Lawrence Berkeley National Laboratory

Spring 2000

Environmental Energy Technologies Division News

Air Quality Advanced Technologies Building Technologies Energy Analysis Indoor Environment

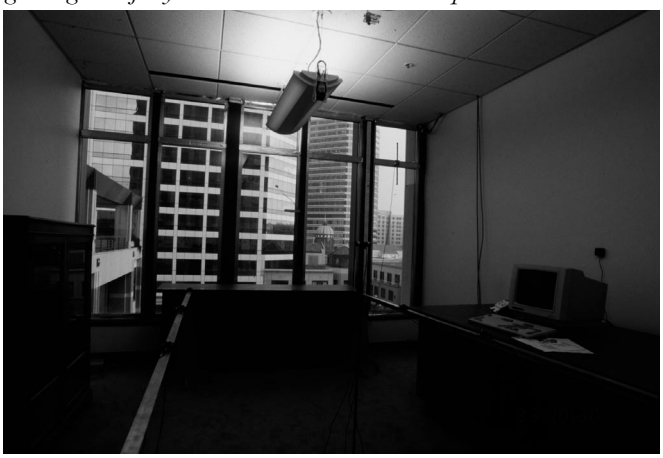
Electrochromic Window Tests in U.S. Office Show Promise

Electrochromic glazings promise to be the next major advance in energy-efficient window technology, helping to achieve the goal of transforming windows and skylights from an energy liability in buildings to an energy source for the nation's building stock. The glazing can be reversibly switched from clear to a transparent, colored state by applying a low voltage, resulting in dynamically controllable thermal and optical properties ("smart windows"). Incorporating electrochromic glazings could reduce peak electric loads by 20 to 30% in many commercial buildings and increase daylighting benefits throughout the U.S., as well as improve comfort and potentially enhance productivity in our homes and offices. These technologies will provide maximum flexibility in aggressively managing energy use in buildings in the emerging deregulated utility environment and will move the building community toward the goal of producing advanced buildings with minimal impact on the nation's energy resources. Customer choice and options will be enhanced further if the customers have the flexibility to dynamically control envelope-driven cooling loads and lighting loads.

Large-area electrochromic windows have recently become available in limited quantities. These windows have been installed in two side-by-side private office test rooms, enabling researchers to conduct full-scale monitored tests (Figures 1 and 2). Full-scale tests bring laboratory devices one step closer to commercialization by solving key design problems in a short test-evaluate-test iterative cycle of development within a realistic building environment.

At this time, large-area windows (90x200 cm) are technically viable but can be produced only in small quantities and at substantial cost (~$1,000/m^2). Volume production facilities are under development and several glazing developers expect new electrochromic window products to emerge in the marketplace by 2001-2002. With volume, glazing costs are expected to drop to about $100/m^2. Material performance, optical characterization, coloration efficiency, durability, and fabrication research remain major foci of the electrochromic R&D community.

Figure 1. Before direct sun enters the windows, the electrochromic glazings are fully bleached at their most transparent state.



Testbed Description and Objectives

Large-area electrochromic windows were installed in two side-by-side test rooms in the Federal Building, Oakland, California, and operated from November 1999 through February 2000. Test objectives included developing control systems, monitoring energy use, and evaluating visual comfort. Each test room was 3.71 m wide by 4.57 m deep by 2.68 m high and furnished with nearly identical building materials, furniture, and mechanical systems to imitate a commercial office-like environment. The southeast-facing windows in each room were simultaneously exposed to approximately the same interior and exterior environment so that measurements between the two rooms could be compared.

A laminated electrochromic glazing was combined with a low-E glazing to form a double-pane window with a visible transmittace (T_V) range of 0.14 to 0.51. Each electrochromic double-pane window was then mounted on the interior side of the building's existing monolithic green-tinted glazing (T_V=0.75). The overall composite T_V range was therefore 0.11 to 0.38. Electrochromic windows were placed in an array of five upper and five lower

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The mission of the Environmental Energy Technologies Division is to perform research and development leading to better energy technologies and the reduction of adverse energy-related environmental impacts.

