards and describe the success of energy efficiency standards for refrigerators.

—Jim McMahon

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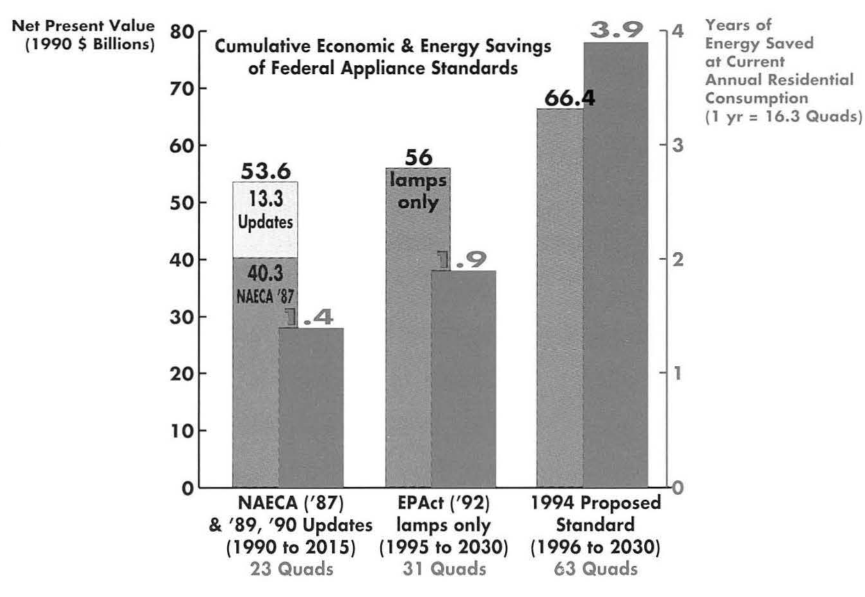
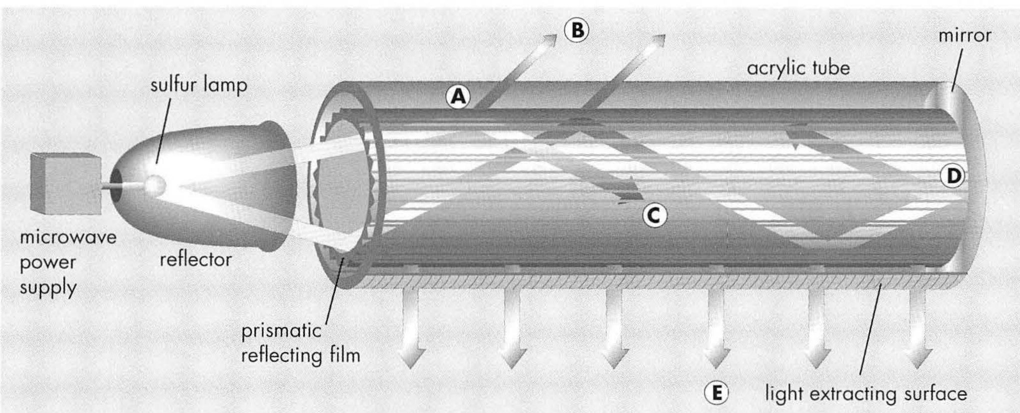


Sulfur Lamps— The Next Generation of Efficient Ligh ?

In 1994, DOE announced that a new, highly efficient lighting system was illuminating the exterior of the Forrestal Building in Washington, D.C., and the Space Hall of the Smithsonian's National Air and Space Museum. The new system is a technological breakthrough that couples high-power sulfur lamps to a light pipe system that distributes the light. The lighting of the two buildings is the first working U.S. example of the high-power version of the sulfur lamp. In these installations, a hollow pipe distributes focused light from the sulfur lamp evenly over large areas.



The figure above *is a schematic of the system installed at the National Air and Space Museum and the DOE headquarters in Washington, D.C., Light from the sulfur lamp is focused by a parabolic reflector so that it enters the light pipe within a small angular cone. Light travels down the pipe, reflecting off the prismatic film (A) that lines the outer acrylic tube. The prismatic film reflects the light through total internal reflection (C), an intrinsically efficient process. Some of the light striking the film (at A) is not reflected and "leaks out" of the pipe walls (B), giving the pipe a glowing appearance. A light ray that travels all the way down the pipe will strike the mirror at the end (D) and return back up the pipe. A special light-extracting surface (another type of reflecting film) is used to draw the light out of the pipe in a controlled manner to where it is most needed (E).*

The sulfur lamp bulb consists of a spherical quartz envelope filled with a few milligrams of sulfur and an inert noble gas, such as argon, which is weakly ionized using microwaves. The argon heats the sulfur into a gaseous state, forming diatomic sulfur molecules, or dimers. The dimers emit a broad continuum of energy as they drop back to lower energy states—a process called molecular emission. Molecular sulfur emits almost entirely over the visible portion of the electromagnetic spectrum, producing a uniform visible spectrum similar to sunlight but with very little undesirable infrared or ultraviolet radiation. Conventional mercury lamps and most other high-intensity discharge (HID) sources are built around atomic emission and produce an artificial-looking light with many missing colors.

