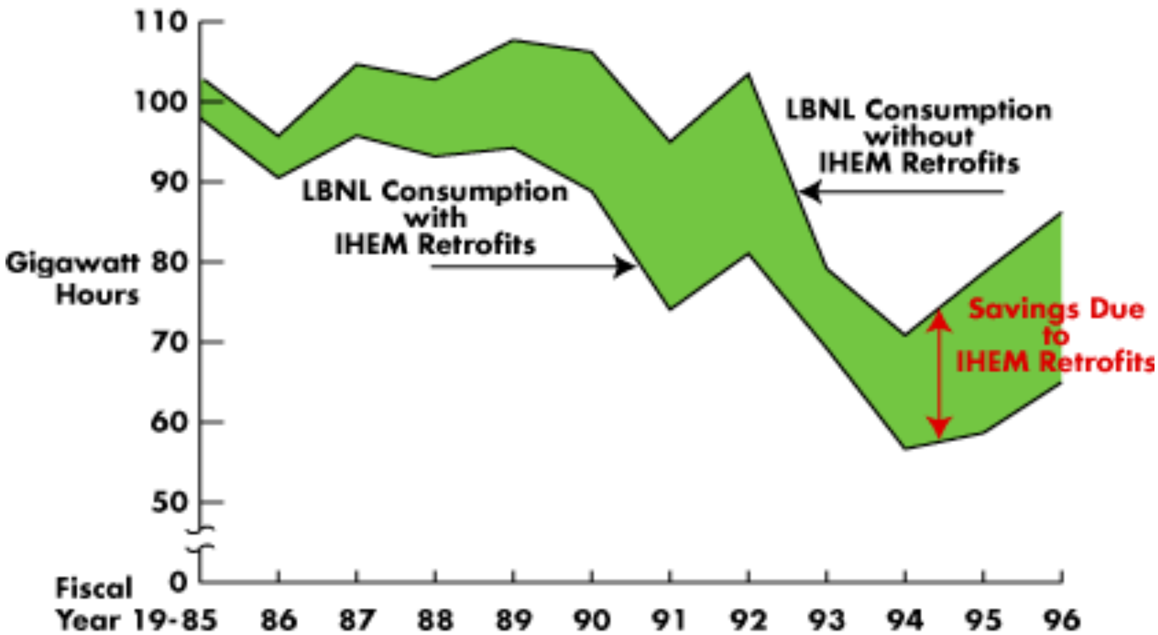
CBS Newsletter
Spring 1997
pg. 1

LBNL's In-House Energy Management Program



IHEM retrofit projects save Berkeley Lab $2.3 million per year in electricity costs. The increase in energy use after 1994 reflects the start-up of new experimental facilities.

Technologies developed at Lawrence Berkeley National Laboratory's Center for Building Science have helped energy users in the U.S. and throughout the world save energy since the 1970s. To save energy and money by applying energy-efficient technology and practices in its own facilities, as well as set an example for the rest of the world, Berkeley Lab launched an energy-savings program in 1985. The efforts of the In-House Energy Management Program (IHEM) have led to an annual savings of $2.3 million in energy costs at Berkeley Lab. Additional benefits include reduced maintenance from capital equipment improvements (far surpassing federal energy use reduction goals for government agencies), decreased pollution, improved worker productivity, and the dissemination of knowledge about energy-efficient technologies.

Success at Home

"IHEM meets its energy-saving objectives by first performing studies to identify energy-efficiency retrofit projects, and then managing the retrofit projects that are found to be cost-effective," says IHEM section chief Doug Lockhart. Since 1985, the organization has conducted more than 40 studies on Berkeley Lab facilities. Between 1990 and 1995, IHEM implemented 27 projects, that collectively saved an estimated 94,250 million BTUs-more than 28 percent of the Lab's annual energy consumption before the retrofit.

"Since 1985, IHEM has reduced the Lab's energy use by 41 percent through the 1996 fiscal year. This figure exceeds a federal goal for all agencies to reduce their energy use 10 percent within the same period," says Lockhart. Berkeley Lab's utilities cost $3.86 million in the 1995 fiscal year. The programs managed by IHEM are saving the lab $2.3 million per year.