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windows to cover the full area of the window opening (3.71 m wide by 2.29 m high) as shown in Figure 1.

Results and Future Directions

Recent material advances have resulted in large-area electrochromic devices with good performance properties. The electrochromic window system tested had excellent optical clarity, no coating aberrations (holes, dark spots, etc.); uniform density of color across the entire surface during and after switching, smooth, gradual transitions when switched; and excellent synchronization (or color-matching) between a group of windows during and after switching. The windows had a very slight yellow tint when fully bleached and a deep prussian to ultramarine blue when fully colored. The glazings were not reflective. To all outward appearances, the electrochromic windows looked exactly like conventional tinted windows with the exception that one can change their coloration. Architecturally, the windows impart a high-tech, spare appearance without the usual intervening window shades.

Figure 2. After direct sun enters the window, the electrochromic glazings switch to their fully colored, darkest transparent state and the fluorescent lighting dims accordingly.

Electrochromic glazings save energy by reducing cooling loads and reducing electric lighting energy consumption when dimmable lighting systems are used. In tests conducted during the winter, the focus was on the lighting energy impacts. Ceiling-mounted photosensor controls were used to modulate the glass transmittance and maintain a light level of 510 lux at the work surface. When insufficient daylight was available, the electric lights provided the additional required illuminance. When comparing the electrochromic glazings to a static dark glass (T_V=11%) on sunny and overcast days, the daily lighting energy consumption for the room with the electrochromic windows was on the order of 6 to 24% lower. Whenever direct sun enters the room, the electrochomic window switches to its darkest state (11%), so there are no savings relative to the static glazing. But much of the time in

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Ernest Orlando 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 the nine laboratories, LBNL is located in the hills above the campus of the University of California, Berkeley.

With more than 4,000 employees, LBNL's total annual budget of nearly $400 million supports a wide range of unclassified research activities in the biological, physical, computational, 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. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of more than 300 and a budget of $36 million.

CLASP Helps Developing Nations Implement Energy Standards

A new organization, in which Berkeley Lab's EETD is a founding partner, has received United Nations funding to help developing nations implement energy performance standards and therefore meet rising energy demand. The Collaborative Labeling and Appliance Standards Program (CLASP), formed in 1999, is a collaboration between Berkeley Lab, the Alliance to Save Energy, and the International Institute for Energy Conservation.

Over the next ten years, developing world nations may invest as much as $100 billion per year in generation and distribution systems to meet the rising demand for energy. This is extremely burdensome to developing economies, which usually have limited capital for investing and a critical need to create new industry and jobs. Energy-efficient appliances, equipment, and buildings help developing economies grow by ensuring that their energy infrastructure can meet demand. CLASP will bring expertise in appliance standards and labeling development to help developing world economies become more energy-efficient.

"Close cooperation with our U.N. partner, UN/DESA (United Nations Department of Economic and Social Affairs), has enabled us to receive a major grant from the United Nations Foundation—$4 million dollars over 2 years—to complement existing funding from the U.S. Agency for International Development, the Energy Foundation, and the Packard Foundation," says Stephen Wiel, head of EETD's Energy Analysis Department. "The goal of the U.N. funding is to significantly reduce the emissions of greenhouse gases and energy use. Our estimates suggest that energy-efficiency standards and labeling can reduce emissions anywhere from 25 to 40 percent within the next three decades."

Although the CLASP initiative received a go-ahead from funding institutions early in 2000, Berkeley Lab has worked with the governments of developing nations for years through an in-house initiative called International Building and Appliance Standards. Since 1996, EETD staff members have worked with the governments of China, India, Mexico, the Philippines, Ghana, and Sri Lanka on a variety of projects ranging from the development of motor-efficiency standards for the Philippines to appliance-efficiency standards in Ghana. Substantial funding for this work has come from the U.S. Agency for International Development.

