DISCLAIMER

Energy Analysis
Building Technologies
Indoor Environment

Center for building science News

LAWRENCE BERKELEY NATIONAL LABORATORY — ENERGY & ENVIRONMENT DIVISION • SUMMER 1996

The Center's Web Works

The global Internet has quickly become the number-one source of information on energy efficiency. Although the Internet has been used since the 1960s by a relatively small number of government and academic institutions, recent developments in networking technology and software have attracted some 50 million users, including energy-related groups such as utilities, buildings professionals, and a wide variety of private companies. About 10 million computers are now connected to the Internet.

The Internet's World Wide Web represents a particularly important innovation by offering access to text-based information, searchable databases, photographs, sound recordings, and video images. For energy professionals, the Web is more than a place to post one's favorite paper-based reports; it's a venue for one-on-one as well as group communications, tracking down detailed energy data, acquiring software, running dynamic on-line calculations, and even collecting energy data from remote sites.

The following are some Web-based activities underway in the Center. (All are available to those who visit our site, currently 7,000 each week. The Center's web site is at http://eande.lbl.gov/CBS/CBS.html.)

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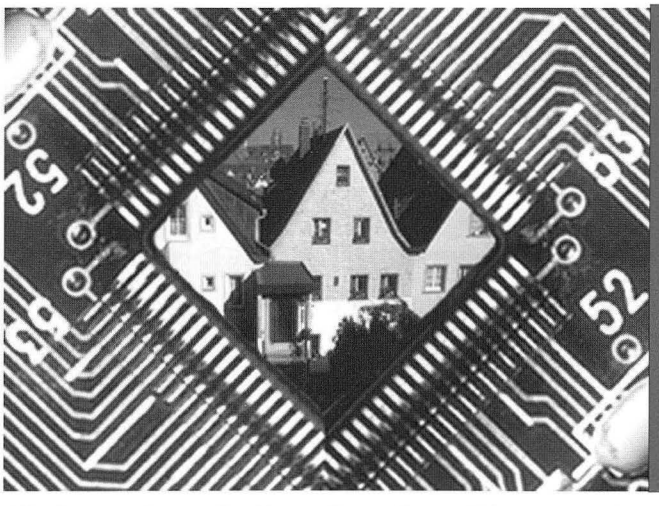

The Center's interactive Home Energy Saver Web project offers powerful but user-friendly ways for residential consumers to estimate how much energy their homes use and how much they can save by applying specific energy-efficiency measures. This web-based tool also directs users to related Web sites with supporting information, such as product lists, utility residential DSM programs, and on-line publications. The site is being developed in support of the EPA/DOE residential ENERGY STAR™ programs. Visit the site at: http://eande.lbl.gov/CBS/VH/vh.html

About the Center

Addressing significant energy-related issues since the late 1970s, 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 efficiency and indoor environment of residential, commercial, and industrial buildings.

The Center is located at a USDOE National Laboratory and 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 of 225 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 resource.

Center for Building Science
Evan Mills

Applications Team
Dale Sartor

Technology Transfer
Michael Wilde

Building Technologies Program
Steve Selkowitz

Energy Analysis Program
Mark Levine

Indoor Environment Program
Joan Daisey

Ordering Information

If you would like to receive this newsletter, correspond, or receive a comprehensive publication list for the Center's programs, please write to:

Center for Building Science News
Attn: Ralph McLaughlin
Mail Stop 90-3058
Lawrence Berkeley
National Laboratory
University of California
Berkeley, CA 94720 USA
Tel: (510) 486-4508
Fax: (510) 486-5394
Email: RDMcLaughlin@lbl.gov

This newsletter may also be found on the World Wide Web at URL:
http://eande.lbl.gov/CBS/NEWSLETTER/CBSNEWS.html

Web Works

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Text and Graphical Information—We have identified about 400 Web sites related to energy efficiency and indoor environment. These span a vast array of resources: government programs and research activities around the world, raw data on energy use and markets for energy-efficient products, vendors of energy-efficient technologies and services, nongovernmental organizations, university-based activities, on-line publications, weather data resources, and a host of discussion groups. In "Energy Crossroads", we have organized pointers to these Web sites into a master index.

