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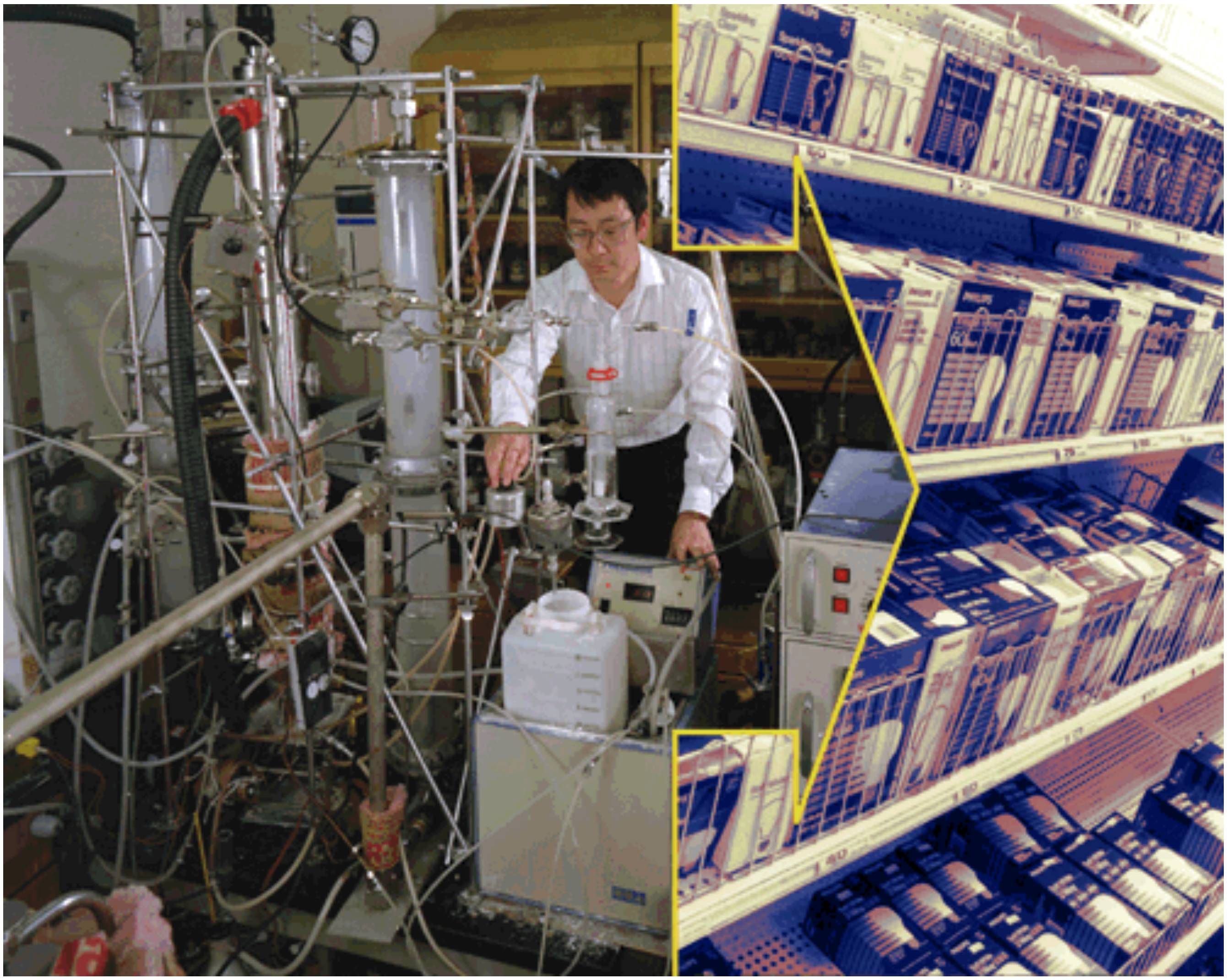
From the Lab to the Marketplace. . .



Some of Our Partners. . .

One of the great challenges facing the U.S. Department of Energy is harnessing the power of its national laboratories in the post-cold-war era. With a workforce of more than 30,000 scientists and engineers and a world- class R&D infrastructure, the labs are a major national asset. Responding to Secretary of Energy Hazel O'Leary's Task Force on Alternative Futures for the Department of Energy National Laboratories, chaired by Robert Galvin, the

Center for Building Science has reviewed its history of doing research for the benefit of the U.S. economy and the environment.