In most cases, Berkeley Lab researchers find substantial savings and economic benefits from appliance standards. For example, a project concluded in 1999 found that a minimum energy performance standard for refrigerators could cost-effectively save consumers in Ghana the equivalent of $50 million by 2010, and standards for room air conditioners and lighting could save an additional $14 million. Reductions in greenhouse-gas emissions could total close to 300,000 metric tons. The government of Ghana is now discussing ways to implement energy performance standards.

Researcher David Fridley and other staffers are working with the Chinese government to develop projects in energy-efficiency appliance standards, labeling, and purchasing. China's State Bureau of Quality and Technical Supervision is taking advantage of support from Berkeley Lab in the development of efficiency standards for household appliances and lighting. An explosion in demand for consumer products in China has led to a large increase in residential electricity use—an average of 16 percent since 1985.

EETD's Laura Van Wie is coordinating CLASP efforts in Mexico, where the government's energy agency, CONAE (Comisión Nacional para el Ahorro de Energía), has agreed to become the Latin American regional partner for CLASP. CONAE will fund a staff person to provide technical advice and outreach to Latin American nations on energy performance standards and labels. In addition, the Instituto de Investigaciones Eléctricas and CONAE will be assessing the impact of appliance standards on energy use in Mexico with technical support from EETD. Division researcher Joe Huang has worked with Mexico on building codes, and Jeff Harris is contributing to an effort to develop an energy-efficient equipment procurement program for the Mexican government.

CLASP's Ambitious Goals

With its focus on appliance standards, CLASP is developing an ambitious program of technical assistance, drawing on experts from the three founding partners as well as a network of other institutions throughout the world. CLASP's technical staff will work with host agencies of interested nations to develop a customized technical assistance program for creating an energy standards and labeling program. Several regional workshops are in the planning stage, including one for Latin America in August of this year, and one for Asia in 2001.

Says Mirka della Cava, EETD staff member and CLASP liaison, "We're working on several projects now for nations developing energy standards. A guidebook that will serve as a practical guide for addressing the analytical, policy, legal, and regulatory actions necessary to establish a successful labeling and standards program will be published later this year. There is a toolkit of training and marketing materials intended for government, industry, nongovernmental organizations, and advocacy groups that includes presentations, brochures, and examples of existing labels and standards. A Web site will host the manual and the toolkit materials and provide access to reports, updates on implementation in different countries, and links to other standards- and labeling-related sites."

CLASP is looking forward to forming partnerships with agencies, stakeholders, and institutions in developing and transitional countries around the world," says Sachu Constantine of the Alliance to Save Energy. "By bringing together policy and technical specialists, research organizations, and universities, we will be building solid institutional capacities and expertise for managing energy-efficiency programs in these countries."

"Energy efficiency standards and labels for appliances, equipment, and lighting products are a cost-effective policy for conserving energy. They fit well with most other energy policies and can play a role as the backbone of all countries' energy policy portfolios," says Kelly Gordon of the International Institute for Energy Conservation.

—Allan Chen

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http://www.ase.org/programs/international/clasp.htm

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CLASP

EETD Scientists Aid Research Efforts Leading to MTBE Ban

In a recent action, California Governor Gray Davis banned the use of the gasoline-oxygenating additive MTBE (methyl tertiary-butyl ether) because it poses a serious threat to groundwater. Following this action, the U.S. EPA has also opposed the use of MTBE.

Instrumental in the governor's move was a report prepared by EETD and UC Berkeley researchers that examined the usefulness of fuel additives. Don Lucas and Bob Sawyer of the Advanced Energy Technologies Department, along with Cathy Koshland of the University of California at Berkeley and graduate student Pam Franklin performed research that contributed to the report the Governor and the California Air Resources Board used. On a national level, work by EETD scientist Nancy Brown and others were part of a National Research Council published report on oxygenated fuels; that report played a part in the EPA's decision to ban the additive. Bob Sawyer was also a member of the EPA Blue Ribbon Panel on MTBE and other oxygenates in gasoline.