We are also establishing a database of energy-efficiency imagery, publishing the quarterly *Center for Building Science News* and *Fenestration R&D Newsletter,* and posting our publications lists and some full-length reports. The Center's Web site features an extensive section on the High-Radon Project, with numerous detailed maps presenting results on indoor radon concentrations at the county level. Information on the Applications Team and our projects with the Federal Energy Management Program are described at the site, as is the Native American Renewable Energy Education Project being conducted by UC Berkeley and the Center [see A-Team Report, p.8]. Linked to the Center's main page are the Web pages of each of its programs (Building Technologies, Energy Analysis and Indoor Environment).

Document and Software Retrieval—From the Center's site, visitors can download the *RADIANCE* and *Superlite* software as well as a large library of performance data on 600 window products; users of the LBNL *WINDOW* software (also downloadable from the Web site) can use this data in their calculations.

Interactivity and On-line Tools—The Center is developing an innovative, Internet-based tool for residential energy analysis that has several advantages over traditional disk-based software. This tool, the "Home Energy Saver," calculates residential building's energy use based on default values or detailed assumptions specified by the user. Within the tool's interface, links to lists of energy-efficient appliances, utility DSM programs, and vendors of energy-efficient software and products make the tool's interface unlike any traditional disk-based product. Another advantage is that users of any Web browser can access the tool regardless of platform (such as Mac or PC).

Remote Monitoring and Diagnostics—The Internet has the potential to become an enormous energy management and control system. Center researchers have initiated a project that uses the Internet to gather building energy performance data in real time from sensors located in a building. The work's potential future directions include actually operating a building by sending instructions over the Internet. Data, as well as audio and video information, can be collected in real time by an energy engineer in a remote location.

—Evan Mills and Sam Webster

Evan Mills
Center for Building Science
(510) 486-6784; fax (510) 486-5394
EMills@lbl.gov

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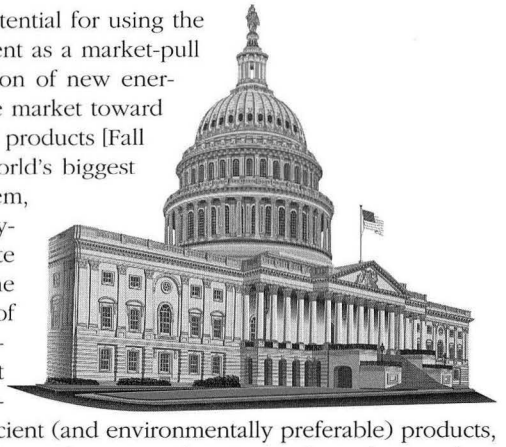
News from the D.C. Office

Government Purchasing and Market Transformation—Revisited



In previous columns, we discussed the potential for using the enormous buying power of the government as a market-pull mechanism to encourage commercialization of new energy-efficient technologies and to help shift the market toward increased use of today's most energy-efficient products [Fall 1994, p.3]. The federal government is the world's biggest customer for almost any commercial item, spending well over $10 billion/year on energy-related products. Adding the purchases of state and local government agencies increases the total by a factor of three or more—an order of magnitude larger than all the spending on utility demand-side management programs at their peak! How can we harness this enormous market power in support of energy-efficient (and environmentally preferable) products, especially in light of recent procurement reforms that stress decentralized purchasing decisions and reduced use of "special government requirements"?

Berkeley Lab projects in both Washington, D.C., and California are supporting the "Federal Procurement Challenge," an interagency effort led by the DOE Federal Energy Management Program (FEMP), the White House Council on Environmental Quality, and the OMB Office of Federal Procurement Policy. Twenty-two federal agencies have signed an agreement to shift their purchasing of energy-using products to the "best 25%" of current models on the market. This is in keeping with a 1994 Executive Order that asks each agency to consider how its purchasing can shift to the energy-efficient end of today's market.