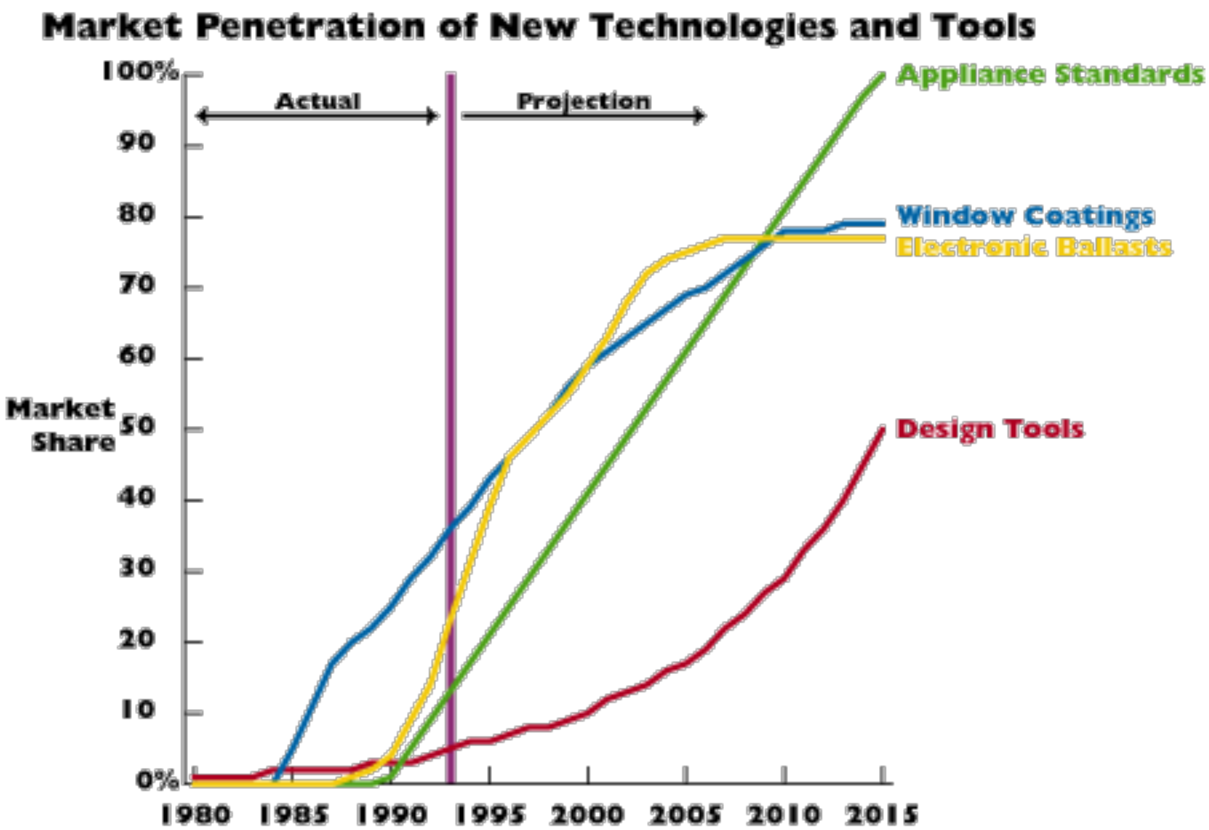
The Center has operated as a catalyst in the energy-efficiency marketplace for two decades, providing an extraordinary rate of return on the federal research investment. From the outset, the approach was not one of belt-tightening, but rather a coordinated technological and deployment-oriented strategy for doing more with less energy while saving money and protecting the environment. Partnerships with industry, utilities, government agencies, universities, and other national laboratories are an integral part of the story. LBL's specific accomplishments in the buildings sector demonstrate how the national labs can serve America today and into the next century.

Since the mid-1970s, a cumulative $70-million DOE research and development investment at LBL helped spawn a $2.5-billion annual U.S. market for four technologies and services. As of 1993, this R&D investment leveraged energy savings worth an estimated $5 billion to consumers ($1.3 billion in 1993 alone). By 2015, electronic ballasts, advanced glazing materials, and residential appliance standards will be saving consumers $16 billion annually. These and other savings will be made possible by new computer design tools, also developed at LBL.

LBL's broader role in the buildings arena includes analyzing public policy issues such as the role of efficiency options as a mitigation strategy for global climate change, developing planning and demand-side management methods used by electric and gas utilities, identifying technologies and analytical methods for improving indoor air quality, contributing to the information superhighway, and focusing on the special problems and opportunities presented by energy use in the public sector. These and other activities are conducted at the local, national, and international levels.

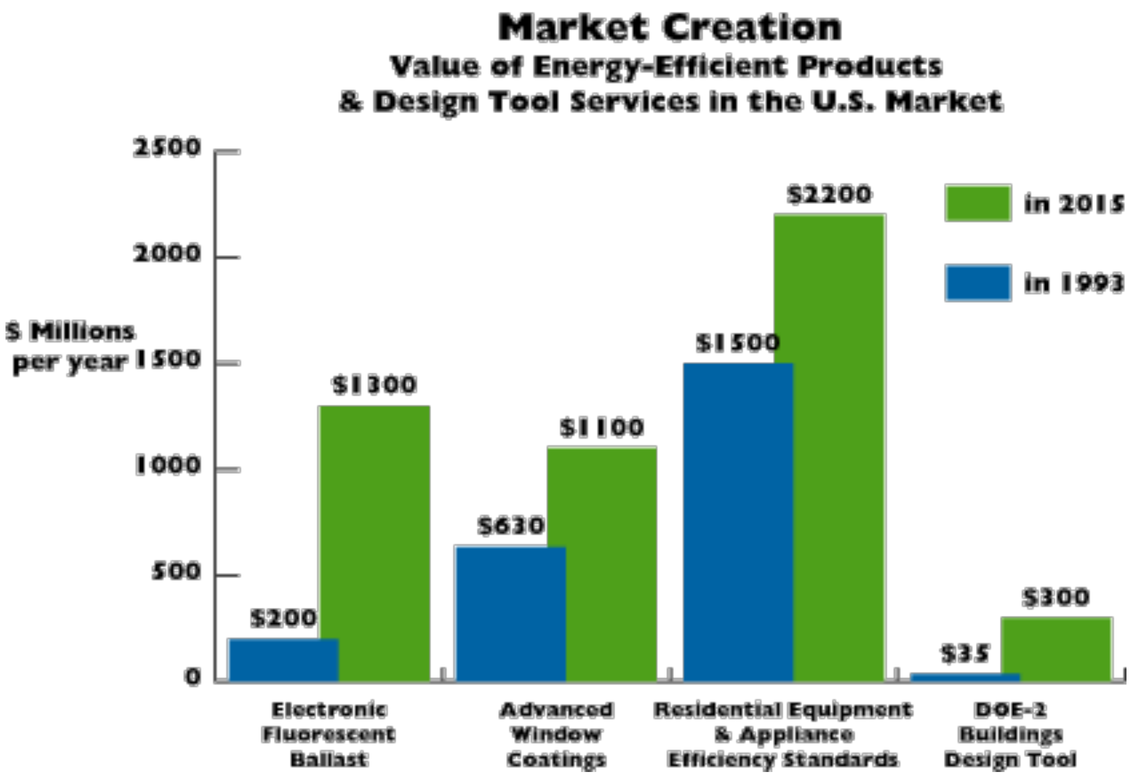
Accelerating the Market for Energy-Efficient Lighting

The electronic ballast is a technology that improves the efficiency of fluorescent lighting systems by up to 30% and enhances quality and flexibility. During the incubation of the electronic ballast industry in the late 1970s, LBL contracted with three small companies to produce early commercial models. The intent of this early effort was to accelerate the availability of electronic ballasts by demonstrating their energy efficiency and reliability in typical building environments. Later work at LBL helped improve the quality of the ballasts and validate the potential for energy savings from dimming. The current market share of electronic ballasts is 23% of all ballasts sold. More recent LBL efficient-lighting breakthroughs are now entering the market, including thermally efficient fluorescent fixtures (see *CBS News,* Winter, 1993, p. 4).