In preparing data for the report to the Governor, Lucas and his colleagues examined claims that MTBE helps internal combustion engines burn gasoline more cleanly. (Refiners began adding MTBE or other additives—among them other ethers or ethanol—to gasoline several years ago to meet stringent air-quality standards and other requirements of the Clean Air Act.) Their research showed that while reformulated fuels reduced air emissions, the oxygenates were not needed. The researchers evaluated three types of reformulated gasoline: one without an added oxygenate, one with ethanol, and another with MTBE. The nonoxygenated fuel was the least costly to produce, while the fuel with the MTBE additive was judged to have the highest net annual cost primarily because of the associated costs of treating contaminated water supplies, higher fuel prices, and lower fuel efficiency.

Greater Dangers

The ineffectiveness of fuel additives is only half the story. Because MTBE is highly soluble, any leaks from underground fuel tanks or pipelines in the gasoline-distribution system pose a great threat to groundwater. Even in small amounts, MTBE renders drinking water unusable, since MTBE can be detected by humans at concentrations as low as 20 parts per billion. Leaks from underground storage tanks or surface spills can contaminate huge reservoirs of drinking water. Given the use of gasoline-burning motors in boats—especially older two-stroke models—drinking water from reservoirs that allow recreational boating is also susceptible.

Recommendations for the Future

Although Lucas agrees with the gradual phasing out of MTBE from gasoline, he is not quick to support replacing it with ethanol. "A lesson to be learned from the MTBE story is that the addition of any chemical compound to the environment in quantities that constitute a significant fraction of the total content of gasoline may have unexpected environmental consequences," he stated. He would like to see refiners given the flexibility to achieve air-quality objectives without wide-scale production of reformulated gasoline required to contain oxygenates. This would require a waiver from the federal government to allow nonoxygenated gasoline to be sold in all parts of California. "Promoting the accelerated removal of older, high-emitting vehicles to reduce air-pollutant emissions would be significantly more cost-effective than mandating the use of oxygenates in fuels," says Lucas. He also suggests implementing an aggressive program aimed at gross carbon monoxide polluters. "This, too," he states, "would be a cheaper and less risky option than using oxygenates."

The UC report also emphasizes the need for underground storage cleanup funds and serious efforts to contain or remedy any known or suspected sites contaminated with MTBE.

—Ted Gartner with Don Lucas

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Power Outage Study Team Examines Electricity Reliability

During the summer of 1999, six major power outages and two serious electrical system disturbances throughout the United States led Secretary of Energy Bill Richardson to charter a group of experts to study what happened and how it could be prevented in the future. Berkeley Lab scientist Joe Eto was appointed to the panel. In March, the Power Outage Study Team (POST) sent the Secretary its final report. The POST study made 12 recommendations to Richardson and is the first to address the issues of electrical system reliability in a changing electrical power industry—restructuring has brought a choice of electrical suppliers to consumers in 24 states, along with the need to assure continued reliability under new market conditions.