The Order also urges federal buyers to help create an entry market that will encourage private firms to invest in developing and introducing even more efficient new technologies because they will have at least one important "anchor buyer"—the federal government. In June, DOE Assistant Secretary Christine Ervin and FEMP director Mark Ginsberg were the keynote speakers at a public meeting soliciting views from manufacturers, vendors, and their federal customers on how federal purchasing can be used most effectively to commercialize new technologies. Already, one promising "technology procurement" is well underway: the Department of Defense is offering to buy six million enhanced-efficiency light bulbs over a three-year period for use in military base housing. The likely technologies include an infrared-enhanced halogen lamp or an improved subcompact fluorescent. Staff from LBNL's lighting program provided technical support for this DOD solicitation.

The E&E Division Washington Office of Berkeley Lab supports these federal procurement initiatives by analyzing data needed for DOE-recommended efficiency levels that help buyers identify the "upper 25% of efficiency" for a number of commonly purchased products. The Office has completed recommendations for several types of residential appliances and equipment and for large water-cooled chillers. Drafts are now under review or in preparation for lighting products, water-saving fittings, boilers, commercial food equipment (ice makers) and office equipment. Commercial HVAC and other equipment will soon follow. These recommendations will be distributed to federal purchasing officers in hard-copy form and also made available at the DOE and LBNL Web sites.

In June, the DOE appliance efficiency recommendations were incorporated in the latest product catalog issued by the General Services Administration (GSA) in the form of an "EE" symbol next to each qualified product. The growing practice of "electronic commerce" offers another important means to disseminate efficiency recommendations. As more federal buyers go on-line to shop for products through the Web-based "GSA Advantage" and other systems, we plan to build in efficiency levels as a primary criterion for product searches.

Procurement strategies will be even more effective if they are linked closely with other market-oriented actions. For example, voluntary programs at both DOE (Technology Introduction Partnerships) and Environmental Protection Agency (ENERGY STAR™) have recently added procurement elements, including not only government buying but also volume purchases by other institutional buyers and retailers. EPA and DOE are now joining forces in a national appliance and equipment labeling program, using an updated version of the ENERGY

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Executive Editor
Evan Mills

Managing Editor
Allan Chen

Contributing Editors
Nathan Martin
Karen H. Olson
Rich Sextro
Michael Wilde

Production/Design/Graphics
J.A. Sam Webster Mayers

Copy Editors
Linda Comer
Ann Kelly

Circulation
Ralph McLaughlin
Pat McLaughlin

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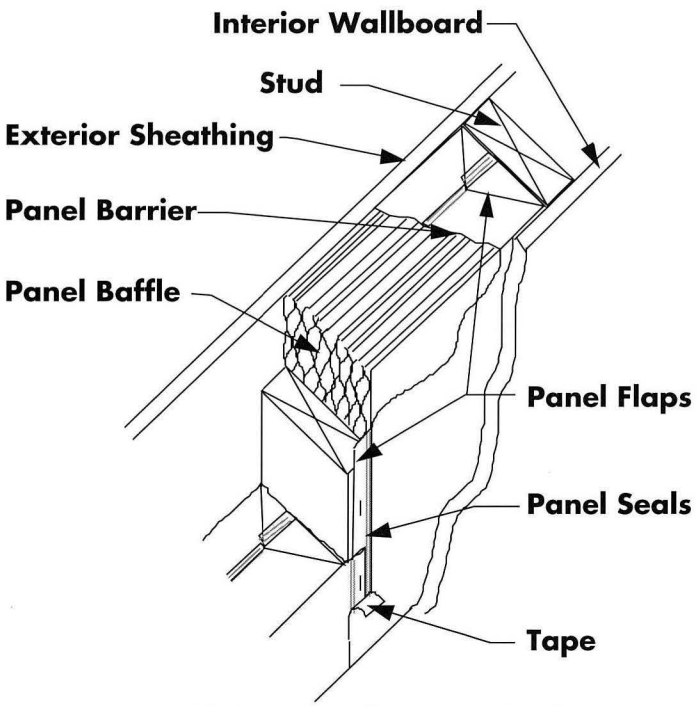
Gas-Filled Panels for the Building Thermal Envelope

Buildings designed for low energy use and thermal comfort require good insulating materials. Although most codes require buildings to have insulation of minimum R-value, it should be possible to reduce substantially, or even eliminate, the need for active heating in a properly designed building with code-exceeding insulation, air/moisture barriers, and high-performance windows. The Center's Building Technologies Program has been studying the potential for gas-filled panels (GFPs) as an advanced insulation system in refrigerator doors and, more recently, in the building envelope. Here, we offer a brief summary of recent results from building envelope studies.