Seeing Windows Through

Although largely invisible to the human eye, windows with advanced coatings offer a one-third efficiency advantage over ordinary double-glazed windows by selectively blocking unwanted heat gain or loss. LBL's research began with researchers studying the heat-transfer mechanisms in windows and identifying technical opportunities for reducing those gains and losses. Based on the findings, LBL became a pioneer in the commercialization of "low- emissivity" windows, awarding subcontracts to several firms to develop prototype coatings and new low-cost thin-film deposition processes. The coatings' performance was tested at LBL and new computer models were developed to determine the best use of the coatings in the overall window system. By the mid-1980s, virtually every major manufacturer was offering low-E windows. LBL developed design concepts using two low-E coatings and new gas fills that would cut energy losses by an additional 50% compared to conventional low-E glazing. LBL then teamed with five manufacturers and suppliers (Andersen, Cardinal IG, Owens-Corning Fiberglas, Pella, and Southwall Technologies) and the Bonneville Power Administration in a program to convert the window concept into commercial prototypes. Within two years of this demonstration project, one of the participating manufacturers introduced the first commercial "superwindow," combining low-E coatings with energy-saving gas fills. The current market share of low-E glazings is 36% of all windows sold. The window industry's National Fenestration Rating Council recently adopted LBL's computer model (Window 4.1) as the definitive method of estimating window performance and creating energy labels for windows (see *CBS News,* Spring 1994).

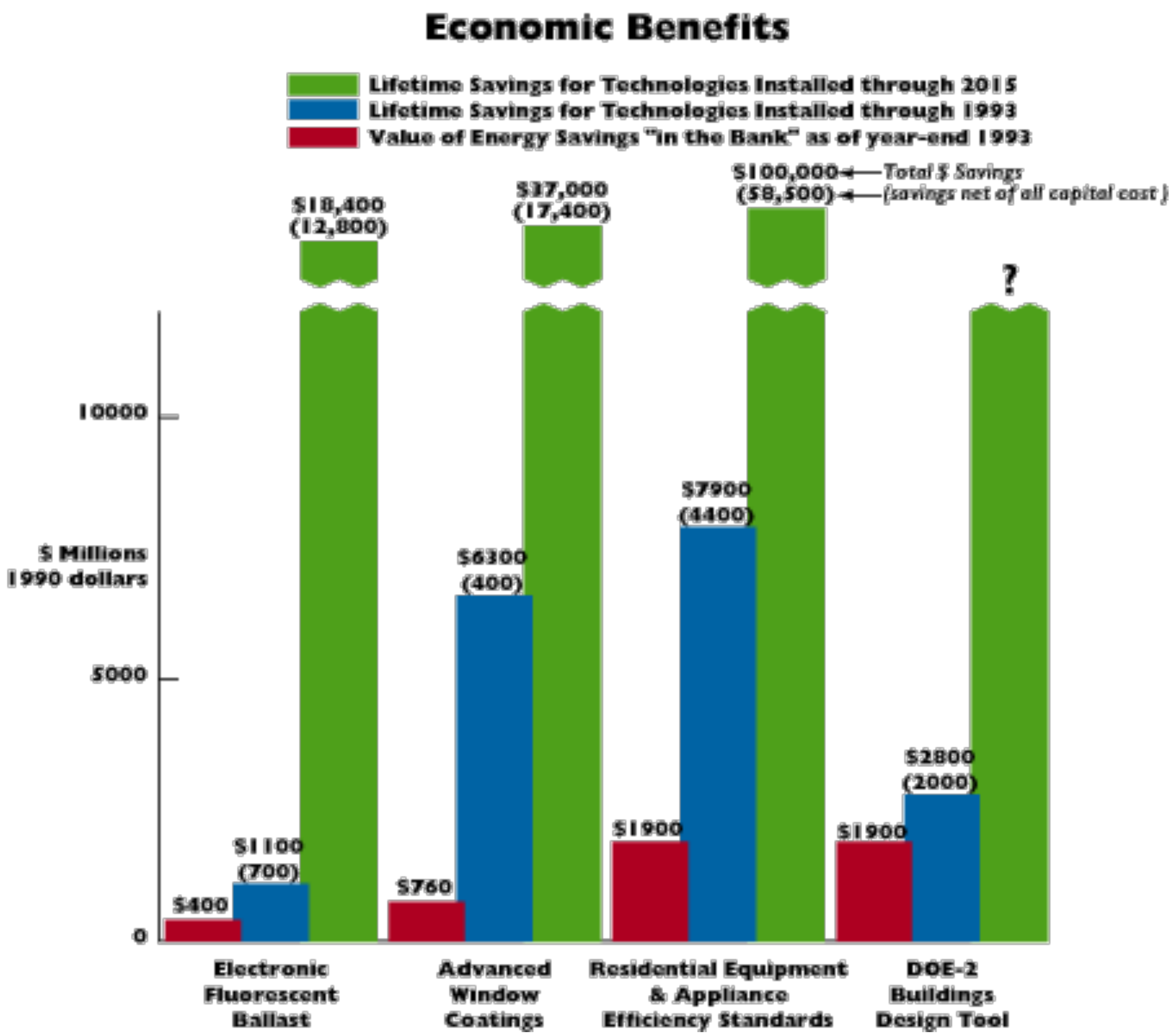


Setting the Standard for Energy Efficiency

LBL has become the national center for appliance standards analysis. Its program provides the technical, economic, utility, and manufacturer-impact analyses on which DOE bases mandatory standards that now apply to all major U.S. appliances and residential space-conditioning systems. In addition to technology-oriented research, the LBL program has provided pivotal support for understanding how the market functions and how certain market barriers to energy efficiency warrant the application of legislative measures such as standards and labeling. The current market share for standards is virtually all applicable equipment sold.