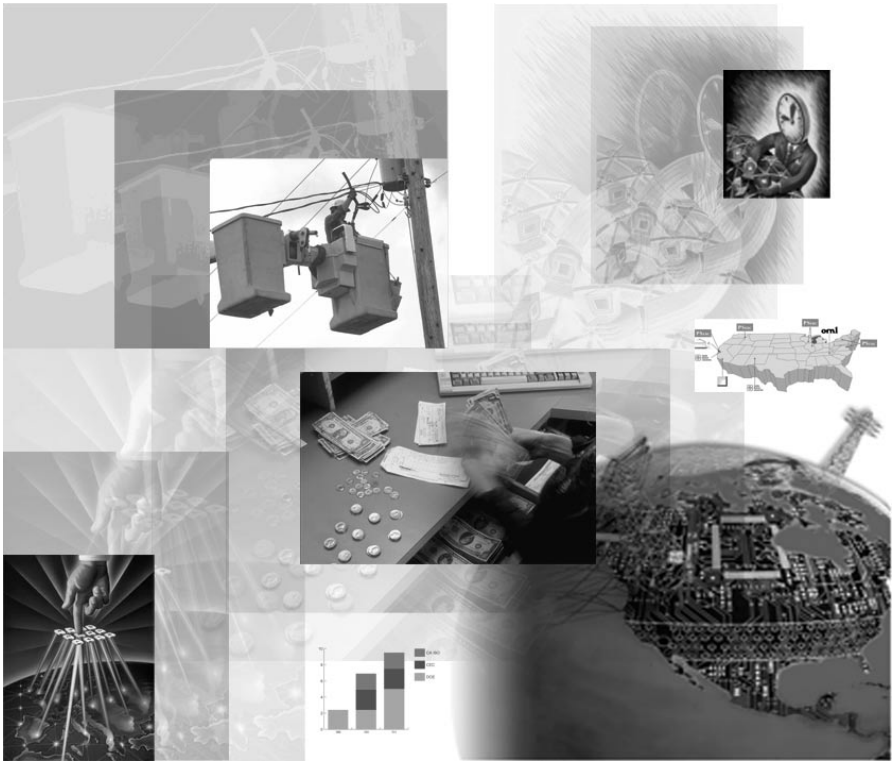
Eto, a scientist in the Environmental Energy Technologies Division, coordinates multi-institutional research projects on the reliability of power systems in restructured markets through the Consortium for Electric Reliability Technology Solutions (CERTS). This Berkeley Lab-led consortium has brought together experts from national laboratories, universities, and the electric utility industry. A number of CERTS advisors served on POST with Eto and authored the team's final report. The team examined technical data from outages and incidents and held three technical workshops around the country to gather public comments.

"There is a wide expectation that competitive markets will bring new efficiencies and innovation to the marketplace, which will save customers money and lead to new services," says Eto. "But the mechanisms that protected electric reliability in the past need to be changed with the market's development."

The Secretary gave the POST report a positive reception. In a mid-March speech before the National League of Cities, which represents local government officials throughout the U.S., Richardson said, "While demand for electricity is soaring along with the use of computers, fax machines and other appliances in our homes, offices and factories, the reliability of our electric grid is, at times, faltering, mainly because policy makers haven't kept pace with rapid changes in the electric utility industry.…Today's report can be a blueprint for how we will work together to keep the lights on and air conditioners running in America's cities this summer."

The POST study makes 12 recommendations about how the federal government can work with the electric utility industry to reduce power outages as the industry undergoes restructuring. It suggests, among other things, that the federal government promote market-based approaches to ensure reliable electric services; remove barriers to distributed energy resources (small-scale generation sources such as fuel cells, solar panels, small hydro sources, and diesel-powered generators); support reliability standards for bulk power systems; and encourage energy efficiency as a means of enhancing reliability.

In his public comments, Richardson threw his support behind Congressional action to address reliability issues: "Federal electricity legislation is an essential component of the effort to help alleviate power outages this summer. Congress must move ahead to make changes in the federal statutory framework to provide the certainty that is needed to achieve reliable electric service in competitive wholesale and retail markets."



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The report is available at: www.policy.energy.gov/electricity/postfinal.pdf
The work was supported by the U.S. Deparment of Energy's Office of Policy.