Gas-filled panel installation in stud wall

GFPs are composed of hermetic plastic bags with a box-like shape which enclose a honeycomb baffle of thin polymer films and a low-conductivity gas. The baffle, a bonded assembly that produces a cellular structure within the panel, uses metalized, low-emissivity film. Low-diffusion gas barrier films are used in the hermetic barrier, whose purpose is to retain the panel's gas fill. The best candidate gases to fill GFPs are argon and krypton. Both have lower conductivities than air. Although krypton-filled panels yield a lower conductivity, their scarcity and high cost ($0.35/liter) make them better-suited to refrigerator insulation than to the building envelope. Xenon yields panels with the lowest conductivity, but its cost ($4.00/l) makes it useful only in exotic applications.

Protoype GFPs fabricated at Berkeley Lab were sent to Oak Ridge National Laboratory for tests using the heat-flow meter apparatus to determine their center-of-panel performance. The performance improvement over glass fiber for air-filled panels was 40%, for argon, 100%, and for krypton, 230%. Air-filled panels show a thermal conductivity of 0.194 Btu-in/h-ft^2 (0.028 W/m-K); argon-filled, 0.138 Btu-in/h-ft^2 (0.020 W/m-K); and krypton-filled, 0.081 Btu-in/h-ft^2 (0.012W/m-K). To test their whole-panel conductivities, we sent several GFPs that were assembled to fit an existing wall opening (27.2 by 17.3 in; 0.69 by 0.44 m) to the National Institute of Standards, where investigators have developed calorimetric procedures to measure the heat flowing through the entire specimen. Final results from the testing are summarized in the table. These tests correct for the three-dimensional heat transfer between panel and wall with different thicknesses. The tests used krypton- and xenon-based panels to demonstrate the high-performance capability of GFP technology.

Panel Type	*Thickness at test temperature inches (mm)*	*Mean test temperature F°(C°)*	*Resistivity R-/inch*
Krypton	0.98 (24.9)	39.4 (4.1)	13.4
Xenon	0.95 (24.1)	38.8 (3.8)	19.3

NIST calorimeter measurements of krypton and xenon GFPs

Working with GFPs in the Building Envelope

GFPs are flexible and self-supporting. Manufacturers could fabricate them in a variety of shapes and sizes to fill most types of cavities in building walls and roofs. The figure shows how GFPs might be installed in a wood-frame wall assembly. Panels are fastened to studs with staples through panel flaps; adhesive-backed tape seals adjacent panels across the stud, so the insulation also becomes an air barrier/moisture retarding component. The far face of the panel adheres to the exterior sheathing to provide added air sealing and to keep the panel expanded. Gas could be added to unfilled panels on site.

Although no manufacturer currently supplies GFPs for building use, it is possible to estimate GFP costs from material component costs. An argon-filled, 3.5-inch- (89 mm) thick panel might cost $0.69/ft^2 ($7.43/m^2) to manufacture; a 10-inch- (254 mm) thick panel, $1.46/ft^2 ($15.72/m^2). The technology appears to be versatile enough for widespread use in traditional wood-frame construction, although some difficulties need to be overcome for site-built construction to make GFPs fit oddly shaped cavities. Initial uses will likely be in manufactured housing and panelized building systems. Current research at Berkeley Lab focuses on making protoype GFPs for testing and demonstration projects.

—Brent Griffith

For more information, request "Gas-Filled Panels: An Update on Applications in the Building Thermal Envelope," LBL report 38093, from the author.