In addition to two architecture and engineering firms, IHEM also draws on the Center's many researchers in energy-efficient technology and program design. This cooperation led in 1994 to the creation of the Applications Team (Fall 1994, p. 1), a joint venture intended to speed the deployment of energy-efficient technologies and financing programs in markets throughout the U.S.

IHEM's retrofits are too numerous to list, spanning the full array of available energy-efficient technologies. Berkeley Lab's wide variety of buildings ranges from temporary office trailers to specialized laboratory buildings to large multilaboratory structures with complex lighting, HVAC, and energy requirements. IHEM's efforts have included lighting, motor, and HVAC retrofits (Summer 1994, p. 5); chiller upgrades and replacements; and the installation of variable-speed drives and improved energy monitoring and control systems (EMCS).

One example of the program's willingness to adopt a new technology is its push toward more energy-efficient lighting. "IHEM standardized the Lab on T-8 fluorescent lighting and installed it throughout the Lab when it was still an emerging technology," according to Lockhart. In a retrofit of emergency exit signs, IHEM adopted LED signs that are up to three times as efficient as their incandescent counterparts.

In the area of controls engineering, IHEM engineers oversaw the installation of an EMCS with more than 8,000 monitoring and control points, with another 2,000 to be installed. All research at the Lab that requires HVAC controls, laboratory pressurization, and central plant equipment is tied into this system, which optimizes energy use and maintains energy services at a high level of quality. The group also analyzes utility bills to ensure that the Lab's energy charges are accurate, and manages an employee energy-awareness program.

Environmental Benefits

In addition to the energy benefits of IHEM's work, there are other environmental benefits. For example, eight retrofit projects completed in 1996 saved more than 16 million kWh in energy annually and reduced the emissions from fossil-fuel power plants by 8,200 tons of carbon dioxide, 9,000 tons of sulfur dioxide, and 12,300 tons of nitrogen oxides. Replacing an old chiller with new, efficient technology also reduced the CFCs in use at the Lab, and a refrigerant recovery program helped ensure that refrigeration equipment was well maintained, to prevent CFC leakage.

Future Plans-Working Outside the Lab

As the number of new opportunities to save energy at Berkeley Lab decreases, IHEM staff members are focusing more on the outside world through the Applications Team. These projects include developing an energy measurement and verification protocol (Winter 1996, p.8), retrofiting the federal building in San Francisco (Winter 1997, p. 4), developing a design guide for energy-efficient labs (Fall 1996, p. 8), and collaborating with the Federal Aviation Administration and the National Park Service (Fall 1995, p. 8; Winter 1997, p. 8).

"With the terrific support we've had from the DOE IHEM program, and now from the Federal Energy Management Program, we are in a unique position to leverage our expertise in ways that will effect a reduction in federal energy use nationwide," concludes Lockhart.

—Allan Chen

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This work is supported by the Federal Energy Management Program.