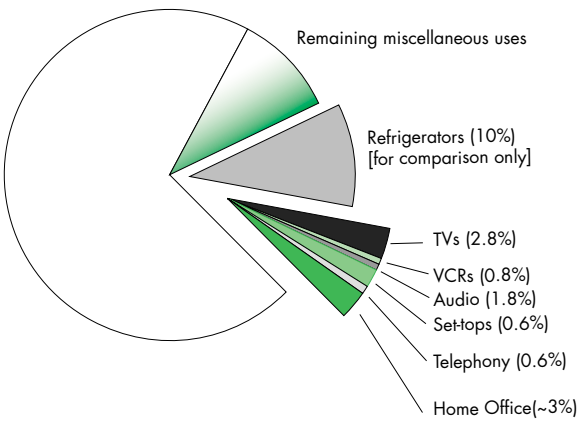
Research Highlights

Miscellaneous Electricity Usage Growing

As the number of small appliances increases in households, so does the percentage of total electricity they require. While the refrigerator has typically been the largest electricity-using appliance in the home (roughly 10% of total usage), recent investigations by EETD scientist Alan Meier show that the combined usage of other, smaller appliances often approaches this figure. Average households often contain several television sets, VCRs, and cable boxes. Home computers and peripheral devices (printers, scanners, and modems) are also prevalent, as are cordless phones, cell phones, fax and answering machines, and audio equipment. Adding to this list are rechargeable appliances, remote-control garage door openers, and burglar alarms. What much of this equipment has to do with the high percentage of electricity use is its "leaks." While appliances do not actually allow electricity to escape, many devices maintain internal clocks, signal reception capability, and an instant-on feature; they also display the time and their power status. The instant-on feature means that the "completely off" feature is not present and the device is actually drawing a small amount of electricity at all times, usually less than one Watt. As the number of devices increases, of course, so do the number of leaks. With the final tally often equaling the refrigerator's consumption. In the larger picture, leaking electricity could be contributing as much as 12 million tons (metric) of carbon to global emissions because of increased demand.

Meier's suggested solutions to this phenomenon include improving the efficiency of low-voltage transformers, moving the switch to the high-voltage side, and installing "smart" recharging circuits. He estimates that the needed improvements would add little or no additional cost to the overall cost of appliances and yet could reduce leaks by as much as 75%. More information can be found at http://eetd.lbl.gov/Leaking/.

The amount of electricity that small household devices use often equals the amount used by a large appliance like a refrigerator.



ProForm: New Software for Environmental Impact Assessment

ProForm is a new software tool designed to support a basic assessment of the environmental and financial impacts of renewable energy and energy-efficiency projects. ProForm calculates basic financial indicators and avoided emissions of CO_2 and local air pollutants expected from a project.

As a Microsoft Excel spreadsheet-based tool, ProForm is easy to use, yet sophisticated enough to provide credible results. A typical ProForm application could be the preparation of a project proposal that developers might submit to potential investors, financiers, or a national climate change office. ProForm allows project developers, financial institutions, and other parties to investigate how changes in basic assumptions affect the key parameters of a project.

The software can be used to assess renewable energy projects that involve either electricity generation or non-electric energy production, as well as energy-efficiency projects that save electricity and/or fossil fuels. ProForm will evaluate a range of project sizes, from a single installation, such as an energy-efficiency improvement at a factory or the construction of a wind turbine, to programs that involve installing multiple units of a technology, such as residential lighting-efficiency measures.

ProForm calculates emissions of CO_2 and several local air pollutants that may be avoided. It allows the user to construct a baseline that reflects changes in emissions impacts expected over the lifetime of the project. The main financial results are the project's internal rate of return and net present value with and without revenue from carbon credits. By modifying assumptions regarding the value of carbon credits, the user can assess what the financial impact of these credits would be under varying future scenarios. This work was initiated with seed funding from the U.S. Department of Energy and is currently supported by funding from the U.S. Agency for International Development (USAID).

EETD is now looking for ProForm beta testers. As a beta tester, you will be requested to input project specs of your own devising, change various parameters in the spreadsheet, evaluate the results, and inform the software developers of mistakes and irregularities. You will need to sign a licensing agreement, but the ProForm software license is free. Contact Bill Golove (WHGolove@lbl.gov; (510) 486-5229; fax (510) 486-6996).

EETD Holds Measurement and Verification Training

This spring, EETD held a training course on monitoring, evaluation, reporting, verification and certification (MERVC) of greenhouse gas emission reductions for government officials from energy, forestry, and other ministries concerned with climate-change issues. There were 21 participants from six countries. The training, which took place May 8 through 26, focused on using the forestry sector in greenhouse gas mitigation programs. It was funded by the U.S. Agency for International Development and administered through the Institute for International Education.