Brent Griffith
Building Technologies Program
(510) 486-6061; fax (510) 486-4089
BTGriffith@lbl.gov

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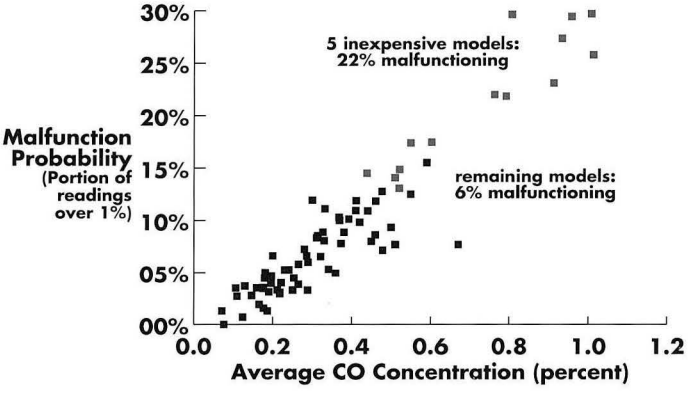
Emissions Control Failures in Passenger Cars

When an automobile's emissions control system fails, it may be because that model is more prone to failure than others, according to a study conducted by the Center's Energy Analysis Program and Marc Ross of the University of Michigan. This finding goes against the conventional wisdom that improper maintenance or deliberate disabling of the emissions systems by car owners is the cause of "high-emitting" vehicles. The results may provide clean-air regulators with more cost-effective strategies to reduce air pollution from autos than the current system of individual automobile inspections. We presented these results at the Asilomar Transportation and Energy Conference last summer and at conferences held by the Society of Automotive Engineers and the Coordinating Research Council earlier this year.

Regulations established by the Environmental Protection Agency (EPA) have resulted in dramatic reductions in tailpipe emissions from new cars: on the order of 95% for carbon monoxide (CO) and hydrocarbons (HC) and 75% for oxides of nitrogen (NO_X). However, increased vehicle use, as well as two loopholes in current vehicle emission regulations, have counteracted these emission reductions; if we don't close these loopholes and/or curb vehicle use, we may see increases in auto emissions and urban air quality problems in the future.



Two measures of car model malfunction probability, fraction of cars over 1% CO (y-axis) and average CO concentration of all cars (x-axis), demonstrate that five 1987-89 car models (14 year-model combinations) have a malfunction probability several times that of all other models.

One of the loopholes is that the test procedures to certify compliance with emission standards do not reflect the high speeds and accelerations of current driving. The test procedures encourage manufacturers to design cars that merely pass the test, rather than minimize emissions over all types of driving. The second loophole is that there is very limited testing of emissions as cars age. Although manufacturers are now responsible for designing cars that meet the tailpipe standards up to 100,000 miles, in practice only cars that have been "properly maintained and used" are selected for compliance testing.

We analyzed a large dataset of car tailpipe emissions measured with a remote sensing system. The system uses an infrared beam to measure the CO, CO_2, and HC emissions directly from the tailpipe as the car drives by, while a video camera records the car's license plate. Researchers from the University of Denver set up the system at sites in Southern and Northern California to gather data for the California Air Resources Board in 1991. The state Department of Motor Vehicles matched each car's license plate with its vehicle identification number, which provides detailed technical data on each vehicle.

We focused on cars that were two to five years old at the time of measurement. We expected that these young cars, which were within the manufacturers' warranty period for emission control components, would have a low probability of malfunction. About 10% of these cars showed CO emissions that were 50 times that of properly functioning cars—a very high rate for young cars.

Next, we grouped the vehicles by manufacturer and model to analyze the probability of malfunction for the most popular models. The malfunction rate varied widely by vehicle model; some models had only a few malfunctions or none at all, while others had average failure rates of up to 30%. The data did not show a correlation between manufacturer and probability of malfunction. In fact, they suggest that the manufacturers whose models had the highest failure rate also had very clean models. The five worst performers were low-priced models from Asian manufacturers: an average of 22% of the models in this category had malfunctioning emissions controls, compared to 6% for all the other models (see figure). At the same time, the mid- and high-priced models from the same manufacturers had very low failure rates. Most domestic models fell in the middle of the range of malfunction percentages. We also found that malfunction rates were higher in vehicles with certain technologies, such as carburetors (as opposed to fuel-injection systems).