CBS Newsletter
Spring 1997
pg. 3

News From the D.C. Office

Monitored Savings from Energy-Efficient Lighting in D.C. Office

More on the DC Office efficiency up-grade: Office Equipment: Part 1, Part 2

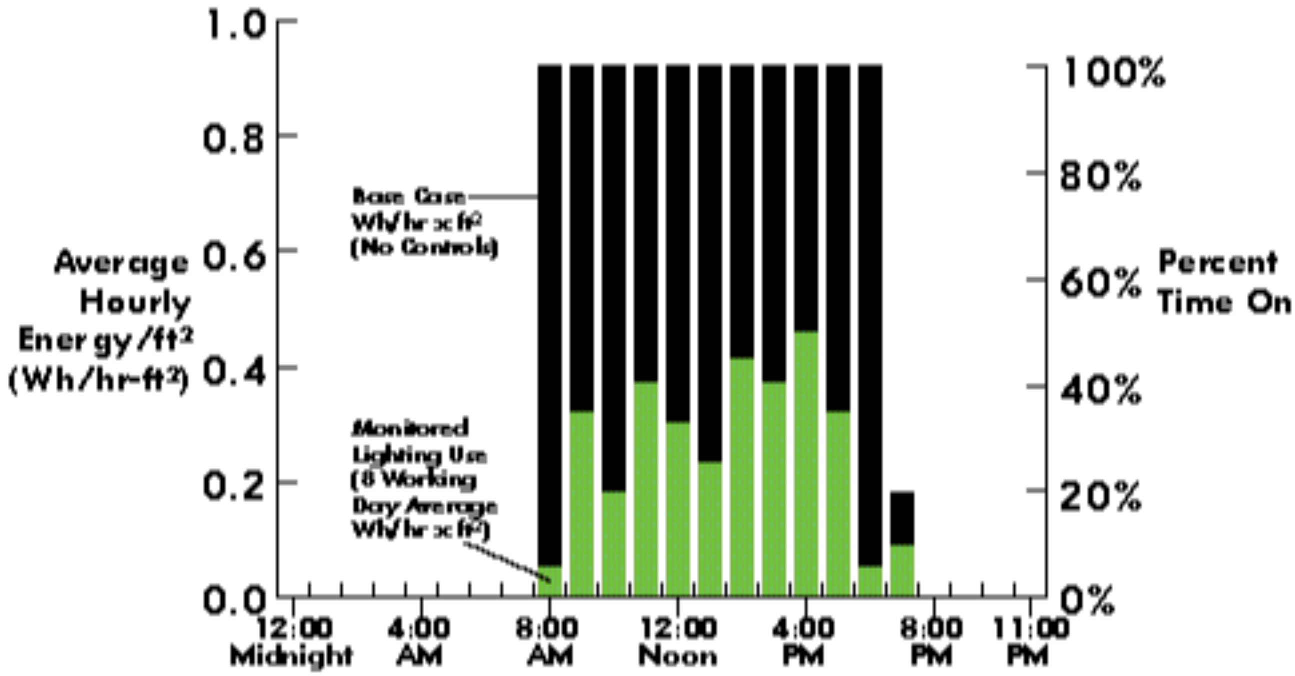

Figure 1: Lighting energy use profile for a typical exterior office.

Berkeley Lab's office in Washington, D.C. is located a few blocks from DOE headquarters, in a five-year-old office building constructed mainly for lease to Federal agencies and their contractors. Despite its recent vintage, the building's standard lighting specifications were far from today's best, cost-effective practice.

In designing the build-out plans for offices and meeting rooms in our 7,500-square-foot suite, we wanted to showcase some of the energy-efficient lighting and office equipment developed for DOE's Building Technologies program by LBNL, other laboratories, or private industry. The lighting design strategy comprised three elements: more efficient lighting equipment to reduce average lighting power densities, occupancy and daylighting controls to avoid unnecessary on-time, and effective design to take advantage of daylight and task lighting. Overall, these measures saved more than 50 percent (about 11,000 kWh/yr) compared with a building's original design.

An important part of the Lab's "practice-what-we-preach" approach was to monitor the actual performance and energy savings of these efficiency features. To streamline both the monitoring and data analysis, we used battery-powered data loggers and a user-friendly commercial software package. The results of this mini-study are discussed in this article; a future article will present savings from energy-efficient office equipment and appliances.

Efficient lighting equipment: The recessed ceiling fixtures were rewired to replace the T-12 fluorescent lamps and magnetic ballasts with high-frequency electronic ballasts and efficient, smaller-diameter T-8 lamps. This rewiring reduced power per fixture by 20 percent, from 110 watts to 88W. If the conversion of recessed ceiling fixtures to T-8 lamps and electronic ballasts were the only retrofit applied throughout this 440,000 ft^2 office building, the annual savings would be about 290,000 kWh, worth $27,000/year to the building owner. We also selected thermally optimized compact fluorescent down-lights and wall-washers as well as low-power LED (light-emitting diode) exit signs, all of which meet the new Energy Star efficiency criteria as recommended for Federal purchasers. Taken together, the lighting equipment changes reduced our overall lighting power density for offices plus circulation and utility areas by 17 percent (1.3 to 1.08 W/ft^2).

Lighting controls: We installed occupancy controls throughout the office to avoid lighting unoccupied rooms or those that have sufficient daylight. In the perimeter offices, we use "off-only" occupancy controls; these must be switched on manually when daylight is inadequate, but they turn off automatically after the occupant leaves. Lighting in the interior offices is controlled by conventional on/off occupancy sensor switches. Based on our monitoring of a sample of occupied offices, we found lighting savings of 68 percent in the exterior, daylit offices and 50 percent in the interior offices (Figs. 1 and 2). We have measured even greater savings from occupancy sensors in intermittently used spaces, such as the kitchenette and storage areas. Controls in the small conference room consist of a continuously dimming ballast with daylight sensor, while the large conference room uses pendant-hung fluorescent fixtures with step-dimming controls (using a wireless remote) to accommodate audiovisual presentations. In the aggregate, controls saved about 25 percent after accounting for efficient lighting equipment.