Tools for Building Designers

LBL's DOE-2 program is a powerful computer-based design tool for evaluating the energy implications of complex building design alternatives. Beginning in the mid-1970s, LBL worked with Los Alamos and Argonne national laboratories to develop the predecessor to DOE-2. The objective was an hourly whole-building energy analysis program that could simulate all building types in all climates and that was unbiased, well-documented, and open to public scrutiny. A private company, Consultants Computation Bureau, assisted with interface development and programming. Continued improvements have been supported by DOE, various utilities, and the Electric Power Research Institute (EPRI). A number of companies have converted DOE-2 into a PC-based program, or developed and marketed ancillary software. There are 1,000 users today, in 42 countries. DOE-2 is used in the design of about 5% of all commercial buildings by floorspace, and users report that it enables them to routinely identify an extra 20% energy-savings opportunity. The program has also been the basis of four major standards: California Title 24, the Building Energy Performance Standard, and the DOE/ASHRAE 90.1 and 90.2 standards for commercial and residential buildings.



Clearing the (Indoor) Air

Some energy-saving measures can create indoor air quality problems unless properly conceived and implemented. Mitigating these problems can waste energy, for example, through excess ventilation without heat recovery. The Center for Building Science has studied the "sick-building syndrome" in depth and houses one of the world's premier research groups on the environmental effects of indoor radon-the second largest cause of lung cancer in the U.S. Its research has uncovered basic insights into how radon gas from the soil gets into homes, helping craft national policy recommendations for more effectively and efficiently identifying regions where houses with elevated concentrations can be found, and once found, to utilize energy-efficient remediation techniques (see *CBS News*, Spring 1994; Summer 1994).

LBL's program has helped stimulate technologies and strategies for measuring and controlling indoor air pollution efficiently, including low- emission building materials and appliances, heat-recovery ventilation systems, blower-door technology (for testing air leakage in buildings), and energy- efficient radon control methods. A notable example: LBL's innovative "airvest" system promises to reduce spray-booth worker exposure to pollutants substantially while cutting ventilation energy costs in half (see *CBS News,* Winter 1993, p. 7). Researchers have also developed passive samplers for indoor air quality (for example, the formaldehyde-based air samplers now sold by Air Quality Research in North Carolina) and contributed to twelve national ASHRAE and ASTM standards pertaining to ventilation and air quality for the built environment.

President Clinton holds up a compact fluorescent lamp on Earth Day 1994. Early work by LBL on the electronic ballast helped pave the way for this technology.

On the Horizon

Future directions in the lighting area include developing more efficient light sources such as the sulfur lamp, "tuning" the light spectrum to optimize visibility and reduce energy use, and analyzing market transformation programs for technologies like residential fixtures. LBL's advanced coating technology will lead to "smart windows" whose dynamic coatings change the windows from clear to reflective. Other work in progress updates existing efficiency standards, expands them into nonresidential end-use areas (such as thermal distribution, small motors, lighting ballasts, and HID lamps). The cooperative development of PowerDOE, a PC-based, user-friendly interface for DOE-2, and an expert system module called the Building Design Advisor (BDA, is continuing in a joint private/public collaboration with support from EPRI, utilities, the California Energy Commission, and DOE.

—Evan Mills

For a full copy of the report, From the Lab to the Marketplace. . ., please click here.

Evan Mills
Center for Building Science
(510) 486-6784; (510) 486-5394 fax

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News From the D.C. Office

Presidential Mission on Energy Investment in Pakistan

Secretary of Energy Hazel O'Leary led a presidential mission on energy investment in the Islamic Republic of Pakistan September 19-25, 1994. Stephen Wiel, who heads the Energy and Environment Division's Washington D.C. Project Office, participated in the mission. It was the first visit to Pakistan by a U.S. cabinet member for a nonmilitary purpose: to build economic bridges and an enhanced business relationship between the two countries.

Members of the mission were assigned to work on oil and natural gas, coal, rural development and renewables, energy efficiency and environment, and electricity (including generation, transmission, and distribution). Stephen Wiel chaired the energy efficiency and environment "pod."

Each group was to work with its Pakistani counterparts to agree on a list of desired outcomes and next-step action items. Throughout the week, groups met virtually nonstop with the Prime Minister's special assistant for energy, the Minister of Water and Power, the Minister of Petroleum and Natural Resources, and dozens of other Pakistani energy officials. The Prime Minister and the President were actively involved in several of the sessions.

The centerpiece of the week was a two-day Energy Conference in Lahore titled "Pakistan/U.S. Energy Partnerships: Benefits, Challenges and Opportunities." After a plenary session, breakout sessions in each technical area, and a state dinner, the Conference reconvened amidst fanfare and media attention to report on the results of the joint deliberations.

From an energy-efficiency perspective, the significant aspects of the trip were the Lahore conference, plugs for investment in end-use efficiency, and the mission's official report. Recognizing that raising capital was the primary focus of our Pakistani hosts, the working group focused on energy efficiency as the Government of Pakistan's best available mechanism for freeing capital from the energy-supply sector for other uses.

During the next 25 years the Government of Pakistan plans to add more than 50,000 MW of electric generating capacity. If through energy efficiency improvements it avoided 20% of this increased demand (about half the savings achieved in the past decade by New England Electric System in the U.S., for example), the Government of Pakistan would free approximately Rs.300 billion (U.S. $10 billion) of capital. This would shift the expected range of electricity-growth-rate to GDP-growth-rate ratio from the 1.0-to-1.5 range to the 0.8-to-1.2 range, offering significant relief from the electricity sector's contribution to the fiscal deficit.