Unlike conventional sources whose outputs typically diminish 75% over time, sulfur lamps will maintain their efficiency and light output over their entire lifetimes. By eliminating the need to compensate for lamp lumen depreciation, fewer sulfur lamps can provide a required light level, possibly for long lives of up to 50,000 hours. In addition, sulfur lamps contain no mercury, an environmentally toxic substance used in all other conventional efficient sources.

The sulfur lamp was developed originally by scientists (now at Fusion Lighting in Rockville, Maryland) who discovered that sulfur excited by microwave energy could be used in place of mercury in ultraviolet industrial lamps to produce a high-quality white light. These lamps operated at power and light output levels (3.5 KW input and 450,000 lumens) too high for most commercial applications. The high wattage required air-cooling and spinning the lamps to operate them. Applying their expertise in electrodeless discharge lamps, LBL researchers developed lower-power lamps using radio frequencies instead of microwaves. In 1993, they demonstrated an RF-driven sulfur lamp that produced up to 15,000 lumens with an RF input of only 100 watts—a luminous efficacy of approximately 150 lumens per RF watt. While the lamps still needed to be rotated, lower-power operation allowed the air cooling to be eliminated. Although they are prototypes, the first-generation lamps at the Forrestal Building and the National Air and Space Museum are nonetheless energy-efficient. The Forrestal Building's 280-foot light pipe and two sulfur lamps replaced about 280 mercury HID fixtures, resulting in a measured energy savings of more than 65% and saving DOE approximately $8000 annually in energy costs. Because the sulfur lamp system replaced an old mercury system at the end of its maintenance cycle, the new light levels were roughly four times those of the old system. Maintenance costs are also lower, saving an additional $1500 per year.

DOE is funding Fusion Lighting through LBL to develop a microwave-operated, high-power sulfur lamp of 1000 watts, producing 125,000 lumens. It is best suited for applications like sports stadiums, convention centers, aircraft hangars, large maintenance facilities, highway and street lighting, and shopping mall and industrial lighting. Another DOE-funded project at Fusion Lighting is aimed at developing a commercial RF-driven sulfur lamp at lower power (50-100 watts)—small enough for use in homes and commercial buildings.

—*Francis Rubinstein*

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An Inexpensive CO Sensor

Carbon monoxide is a colorless, odorless, toxic gas whose primary source indoor is the incomplete combustion of fossil fuels. This gas can be a potential problem in any house that uses combustion appliances for space or water heating, cooking, or idling an automobile in an attached garage. Although most appliances work correctly, a problem can exist in houses when the appliance is unventilated or its ventilation system does not properly eliminate exhaust gases from the house. Since Americans spend 90% of their time indoors and 65 to 70% in their residences, understanding how and when CO builds up indoors could save lives. We have very little systematic data on how CO hazards are distrubuted in the indoor environment, but mortality data from the Centers for Disease Control in Atlanta suggests that the lifetime risk of unintentional fatal CO poisoning indoors is about one in 3,000. This is 300 times greater than the risk at which the Environmental Protection Agency regulates toxic chemicals such as benzene.

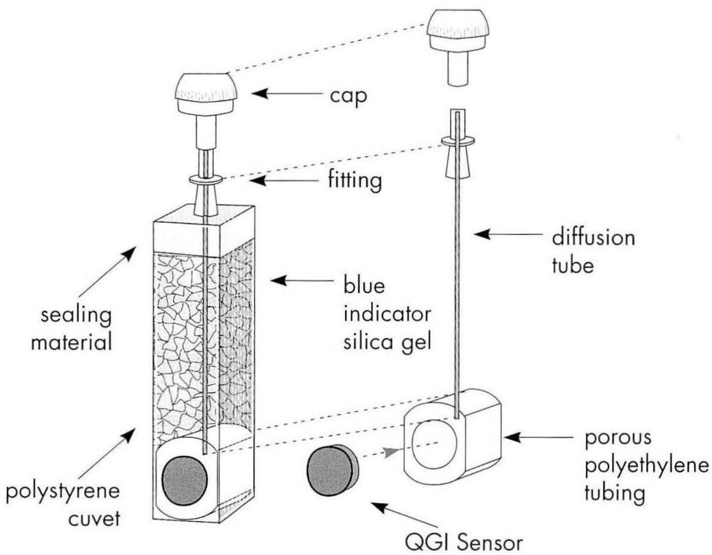
Last year's death of tennis star Vitas Gerulaitis by CO poisoning from a faulty space heater focused public attention on the danger of carbon monoxide poisoning. More than 12,000 carbon monoxide poisonings were reported to the American Association of Poison Control Centers in 1993, but the Association believes this represents only a fraction of the actual number of events—often, nonfatal poisonings are misdiagnosed as flu or other afflictions.