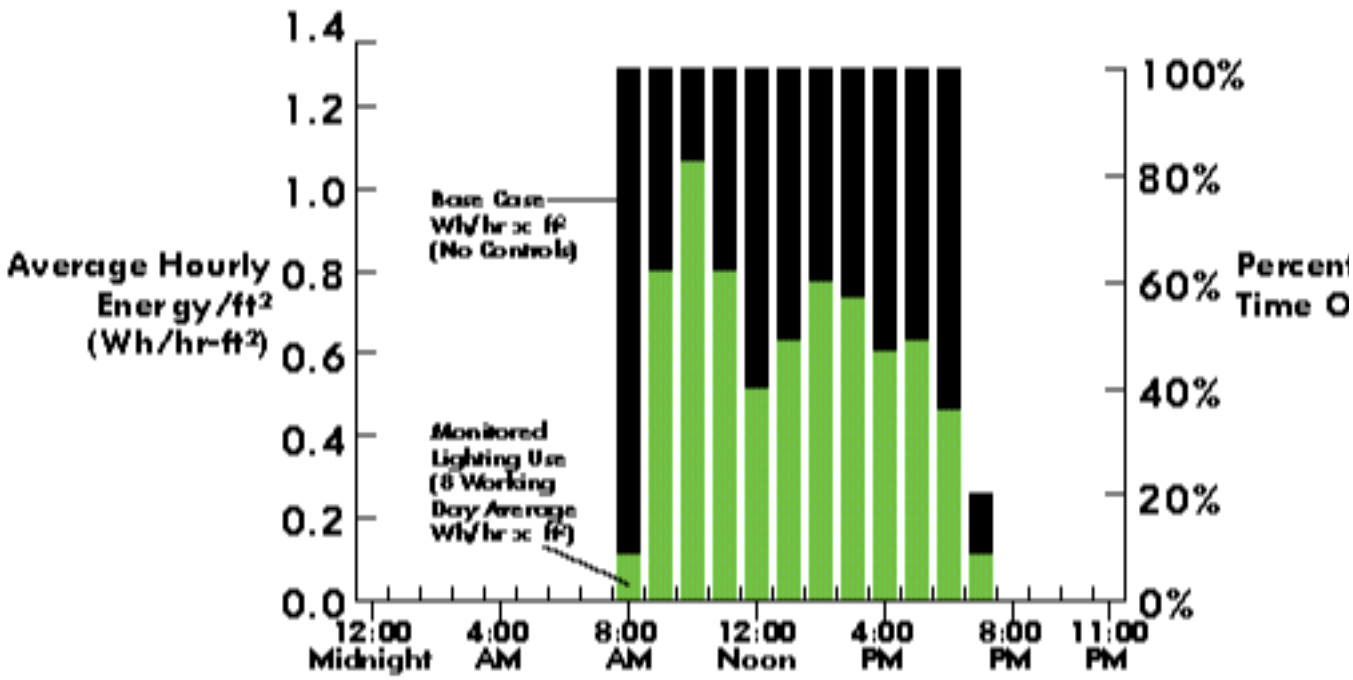

Figure 2: Lighting energy use profile for a typical interior office.

Use of daylight and task lighting: The office layout itself was designed to make the best possible use of daylighting. For example, the hallway was offset to increase daylit space (shared rather than single offices are on the window side), and interior, fixed-glass windows help bring daylight into the hallway and interior offices. Many staff keep the overhead lights off in the exterior offices, preferring natural light with occasional desktop task lighting.

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More on the DC Office efficiency up-grade: Office Equipment: Part 1, Part 2

This work is supported by the Federal Energy Management Program.

CBS Newsletter
Spring 1997
pg. 4

A Sulfur Lamp and Fixture Demonstration at SMUD

Martha Krebs, head of DOE's Office of Energy Research, was in Sacramento for the public debut of a sulfur lamp lighting system (in background) designed by Berkeley Lab scientists.