Not only would electricity-sector efficiency increases effectively generate investment capital, they would bring two important collateral benefits: dramatic reduction in pollutant emissions; and improvement in the competitiveness of Pakistan's industries. Throughout the mission, these issues were conveyed to the President of Pakistan, the Prime Minister's special assistant on energy, the secretaries of several ministries, and the head of the primary national electric utility. The mission also focused attention on the need for utility DSM profitability. Surprisingly, no one the group encountered in Pakistan had previously heard of or thought about this concept. Making this profitability a part of Pakistan's power-sector privatization and restructuring through establishing a new regulatory agency, or simple tariff reform was the pod's number one recommendation, and it was well received by the Pakistani officials. The U.S. delegation promised a conference in Pakistan on this subject as the next step.

The group made other recommendations and attended other events during the week, including a visit to Tarbela dam and an unelectrified rural village, a roundtable strategy discussion with Pakistan's President, signings of private-sector business deals presided over by Secretary O'Leary and Prime Minister Bhutto (more than $3 billion and 2500 MW in new power plants "committed"), and the dedication of a new ENERCON (Pakistan's energy agency) building.

—Stephen Wiel with Jeff Harris

Stephen Wiel
Environmental Energy Technologies Division
1250 Maryland Ave. SW, Suite 150
(202) 484-0880

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Energy Efficiency Takes Root at the Presidio of San Francisco

The Presidio from the Golden Gate Bridge

The Presidio of San Francisco, recently turned over to the National Park Service, should soon be home to a sustainable development center. Thanks to a public- and private-sector vision of a world-class center for improving the global environment, the Clinton Administration and the Coalition for the Presidio Pacific Center-a group of mainly private-sector interests in the Bay Area-have joined forces to found the Institute for Sustainable Development at the Presidio. One of the Institute's first and most important initiatives is establishing an energy efficiency and renewable energy training activity.

The training initiative emerged at both federal and local levels. In Washington, an interagency task force headed by the White House and the Office of Science and Technology Policy has been generating ideas for sustainable development programs at the Presidio, strongly supporting the concept of a training activity for energy efficiency and renewable energy. The Coalition for the Presidio Pacific Center also supported the training idea. The efforts of Mark Levine, Energy Analysis Program Head and Stephen Wiel, the Energy and Environment Division's Washington D.C. Office leader were central to bridging the gap between the federal and local visions into a single project. DOE's Office of Energy Efficiency and Renewables and its director, Christine Ervin, are playing a role in implementing this initiative.

During the next three decades, energy use in the developing world is expected to quadruple. The result will be a large increase in emissions of greenhouse gases, particulate matter, and water pollution. The aim of the new Institute, according to Mark Levine, is to "promote the transformation of energy systems around the world from their current inefficient use of depletable resources to a much more efficient and sustainable system."

Although many energy-efficiency and environmental technologies exist, there is a barrier to the adaptation and widespread use of these advanced technical systems throughout the world. Levine and others on the Presidio task force believe that the paucity of institutions and lack of skilled personnel are a primary factor slowing the spread of cleaner, more efficient technologies. Developing a credible institution with the mission of improving the transfer of knowledge and skills to countries that need them can make a tremendous difference to the health of the global environment.

Goals of the Presidio Pacific Center

Participants in the planning process see the Center, and the Institute it will house, helping to coordinate U.S.-sponsored international energy efficiency and renewable energy training. They hope it will become a testing ground for developing new training ideas and methods that promote environmental sustainability. They also see it acting, in the long run, as a resource base, providing expertise or seed funding to create training programs in the home countries of visitors. In addition to providing a service to the international community, these activities benefit U.S. energy efficiency and renewable energy manufacturers, since they are among the world leaders in the export of these goods and services.

The challenge is to identify and target the training to the energy efficiency experts in developing countries who are expected to have a significant influence on future efficiency and renewable energy technology decisions. In the near term, the objectives are more modest but just as critical. These include securing core funding for start-up and operation of the training activity; identifying and leasing appropriate building space; developing a detailed management plan; development and testing of training courses; and identifying and recruiting the Center's leadership.

The Center's planners expect that it will open its doors and begin offering courses in September 1995. Before then, it will need to complete all of its curriculum planning and development, establish a library of materials, identify participants from countries that can benefit, and, of course, ensure that all physical infrastructure is complete.

In recent planning meetings between the interagency task force and the Coalition for the Presidio Pacific Center, serious efforts toward developing a business plan for the Center began. The task force is establishing links to domestic and international organizations that address energy efficiency and renewable energy policy and forging partnerships with corporate and foundation sponsors of the Center.

Annual operating costs of the Presidio Pacific Center will average about $6 to $9 million per year once it is fully operational. Around $3 million will come from federal sources the rest from private-sector and foundation contributions.

Already, the Center has received a federal commitment of $800,000 for planning and curriculum development, with a matching contribution to be made by the Coalition for the Presidio Pacific Center, bringing initial planning and start-up funds to $1.6 million.

—Nathan Martin

Mark D. Levine
Head, Energy Analysis Program
(510) 486-5238; (510) 486-6996 fax

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Envelope & Lighting Technologies to Reduce Electric Demand in Commercial Buildings

The basic functional goal of incorporating window and lighting systems in commercial buildings is to give occupants an adequate level of daylight or electric lighting to perform visual tasks productively. Occupant surveys reveal some of the shortcomings of conventional design practice and broaden the definition of an acceptable office environment. In a study of office workers in the Pacific Northwest region, slightly more than 40% of the occupants said the sunlight in their offices was too bright at least some of the time, and 60% of the occupants said the window was a primary source of glare and interfered with their work. Yet more than 50% of the occupants in several Tokyo high- rise office buildings preferred to have seats nearer the window, citing the brightness, outside view, wide visual range, and open feeling as advantages.