If confirmed, these findings have important policy implications at both the state and federal level. Current policies, such as California's Smog Check program, are designed to identify individual vehicles for repair through regularly scheduled vehicle inspections. A controversy is currently raging between states and the EPA over what is the most cost-effective system to identify individual high-emitting vehicles: a network of remote sensors or more detailed laboratory tests. The results from this study may shift the focus of the debate.

Our analysis indicates that emission control problems in new cars are not necessarily the fault of drivers not properly maintaining their cars; certain models appear to have more problems than others. Policies that focus on improving the durability of emission controls on all models may therefore be more cost-effective in reducing emissions than the current or proposed approaches.

—Tom Wenzel

Tom Wenzel
Energy Analysis Program
(510) 486-5753; fax (510) 486-6996
TPWenzel@lbl.gov

Energy Management in Semiconductor Cleanrooms

Cleanrooms are used extensively in the manufacturing of integrated circuits and in the biological and pharmaceutical industries. For particle concentrations to remain low, for example, less than 100 particles/ft^3 at >0.5 micrometers (Class 100), the air in the cleanroom must be filtered. Typically, the air is circulated through high-efficiency particulate air (HEPA) filters at a very high rate, such as 400 to 600 room air volumes per hour, to maintain low particle concentrations. The combined effect of high recirculation and a high pressure drop through HEPA filters is higher power costs per unit floor area to operate the cleanroom than to ventilate a commercial building. Cleanrooms are usually ventilated constantly and turned off only for maintenance, contributing to high energy costs.

The Center's Indoor Environment Program, along with LBNL's In-House Energy Management Program and Engineering Division, conducted a research project to study ways of reducing cleanroom energy use. We used a technique called demand-controlled filtration (DCF) which controls the particle concentration in a room by changing the recirculation flow rate based on the real-time measurement of particle concentrations. As the measured particle concentration rises above a threshold, the speed of the recirculation fan increases. As the concentration falls below the limit, the fan speed falls with it. Lower average fan speed reduces fan motor energy consumption.

To evaluate DCF, we used a Class 100 cleanroom at LBNL with a floor area of 300 ft^2. The facility is used by researchers two to four times a week for one to four hours per day, and its primary activity is fabricating silicon detectors. A $2,500 particle counter measured the concentration of two size ranges (>0.3 and >0.5 micrometers in diameter) of particles in the cleanroom and was located on a benchtop near a machine that operators used frequently.

The cleanroom's preexisting control strategy (see "Preexisting" in the table) was to maintain a set pressure drop across one bank of HEPA filters. The daytime setpoint was established to maintain the cleanroom's Class 100 certification. At night, the setpoint changed so the fans could run at a lower speed, cutting energy costs by about 10%.

In the first DCF control scheme ("Ten Percent" in the table), the counter read particle concentrations once per second. Each second, if particle concentrations in either size range exceeded the upper limit, fan speed increased by 10%. Likewise, if the particle concentration in either size range was below the lower concentration limit, fan speed decreased by 0.13%. With a second DCF scheme ("Proportional" in the table), if particle concentration in either size range was above the upper limit, the fan speed changed in proportion to the magnitude of the difference between the concentration and the upper limit. If the counts were below the lower limit, the fan speed decreased by 3%.

Depending on the choice of baseline energy use, the two DCF control routines reduced the energy consumption of the recirculating fans by 60 to 84%, with no significant difference between the two methods (see table). The percent energy savings while the cleanroom was occupied was nearly the same as when it was unoccupied (and thus equal to the daily energy savings). When the cleanroom was occupied, the fan speed sometimes increased for only short periods, hardly affecting the daily average power consumption.

Changes in recirculation fan speed by 10% or more did not cause a noticeable particle release from filters or resuspension from indoor surfaces, as many cleanroom users had predicted. Cleanroom users' prediction that it would take hours to reestablish proper conditions after recirculation fans speeds were lowered was also found not to be true. With either of the two DCF control routines in operation, there were occasional (usually fewer than 10 per day) nonconsecutive one-minute episodes in which the particle concentration exceeded Class 100 status. Thus the DCF maintained Class 100 specifications at least 98% of the time while saving significant amounts of energy.