Researchers at the Center's Lighting Research Group have developed the first high-efficiency lighting fixtures to capitalize on the extraordinary brightness and remarkable energy efficiency of the award-winning sulfur lamp. Through a partnership between Berkeley Lab and Cooper Lighting, a major U.S. lighting manufacturer, prototypes of these new fixtures have been installed in the headquarters lobby of the Sacramento Municipal Utility District, one of the largest municipal utilities in California.

"This system will make it practical for sulfur lamps to be integrated into common interior spaces, which should accelerate their market penetration," says Michael Siminovitch, a principal investigator in the Building Technologies Program's Lighting Group. Although these new fixtures were designed around the physical dimensions and photometric properties of a specific commercial sulfur lamp, the technology behind them can be applied to other bright, energy-efficient electrode-less lamps now under development.

Indoor lighting accounts for about 25 percent of the electrical energy consumed in the United States each year. This consumption, which costs about $30 billion, could be cut in half if existing lighting systems were to be replaced with advanced energy-efficient alternatives. The sulfur lamp (Spring 1995, p. 5) was unveiled two years ago. Consisting of a golf-ball-sized glass globe filled with argon and a tiny amount of sulfur, the 1,000-watt version of this microwave-powered lamp is six times more efficient and 75 times brighter than a conventional 100-W incandescent bulb.

The sulfur lamp was invented by Fusion Lighting Inc. of Rockville, Maryland, which is now selling a 1,000-W version called the Solar 1000. (DOE provided some of the financial support for this R&D.) A major impediment to the widespread adoption of the sulfur lamp has been the lack of high-efficiency fixture systems for delivering its light to the interiors of commercial spaces. To distribute the illumination, sulfur lamps on display at the Forrestal Building, DOE's headquarters in Washington, D.C., relied on a light guide, a hollow tube lined with a reflective material. Light from the source travels along the reflective material, diffusing out to illuminate the space.

"Illumination from a light guide can pose problems with glare and low efficiency when used to light interior spaces," according to Siminovitch. What has been needed is an indirect, low-glare system that takes advantage of not only the high energy efficiency and brightness of sulfur lamps, but also their high CRI (Color Rendering Index), which puts them on par with sunlight for quality of illumination.

Siminovitch, Carl Gould, and Erik Page, all with the Lighting Group, have developed a fixture that can be fitted with different reflectors to provide a variety of light distribution patterns. The fixture can also be mounted in various ways-on a free-standing kiosk, or on a wall or ceiling-to provide a high degree of flexibility and suitability across a broad range of applications from interior spaces of shopping malls to building complexes and offices.

The free-standing kiosks are especially adaptable. "A series of detailed studies have been completed on developing optimized reflectors for the kiosks to accommodate different ceiling heights," says Siminovitch. "By varying the distribution geometry and the relative spacing of the kiosks, they can deliver a large range of illuminances." A single kiosk could replace from 10 to as many as 30 conventional ceiling fixtures in an open-space office. In laboratory tests, the light fixtures scored an efficiency rating of 90 percent, which is significantly higher than the ratings for light guides and among the highest ratings for any white light source/fixture system. Working closely with a manufacturer of light fixtures was a critical asset to this research.

"Cooper Lighting brought insights and capabilities to the table as to how this technology could be manufactured," says Siminovitch. "It's a good example of how the products of science can lead to commercial opportunities through an industrial partnership."

—Lynn Yarris

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This research is supported by DOE's Office of Building Technologies, State and Community Programs, with cost-sharing from Cooper Lighting and SMUD

CBS Newsletter
Spring 1997
pg. 5

The China Energy Group

A city-owned cogeneration plant, built in 1989 in Weihai, Shandong, received an award from the Chinese government as an advanced energy-efficient enterprise.

The Energy Analysis Program's China Energy Group-a core team of four Mandarin-speaking U.S. and Chinese researchers, plus leader Mark Levine and a dozen other staff members-has worked closely with energy policymakers in China for nearly a decade. Their goal is to better understand the dynamics of energy use in China and to develop and enhance the capabilities of institutions that promote energy efficiency in that country. This unique collaboration began as a joint effort with the Energy Research Institute of China's State Planning Commission, but the Group's network has expanded to include other research organizations, government offices, and enterprises.