Traditional approaches to creating energy-efficient buildings involve selecting from long lists of efficient components. By taking an integrated systems approach to combining disparate building envelope and lighting components, we can attain greater energy savings can be attained and improved occupant comfort compared to conventional energy-efficient design practice. This integrated systems approach is the basis for a multiyear project, supported by the California Institute for Energy Efficiency and DOE, to develop and promote advanced building systems integrating high-performance envelope and lighting technologies. Since the illumination and cooling of commercial buildings account for the largest portion of peak electrical demand, these integrated systems can become a cost-effective DSM option for utilities.

Smart Envelope Systems

For commercial office buildings in moderate climates, choosing glazing materials to optimize energy use and electric demand may be viewed as a trade-off between lowering the solar heat gain coefficient to reduce cooling while maintaining the visual transmission of the glass to capture daylight savings. However, harnessing daylight in a building poses a significant technical challenge because of the great variability in daylight intensity. Achieving higher energy savings under these conditions requires looking beyond static systems to dynamic systems that respond to changing climatic or occupant conditions. By linking a dimmable electric lighting system with daylighting sensors to a fenestration system that can automatically modify the transmission of daylight, we can get real-time control of the cooling and lighting energy balance while addressing glare and thermal comfort.

"Smart" electrochromic glazings now under development offer the best long-term potential for dynamic control. The technology consists of a multilayered, thin-film device that changes from a clear to an increasingly dark, colored state when low-voltage current is applied. By using electrochromic glazings in a curtain wall, we can dynamically alter daylight levels and visual privacy in the space and control thermal energy flows in the entire building envelope.

We are investigating this concept using an automated blind system (Figure 1) as a substitute for electrochromic glazings, working toward a responsive system that can be linked to the building HVAC system by a network of sensors and operated by intelligent energy management controls. Currently, the position of the blind system is coupled actively to variable external and internal conditions-the sun going behind a cloud or changing functional needs in a room, for example. The system could accommodate preferences for controlling view, glare, privacy, and task lighting levels when the space was occupied, and could switch to a minimum energy consumption mode whenever the occupant left the office.

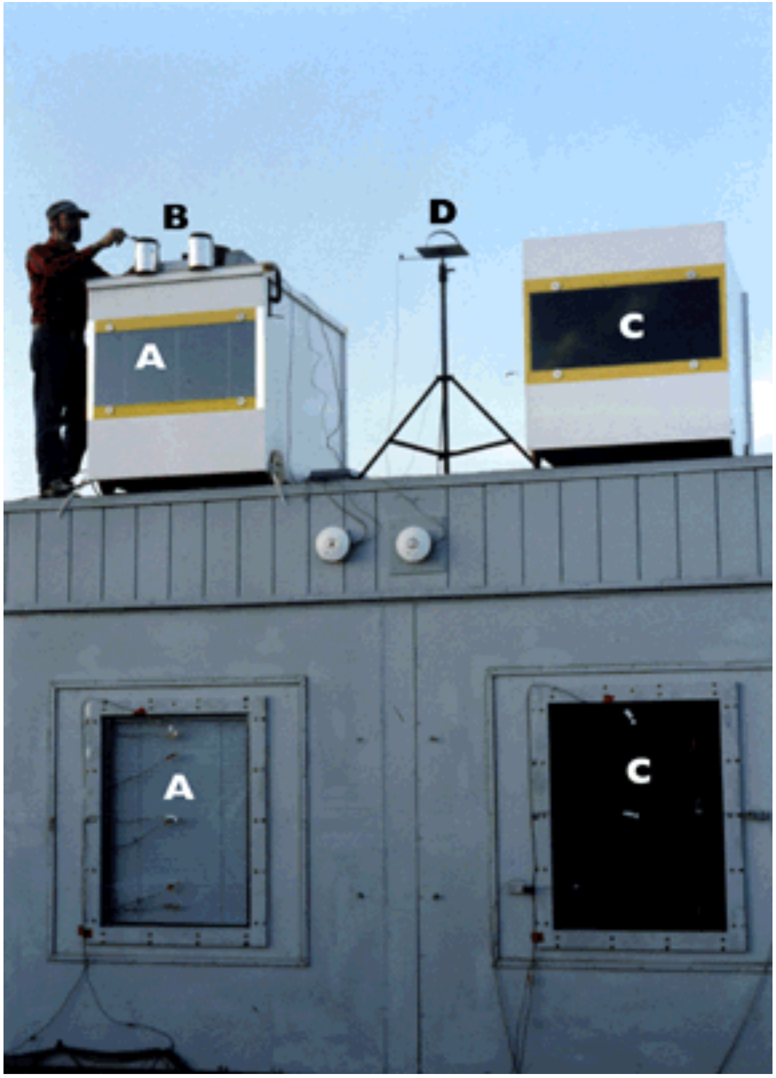

Figure 1. This "smart" automated venetian blind system has been designed to respond to changing solar conditions and access to view in real-time by using a network of sensors and an intelligent computer control system to operate the slat angle of the blinds. In this field test, we are comparing the thermal performance of the smart system (left) to a static tinted glazing system (right) using the Mobile Window Thermal Test (MoWiTT) facility.

A. "Smart" automated venetian blind system operated by computer controls
B. Prototype sun angle sensors
C. Static tinted glazing system
D. Solar radiation and shadowband sensor

Deep Perimeter Daylighting Systems

Conventional windows provide daylight in the outer 10 to 12 feet of a perimeter space. New daylighting technologies extend the daylit area by redirecting sunlight further from the glazing aperture, reducing electric lighting and cooling energy within a larger floor area. The challenge of successful daylighting design is to collect sunlight from a source that varies in both intensity and position and to distribute the luminous flux comfortably with minimal glare and thermal impacts.

The system we have been developing consists of a window wall divided into an upper daylighting and a lower view aperture. The lower view aperture incorporates spectrally selective glazing with a shading device to control glare, direct sun, heat gains, and view for those occupants adjacent to the window. The upper daylighting aperture incorporates a prototype light shelf or light-pipe technology to redirect or transport direct sunlight to depths of 9.28 m (30 ft) from the window wall; supplemental daylight is contributed from the lower view window for the first 4.57 m (15 ft) from the window (Figure 2). These technologies use a customized geometry developed for the solar path at a given latitude and unique reflective films to control the redirection of daylight.