Depending on the energy consumption baseline used in the calculations and whether or not variable fan drives are in the facility, the simple payback time for retrofitting a 1,000-ft^2 Class 100 cleanroom to use DCF methods is from one to four years. This assumes a cost of electricity of $0.08/kWh.

DCF holds the most immediate promise for small cleanrooms that are not continuously in use and in which users are performing one activity at a time such as in universities and research institutions. Implementing DCF in large manufacturing cleanrooms would require a more sophisticated control system than the one outlined here, but the potential savings in energy may justify its development.

—David Faulkner

David Faulkner
Indoor Environment Program
(510) 486-7326; fax (510) 486-6658
D_Faulkner@lbl.gov

This research was sponsored by DOE's Office of Energy Research and the California Institute for Energy Efficiency.

Control Strategy	Average energy savings per day		Average energy savings during occupancy	
	*Baseline 1**	*Baseline 2***	*Baseline 1**	*Baseline 2***
Preexisting	10% ± 5%	60% ± 2%	0% ± 5%	56% ± 2%
Ten percent	64% ± 1%	84% ± 1%	63% ± 2%	84% ± 1%
Proportional	64% ± 3%	84% ± 1%	60% ± 6%	83% ± 2%

*Average power for the first baseline is 2.6 kW (3.5 HP). Based on fans operating at 75% of full speed.
**Average power for the second baseline is 5.9 kW (7.9 HP). Based on fans operating at full speed.

Government Purchasing—Revisited

continued from page 3

STAR™ logo. The utility-sponsored Consortium for Energy Efficiency is also considering adding a procurement element to its program to complement utility demand-side management as a source of market pull for energy efficiency.

As other important initiatives come along, we are looking for opportunities to build in an energy-efficient purchasing dimension. For example, a new government wide specification for buying replacement chillers, under an accelerated process called a Basic Ordering Agreement, will include efficiency criteria reflecting the best 25% of models available (Spring 1996, p.3). And there may be important opportunities for using new performance contracting methods, targeted to a specific piece of equipment or building subsystem, to help overcome some of the obstacles to federal purchase of new, pre-commercial technologies.

These ideas are now spreading well beyond the boundaries of federal agencies—and beyond U.S. borders. The Energy Efficient Procurement Collaborative, recently incorporated as a non profit organization, is developing cooperative purchasing programs among state agencies and local governments using shared tools such as product databases and model specifications. This program is led by New York State, with cosponsorship from DOE, EPA, and DOD at the federal level. Recently, the Metropolitan Washington Council of Governments expressed interest in a regional Procurement Challenge, modeled on the federal program. The concept of harnessing government purchases as a force for efficiency in the wider market is also being discussed as part of multinational programs for sustainable development, such as the Climate Technology Initiative and the Hemispheric Energy Strategy. Energy-efficient procurement will be a major theme in presentations and exhibits at meetings this year, including EPA's annual ENERGY STAR™ Forum, the ACEEE-96 summer study this August, the intergovernmental TEEM-96 conference in September, and the World Energy Efficiency Congress later this fall.

—Jeffrey Harris

Jeffrey Harris
E&E Division Washington Office
1250 Maryland Ave. S.W. Suite 500
Washington D.C. 20024
(202) 484-0880
JPHarris@lbl.gov

About Lawrence Berkeley National Laboratory

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 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.

BERKELEY LAB

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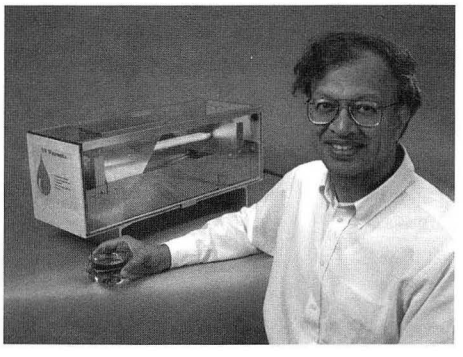
Ashok Gadgil Wins *Discover* Magazine Award for Technological Innovation



Discover magazine has given Ashok Gadgil of the Center's Indoor Environment Program its 1996 Award for Technological Innovation in the environment category. He invented a device called UV Waterworks, described in the Winter 1996 *Center for Building Science News* (p. 6), that disinfects drinking water inexpensively and efficiently using ultraviolet light. Gadgil's invention has tremendous potential to save lives in the developing world, where dysentery, typhoid, and cholera caused by pathogens in contaminated drinking water kill more than 400 children every hour.