A central achievement of the Group has been to support an ongoing exhange program, begun in 1989, with Chinese energy research organizations. Major analytic reports include the first assessment outside China of the country's remarkable energy-conservation programs (1990) and five sectoral studies demonstrating large energy-efficiency opportunities (1991-1994). Perhaps the most popular of the Group's reports has been the China Energy Databook, the most authoritative sourcebook of its kind (1992, revised 1994 and 1996). Group members also participated in the 1995 Presidential Mission on Sustainable Development and Trade to China.

The Group's current work includes a broad range of activities, from policy studies at the national level to business-oriented evaluations of specific energy-efficiency projects. The U.S. Department of Energy and the Environmental Protection Agency (EPA) are jointly funding a study of energy-efficiency opportunities in China. The study includes a scenario-based assessment of the maximum realistic penetration of energy-efficient and renewable energy technologies and promising technologies and programs in buildings and building materials manufacturing. This work will help the U.S. cooperate with China to develop practical response strategies to global climate change and other energy-related issues of mutual interest.

According to David Fridley, who leads the Group's efforts: "We have helped to manage an international effort to transform China's refrigerator industry and market, which is the largest in the world. Developed with support from EPA, a CFC-free, super-efficient prototype refrigerator model has undergone laboratory tests and year-long field testing, demonstrating up to 50% reduction in energy use over the model on which it was based. We have also led the effort to obtain Global Environmental Facility funds to help refrigerator manufacturers adopt the energy-efficient designs, as well as develop a consumer awareness campaign, energy-efficiency labeling, and a three-year technical training program. We have also provided China with training in analytical techniques and procedures in their effort to develop mandatory refrigerator energy-efficiency standards."

China is vigorously pursuing its Green Lights Program, aimed at raising the efficiency of lighting systems throughout the country. Lighting accounts for more than 10% of China's electricity use and is dominated by cheap but inefficient incandescent lamps. The China Group works closely with the Beijing Energy Efficiency Center (BECon), to provide technical assistance and training using funding from EPA and the United Nations Development Program. BECon is managing technical work for China's Green Lights Program.

Building on its work promoting U.S. participation in China's cogeneration industry, the Group is now collaborating with the China Energy Conservation Investment Corporation-a state-funded energy-efficiency investment firm-to identify and evaluate business opportunities in industrial-process energy efficiency. The Group is also working with organizations in the U.S. to identify the needs of American businesses who wish to invest in China and to bring together potential Chinese and U.S. energy-efficiency business partners.

The Group's initial work in promoting cogeneration is expected to receive continued support from DOE. In collaboration with Jack Siegel of Energy Resources International, the Group is working with the Chinese to develop procedures for simplifying approvals of U.S. investment in Chinese cogeneration.

Jonathan Sinton, another core member of the scientific team, adds: "We have always emphasized close collaboration with our colleagues in China. This year, we expect to host groups from China for training in efficient lighting technologies and standards and in energy management and financing. We also travel frequently to China for joint research projects and conferences. Upcoming trips will involve work on the lighting and refrigerators projects, as well as participation in a major industrial energy-efficiency activity sponsored by the Asian Development Bank (ADB), presentations at the regional meeting of the World Energy Conference in China, and participation in Sino-U.S. meetings of the Energy Efficiency Working Group. The ADB project will be the basis for a larger assistance program for regulatory change and investment packages to promote energy efficiency in China's reformed economic environment."

Besides carrying out numerous collaborative research projects, in 1993 the Group helped found BECon-China's first market-oriented organization for energy-efficiency consulting and advocacy. Mark Levine leads the Energy

Policy Team of the China-U.S. Energy Efficiency Working Group, which is coordinating bilateral energy-efficiency activities.

—Karen H. Olson and Nathan Martin with Jonathan Sinton

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This work is supported by DOE's Office of Fossil Energy, Office of Energy Efficiency & Renewable Energy, and Office of Policy, and by EPA's Air Pollution Prevention Division and Office of International Activities.