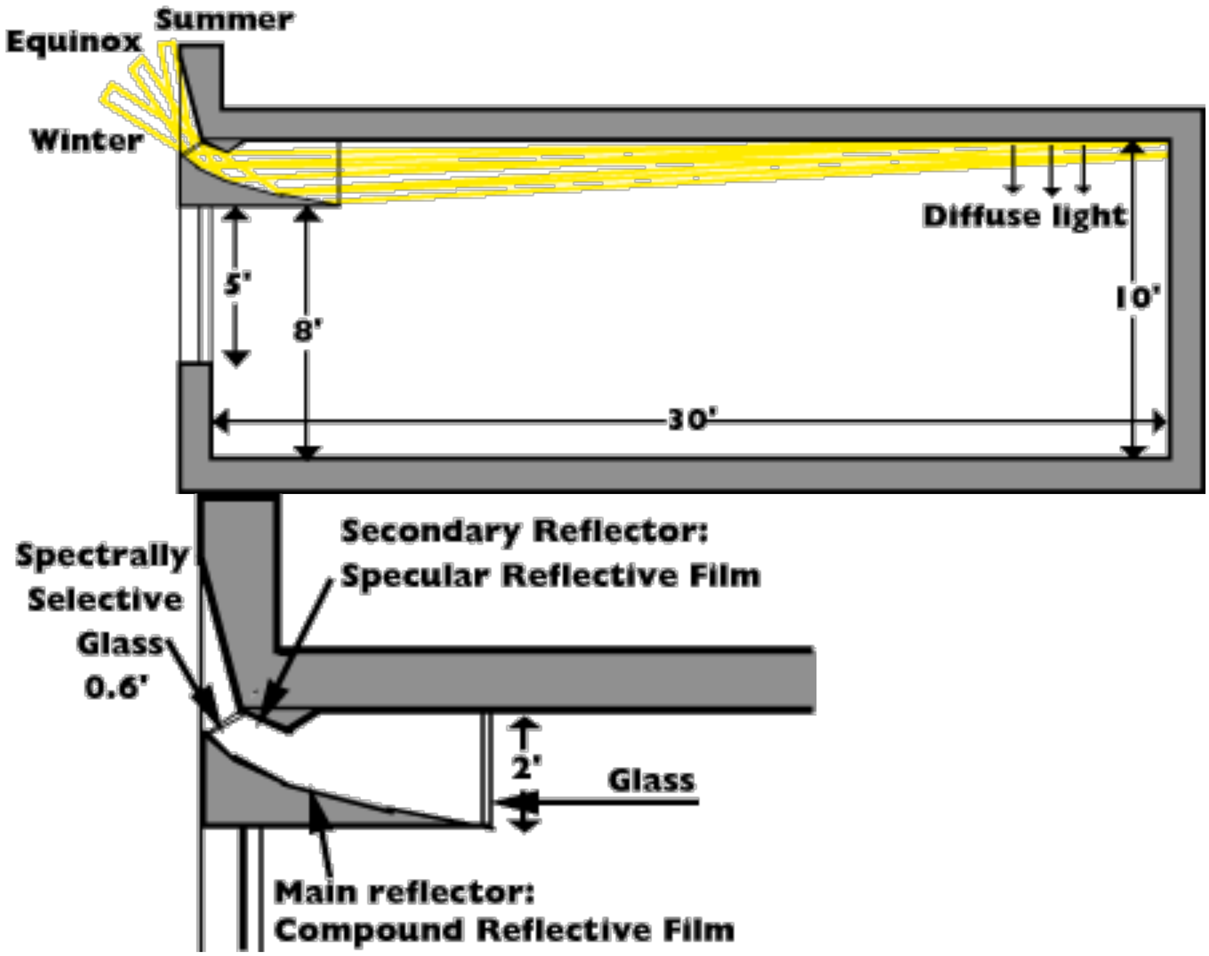

Figure 2. South-facing light shelf: (a) Section along centerline of room, and (b) detail of light shelf reflectors.

Deploying Integrated Systems

Realizing the full energy-saving potential of envelope and lighting technologies for commercial buildings means designing and packaging them as integrated systems, supported by appropriate design tools. The focus of the third phase of research is deployment, conducted along the lines initiated in earlier phases of research-through showcase demonstration projects in partnership with California utility sponsors-and evaluation in an occupied testbed office building. By demonstrating the conceptual designs and prototype technologies, we hope to accelerate their adoption by building professionals. We are also working to establish manufacturer-utility partnerships to foster the commercialization of products.

Results

To develop a preliminary assessment of how an integrated, dynamic envelope and lighting system would perform, we conducted a series of building simulation tests modeling both conventional glazings and automated blind systems. The DOE-2 energy simulation program helped us understand the performance of various control strategies. The initial results show that automated systems with motorized blinds that are adjusted continuously to maintain desired light levels and block direct sun provide substantial energy and demand savings compared to conventional static glazing design solutions.

In a second study, field measurements were taken in the outdoor Mobile Window Thermal Test (MoWiTT) facility (see Figure 1 and Center Research Facility article). Side-by-side measurements were made of the thermal performance of conventional tinted glass compared to a spectrally selective glazing with an automated venetian blind. Solar sensors and a smart controller kept the blinds tilted at the optimum angle throughout the day. The automated blind with photocell controls showed a 50% reduction in total solar and lighting heat gains for a south-facing window (Figure 3).