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Energy & Environment Division
Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720 USA
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A-Team Report

The Native American Renewable Energy Education Project

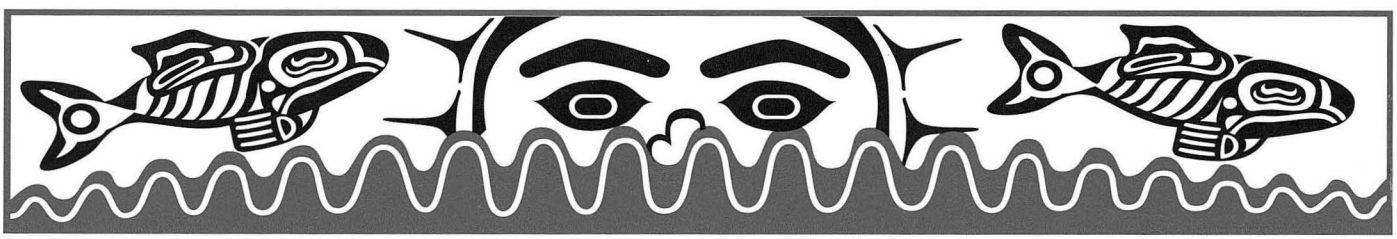
NAREEP is a DOE-funded joint project of Berkeley Lab and UC Berkeley that provides technical assistance to Native American reservations in the areas of renewable energy and energy efficiency. Its purpose is to respond to the desire of Native Americans for cost-effective, culturally appropriate, environmentally benign energy services for tribal community needs and economic development. NAREEP's ultimate goal is to help tribal communities control their own energy future. To support this goal, the Applications Team, working with the Energy and Resources Group at UC Berkeley, is leading efforts to develop the information base and to transfer the relevent technology. NAREEP's research agenda is directed toward producing the following products, scheduled for completion in the fall and winter of 1996:

- a workbook on energy efficiency and renewable energy (EE/RE) for tribal decisionmakers and staff that covers project development, decision tools, EE/RE technologies, finance and funding, legal and regulatory issues, and tribal business;
- a technical information volume that supplements the workbook and includes reprinted materials covering the same topics as the workbook but in more depth;
- a resource guide listing contacts useful to tribes interested in EE/RE projects;
- a case-history volume assessing; tribal experience with EE/RE projects;
- a study quantifying the energy budgets of reservations;
- a study of electric utility issues from the perspective of tribes and tribal utility authority in the current climate of restructuring; and
- creation of a World Wide Web site for NAREEP.

Partnering with the General Services Administration, the A-Team plans to hold several workshops on EE/RE issues and project development for tribes in different regions of the country. The first is expected in Fall/Winter in New Mexico, in cooperation with that state's energy office.

—John Busch

John Busch
Energy Analysis Program
(510) 486-7279; fax (510) 486-6996
JFBusch@lbl.gov



Sources

EREC: Energy Efficiency and Renewable Energy Clearinghouse
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fax: (703) 893-0400
Computer Bulletin Board
Dial EREC's data line toll-free at (800) 273-2955 (VT-100 [ANSI] terminal emulation, 8 data bits, 1 stop bit, no parity).
email: energyinfo@delphi.com
On the World Wide Web accessible from the EREN page at: http://www.eren.doe.gov

Other national laboratories conducting buildings-related research:
Brookhaven National Laboratory (BNL)
Barbara Pierce (516) 282-3123
National Renewable Energy Laboratory (NREL)
Lou Abernathy (303) 384-7501
Oak Ridge National Laboratory (ORNL)
Pat Love (423) 574-4346
Pacific Northwest National Laboratory (PNNL)
Diana Shankle (509) 372-4350

Energy Crossroads
The Center's listing of energy-efficiency resources on the World Wide Web:
http://eande.lbl.gov/CBS/eXroads/EnergyXroads.html

U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs
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Center for Building Science
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