CBS Newsletter
Spring 1997
pg. 6

Indoor Air Quality in New Energy-Efficient Houses

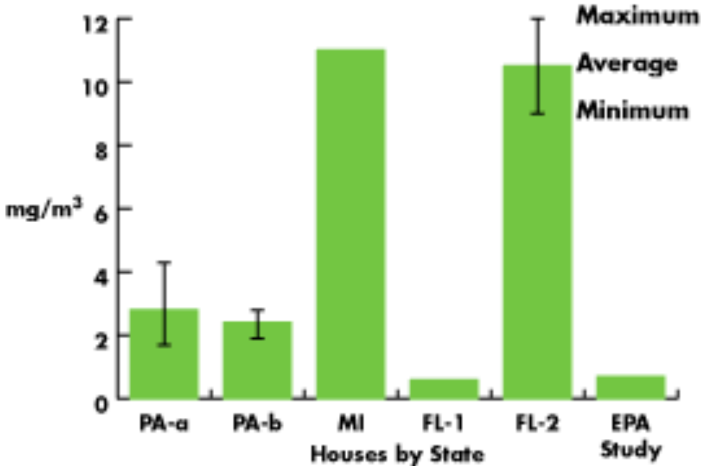

Figure 1: Measurements of total volatile organic compounds in five new houses in Pennsylvania, Michigan, and Florida and median concentration in U.S. EPA study.

In 1993, the Indoor Environment Program began investigating indoor air quality in new energy-efficient houses. Five new houses have been included in the study, all in the eastern U.S. Two had nearly identical floor plans and were part of a demonstration project near Pittsburgh, PA; one was built conventionally, while the other incorporated a number of energy-efficient features. The conventional house was studied for one year following construction, and the energy-efficient house was sampled on three occasions over a two-year period. The other three demonstration houses were in separate projects. One of these houses was investigated over a period of four months following construction. Ventilation rates ranged from 0.07 to 0.4 h^{-1} (air changes per hour) with a median value close to 0.2 h^{-1}, indicating that these houses have tighter envelopes than older housing and that current building practices have improved building tightness.

Concentrations of airborne organic contaminants were measured in all of the houses. These measurements included formaldehyde, individual volatile organic compounds (VOCs), and total VOCs (TVOC). Since ventilation rate data were also collected, source strengths were calculated with a mass-balance model. These estimates of source strengths made it possible to compare the magnitudes of the emission sources in houses with different volumes and ventilation rates.

The concentrations of formaldehyde in all five houses were generally about 0.05 ppm (0.06 mg/m^3), or lower, a level at which less than one percent of the population is expected to experience sensory irritation. The major sources of formaldehyde in houses are primarily particle board underlayment for floors and particle and fiberboard used for cabinetry and furniture. In an early-1980s study of formaldehyde concentrations in new energy-efficient houses, concentrations of 0.2 ppm were common. In the intervening years, composite-wood manufacturers have reduced the formaldehyde emissions of their products in response to concerns about the adverse health effects of this compound.

The concentrations of TVOC in the houses ranged from 0.65 to 12 mg/m^3; the median value was 2.4 mg/m^3 (see Figure 1). A large probability-based study of existing residences by the U.S. EPA found that the median concentration of TVOC representative of a population of about 600,000 was 0.7 mg/m^3. Thus, the TVOC concentrations in the new houses were, with one exception, elevated compared to typical values. Calculated whole-house source strengths ranged from about 0.2 to 3 grams per hour of contaminants. Interestingly, there was only about a factor of two reduction in source strengths over the one- and two-year study periods in the two Pittsburgh houses. If interior finish materials such as paints and floor coverings are the dominant sources, source strengths should decrease substantially over a period of only a few months. Because of the magnitude and persistence of the source strengths in the Pittsburgh houses, the dominant source was probably not these finish materials but rather some other element of the houses (see below).

The dominant classes of compounds detected in the house air samples were terpene hydrocarbons, aromatic hydrocarbons, ketones, and aldehydes. In the Pittsburgh houses, the most abundant compounds were alpha-pinene, d-limonene, acetone, pentanal, hexanal, heptanal, nonanal and acetic acid. The aldehydes are of particular concern because they are irritants and produce unpleasant odors at low concentrations. Hexanal, the aldehyde with the highest concentrations and source strengths in the houses, ranged in concentrations from 0.02 to 0.9 mg/m^3. Thus, concentrations of hexanal alone often significantly exceeded the odor threshold of 0.06 mg/m^3. In the Pittsburgh houses, acetic acid also exceeded its odor threshold and probably accounted for some of the detectable odor.