The MERVC forestry training addressed a variety of issues, from designing forest programs for carbon conservation and sequestration to measuring and verifying carbon reduction results

of these programs. The training included discussion of actual forestry projects in Zimbabwe and Costa Rica and field trips to UC Berkeley soil laboratories and a certified forest in the Santa Cruz Mountains of Northern California. The chief course instructors were EETD's Ed Vine and Jayant Sathaye; other instructors were drawn from EETD, UC Berkeley faculty, and other organizations.

Search for Indoor Air Department Head

EETD is looking for a scientific leader to step into the role of Department Head of the Indoor Environment Department (IED).

Responsibilities: The IED head is in charge of about 55 staff and an annual $6 million budget, conducting research on indoor environmental quality; exposure and risk; health; indoor air and pollutant transport and chemistry; building heating, ventilating, and air conditioning; and building energy performance. The department head provides scientific leadership, develops and implements strategies to maintain and strengthen the Department's research, assures research quality, fosters an environment that supports staff development, raises research funds, provides administrative and financial oversight, and manages the Department. The department head is also expected to develop and manage research projects.

Qualifications: An international reputation as a leader in indoor-environmental research, or in a closely related field, and a record of scientific excellence. The record should also demonstrate excellence in managing substantial research activities and a strong commitment to developing junior staff. An individual's interdisciplinary perspective could include chemistry, applied physics, engineering, health sciences, building technology, or environmental science, with an appreciation of the relevance of research on indoor environment to society. The person must work with others to create a broad vision for the department and invest substantial energy in achieving that vision. Familiarity with federally funded research programs, particularly those of the U.S. Department of Energy, is highly desirable. An advanced degree in science or engineering is expected.

To apply: Mail a curriculum vitae, a statement of interest, copies of up to three publications, and a list of five references to Professor William Nazaroff, Chair of IED Head Search Committee, c/o S.L. Harding, Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 90-1127, Berkeley, CA 94720. Review of applications will begin on August 15. The position will remain open until filled. Berkeley Lab is an AA/EEO Employer.

A more complete description is also available on the web at http://eetd.lbl.gov/IED_Search.html.

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—Editorial Staff

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the afternoon, there is no direct sun on these facades, and under most overcast conditions the electrochromic window switches to a clearer state, allowing the lights to be dimmed, saving energy (Figure 2). However, when the electrochromic glass is compared to a higher transmittance glass (T_V=38%), the lighting energy use is actually 0 to 13% greater. This is because the static glazing always transmits as much light as or more light than the electrochromic, which will often be switched to control direct sunlight, thus requiring some added electric light. Overall, however, the high-transmittance static glass is likely to have higher cooling loads and result in more glare problems. And in an occupied space, people would likely have added blinds or shades to control glare, further reducing the apparent advantage of the clearer static glazing.

Two strategies can improve lighting energy savings with electrochromic glazings: increase the upper Tv limit and decrease the lower Tv limit for glare control. For this test, the upper T_V limit could have been increased if the existing building glazing had been removed. This work also suggests that it may be advantageous for electrochromic devices to have a larger contrast ratio and higher transmission in the bleached state; for example, a device that can switch between T_V=0.06-0.85 will have greater daylight efficacy and control over intense sunlight than the device tested in-situ. Additional field tests will be conducted to better understand electrochromic glazing properties, the relationships between these properties and lighting savings, cooling savings, and occupant satisfaction and methods to integrate dynamic control of the window system with whole building energy management systems.

—Eleanor Lee, Dennis DiBartolomeo, and Stephen Selkowitz

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This work is sponsored by the U.S. Department of Energy's Office of Building Technology, State and Community Programs.

It is with great sadness that we anounce the death of Indoor Environment Department Head Joan Daisey. Dr. Daisey died in February after a long illness. *EETD News* will carry an article about her many scientific accomplishments and contributions in the next issue. Readers can view a brief on-line biography at http://eetd.lbl.gov/joandaisey.html.

A search is now underway to fill the IED Head position. Please refer to the story on page 7, which lays out the requirements for this position.

Sources

EREC: Energy Efficiency and Renewable Energy Clearinghouse

P.O. Box 3048, Merrifield, VA 22116

call toll-free: (800) 363-3732; **fax:** (703) 893-0400

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