Each year, about 1,500 deaths result from CO poisonings. Of these about 1000 are from CO emissions caused by malfunctioning, incorrectly installed, or misused combustion appliances such as furnaces and gas ranges, by the improper indoor use of outdoor appliances like barbecues, and by operating automobiles or generators in garages.

The possibility of hazardous CO exposure is greater in houses that have been sealed to improve their energy efficiency if precautions were not taken. CO from vented combustion appliances can enter a home through a cracked heat exchanger, a blocked vent, or by appliance "Backdrafting." Backdrafting is a reversal of the normal appliance ventilation flow; outside air is pulled through the appliance vent and hot combustion gases flow into the indoor environment. This potentially serious situation can occur when the vented gas appliance is located indoors and the house is severely depressurized through the operation of an unbalanced forced-air heating system, or if powerful exhaust fans such as range hoods or bathroom fans are used, or even when a large fire is built in a fireplace. Although not every house has a backdraft problem, it's best to call in a professional when one is suspected. The gas company or a heating contractor can test for CO and recommend such measures as changes to the ventilation system or appliance repairs to remove the hazard.

One reason for the lack of research on CO hazards in the United States is the absence of a simple, inexpensive way to measure its concentration in the field. Mike Apte and Greg Traynor, Indoor Environment Program researchers, are developing an inexpensive CO passive sampler designed for large-scale indoor surveys in cooperation with The Quantum Group of San Diego. The technology could also be adapted as an occupational hazard CO sampler or as a residential warning system that would turn off combustion appliances when CO reached dangerous indoor levels.

The prototype passive sampler consists of a flat disk with a chemical coating that darkens when exposed to CO. The disk is housed within a sealed vial filled with silica gel, a substance that removes moisture (which could interfere with accurate measurement) from the air. A narrow diffusion tube with known dimensions brings external air to the sensor disk. The sampler is exposed to air for one week or less and is then analyzed using a spectrophotometer to measure a "time-averaged" CO concentration. Researchers have conducted preliminary tests at an outdoor location, a parking garage, a toll both, a residence with a gas range, and in an environmental chamber. They compared the passive sampler to a standard analytical measurement technique and found that the prototype sampler was accurate to nearly 1 ppm at low concentrations (< 5 ppm) and to within 20% at higher levels. The sampler can eliminate the need to test each site using expensive equipment and trained technicians. For example, a public health department or gas utility conducting a hazard study could mail the sampler to customers, who could use it in their homes for a week and then mail it back for analysis.



A schematic of the prototype CO passive sensor.

The team's plans include further refining and field-testing, making the sensor widely available through commercialization, and using it for large-scale field studies of residential and occupational environments. Eventually researchers hope to conduct regional field surveys to characterize the distribution and magnitudes of CO hazards in homes.

—Allan Chen

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The Geographic Information Systems Laboratory

Center Research Facilities

Visualization using geographic information systems (GIS) can be an indispensable tool of the energy analyst. Patterns that were once hidden in impenetrable numbers reveal themselves when they are plotted superimposed on such maps as terrain, climate, population density, and utility service area. Another important use of the GIS is combining data sets with dissimilar geographic boundaries. Now, an effort is underway in the Center to use the power of GIS to understand everything from regional patterns of appliance energy use to the effects of climate on energy-saving strategies.

Geographic information systems are not just maps, they are relational databases linked to geographic features that help users better query and visualize relationships among data and make those relationships easier to present. Researchers in the GIS Lab use SUN workstations—including a SPARC 20 and SPARC 1—Calcomp 9500 digitizer, a 486 PC, and several types of GIS software, primarily ARC/Info and Earth Resources Data Analysis System. ARC/Info is a vector-based GIS program produced by the Environmental Systems Research Institute; the ERDAS is a raster-based system. The vector-based GIS is better adapted for political boundaries and discontinuous data. However, ERDAS has superior image-processing capabilities.