The sources of the VOC emissions in these new houses are still under investigation through field and laboratory studies. One possibility is that structural components consisting of natural lumber, laminated lumber, plywood, and oriented strandboard are the dominant sources. These wood products are the most logical sources of terpene hydrocarbons, aldehydes, and acetic acid. Because they are present in a house in large amounts, they may form a sizable chemical reservoir that could be a source of contaminant emissions over extended periods. These contaminants may be entering the indoor air through walls, ceilings, and floors for duct work, plumbing, and electrical systems.

As demonstrated by the paired Pittsburgh houses, the problems of persistently elevated VOC concentrations and odors are probably not unique to energy-efficient houses, but rather may be relatively common in new houses built with current construction materials and techniques. Further research should be able to demonstrate ways to reduce emissions, thereby reducing concentrations of VOC contaminants in houses, by modifying materials and construction practices used for new houses, including those built with specific energy-efficient features. This solution might avoid the need for increased ventilation rates, which would diminish the energy-efficiency and comfort benefits of houses with tightly sealed envelopes.

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This research is supported by DOE's Office of Building Technologies, and State and Community Programs.

CBS Newsletter
Spring 1997
pg. 7

New Division Name and Director

Mark Levine has been named Director of the Environmental Energy Technologies Division (EETD) by Charles Shank, Director of the Ernest Orlando Lawrence Berkeley National Laboratory. Levine was head of the Center for Building Science's Energy Analysis Program. EETD, which used to be called the Energy & Environment Division, formally assumed its new name on Levine's appointment. Stephen Wiel is now the Acting Head of the Energy Analysis Program. The next issue will provide more details about the new division and the plans of its new Director.

CBS Newsletter
Spring 1997
pg. 8

A-Team Report

Cool Sense

The Cool Sense program, the latest project undertaken by the Applications Team, aims to bring information about integrated chiller retrofits to the people in charge of the 80,000 chillers in the United States currently using CFC refrigerants.

Production of CFC refrigerants ceased in 1996 as a result of an international agreement to limit their effects on the atmosphere's ozone layer. This moratorium is expected to bring about an unprecedented wave of 20,000 chiller replacements or conversions by the year 2000. If no integrated retrofits are made, the capital investment needed to replace these chillers will be $1.8 billion, for a savings of $5 billion over the lifetime of the chillers. If only half the replacements are made in conjunction with integrated retrofits, the investment will be $7.89 billion, but the lifetime savings will increase to $25 billion. The payback period will also be short-5 years with integrated retrofits versus 6 years without. Although the capital investment increases fourfold, the monetary savings reduced energy use increase fivefold for a savings of $25 billion dollars over the chiller's lifetime.

What is an integrated chiller retrofit? Simply put, it means implementing the load and system improvement opportunities in a building when replacing or converting the chiller. Many buildings can benefit from new technologies that reduce the cooling loads on a building (efficient lighting and appliances) and decrease chiller plant energy consumption (variable-frequency drives, direct digital controls, and proper commissioning and operation). These changes not only reduce the energy needed for cooling, but often allow the chiller to be downsized for even more savings. The added energy savings from an integrated retrofit also make chiller replacements more economically viable. Even though integrated retrofits require a much larger capital investment, their payback period is less than that of chiller replacement.

Responding to the recognized need to encourage and provide information about integrated chiller retrofits, the Cool Sense program is spreading the word in three ways: through a World Wide Web site, regional workshops, and a national forum.

The Cool Sense Web site will serve as a clearinghouse for information about CFCs, chillers, system and load improvements, economics, case studies, rebate programs, and seminars and conferences related to integrated retrofits. The URL is: http://ateam.lbl.gov/coolsense

The regional workshops explain the concepts and benefits of integrated chiller retrofits to facilities managers. Each workshop covers the basics of integrated retrofits and includes regional case studies, a panel of local utility representatives, and perhaps a tour of a local facility. A workshop took place in Boston in early April; others are tentatively scheduled in Denver, Iowa, and New Jersey this summer.

The national forum will bring experts in integrated chiller retrofits together with those wishing to learn more. This two-day forum will have a technical track and a market transformation track and is tentatively scheduled for September in the San Francisco Bay Area.

—Lisa Gartland

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The Cool Sense project is sponsored by the U.S. Department of Energy, the General Services Administration, and the Environmental Protection Agency.