The GIS's ability to manipulate, organize, and display detailed information about appliance type and ownership, demographic variables, and energy use has been invaluable to its users in the Energy Analysis Program's appliance standards group. The GIS is helping researchers fine-tune the appliance energy standards they are developing under a Congressional mandate, the National Appliance Energy Conservation Act. When completed, these standards will require 13 appliance types to meet uniform minimum energy-efficiency requirements in the U.S. Susan Mahler, Jim McMahon, and Xiaomin Liu are using the GIS to model the effects of proposed national appliance standards, examining the effects of different climates on energy consumption and studying the economics of efficient technologies in regions with differing energy prices.

Rich Brown and Jonathan Koomey are using the GIS for targeted marketing of energy-efficient residential products as part of a project funded by the Environmental Protection Agency. This project is helping the EPA design effective energy efficiency programs. They are developing a detailed, GIS-based model to identify regions and market segments in which energy-efficient technologies are technically feasible, cost-effective, and acceptable to consumers. The EPA then applies this information to the design of programs targeted at the most attractive market segments. The GIS allows the researchers to compile and understand larger, more detailed data sets than they have worked with in the past. This is critical to defining the appropriate markets for energy efficiency program implementation.

Xiaomin Liu used ERDAS to create a different type of GIS database for the Center's Heat Islands/Cool Communities Project (*CBS News*, Spring 1994, p. 6). Liu and Haider Taha created a database of the albedo (surface reflectivity) of Southern California using images taken from the AVHRR satellite. They worked with the albedo data in a meteorological model to simulate the Los Angeles basin's climate, including its temperature field. With an urban airshed model, they produced a map of ozone concentrations for the basin. The research will produce a better understanding of how air quality correlates with air temperature.

Others researchers are using the GIS Lab's capabilities to study indoor radon concentration in the U.S., and analyze thermal emissions in the Sacramento area. A project to analyze energy policy in China is in the formative stages.

—*Allan Chen*

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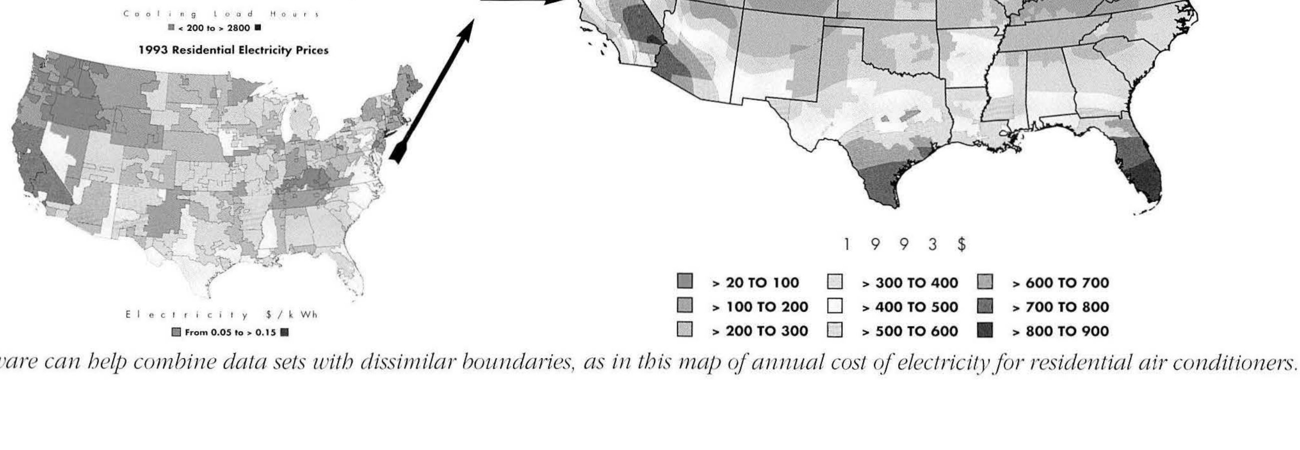

GIS software can help combine data sets with dissimilar boundaries, as in this map of annual cost of electricity for residential air conditioners.

Sources

EREC
Energy Efficiency and Renewable Energy Clearinghouse

If you have questions about:

- Passive solar home design
- Energy-efficient appliances
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- Home heating options
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- Solar, wind, and small-hydro technologies
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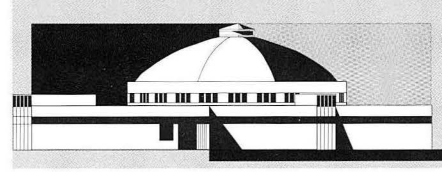
About Lawrence Berkeley Laboratory

Lawrence Berkeley Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of these nine laboratories, LBL is located in the hills above the campus of the University of California, Berkeley.

With more than 3,000 employees, LBL's total annual budget of about $250 million supports a wide range of unclassified research activities in the biological, physical, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, LBL has had nine Nobel laureates, more than all the other U.S. national laboratories combined. The Center for Building Science is one of 12 centers at LBL.



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