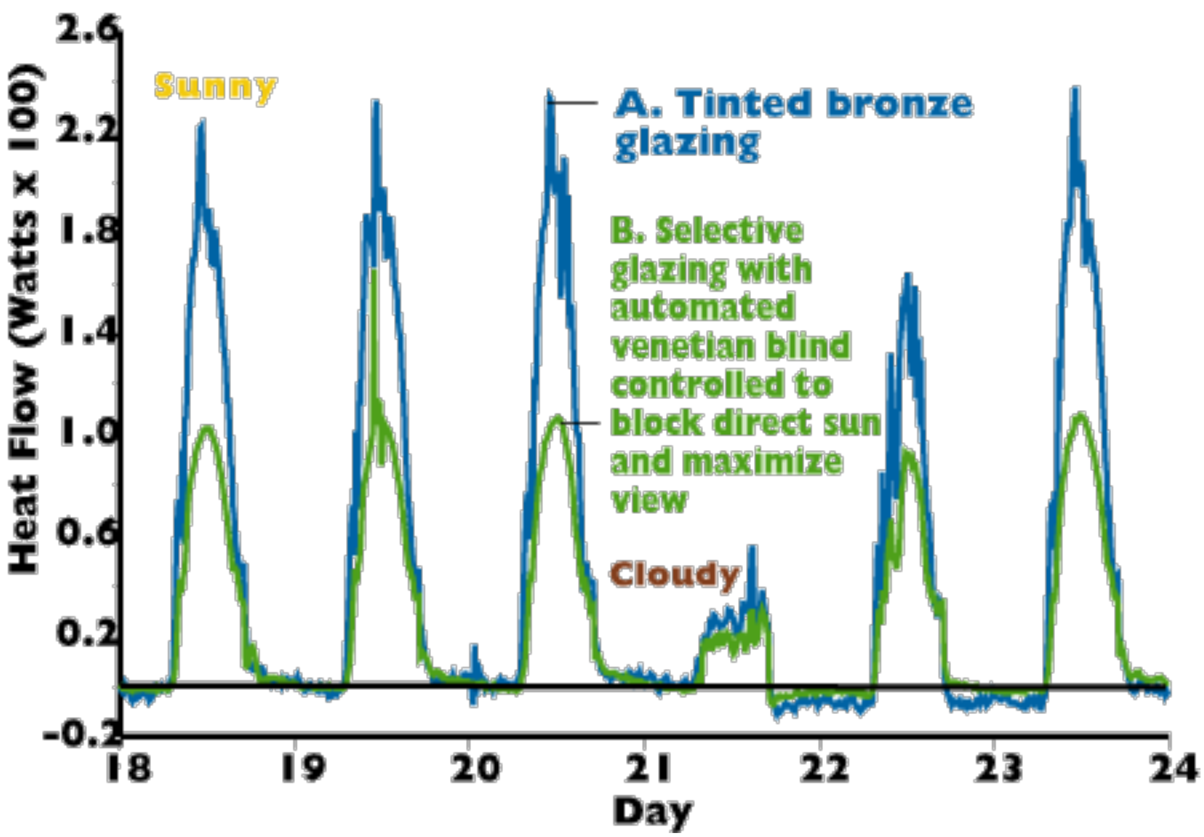

Figure 3. Results from the MoWiTT facility for a clear day indicate that the automatically controlled interior blind coupled with a selective glazing system (B) was more than twice as effective at reducing solar heat gain as a commonly used nonoperable system, single-tinted (bronze) glazing (A), while providing approximately the same electric light energy savings. The large differences in the heat flow between the two samples were driven principally by the admittance of direct sun into the base-case chamber.

With Southern California Edison, we applied our project results to the problem of providing daylight in a windowless office at the Palm Springs Chamber of Commerce. In addition to using advanced, commercially available envelope and lighting technologies throughout the building, we designed a skylight prototype to split and redirect incoming daylight to the ceiling plane in two separate windowless internal offices (Figure 4A). We gained considerable experience working with the manufacturer of special optical films, the building contractor, the architect, and the utility. Occupants reported that the skylight provides lively, bright, and uniform daylight throughout the space (Figure 4).

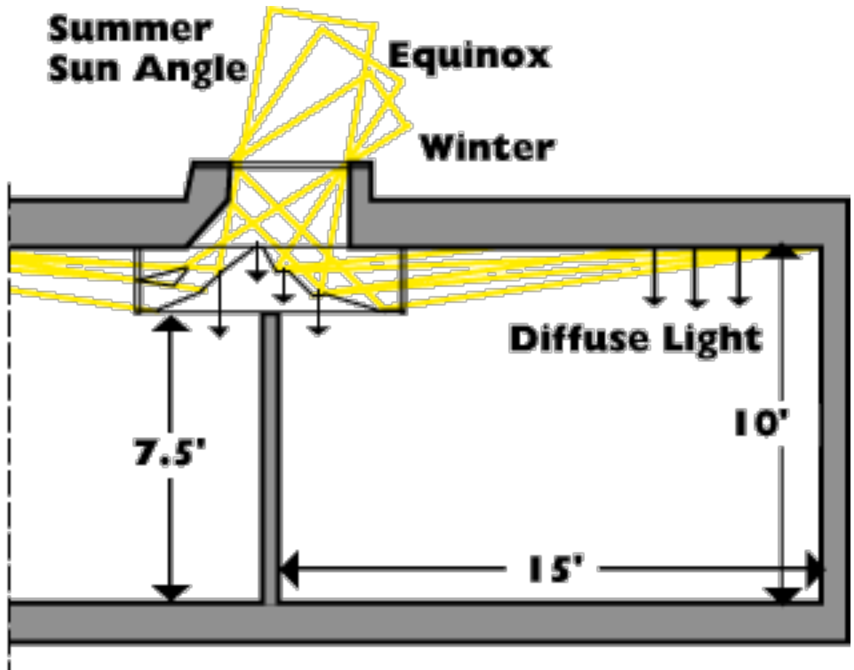

Figure 4. The reflector system used in the prototype skylight for the Palm Springs Chamber of Commerce was designed to split the incoming daylight flux and redirect it to the ceiling plane of two separate rooms (Figure 4a). The installed skylight (above) yielded excellent illuminance uniformity on the workplane and brightened typically dark wall and ceiling surfaces.

The testbed demonstration approach is designed to help make the transition from Phase I and II scale model prototypes, reduced-scale field tests, and building energy simulations to a more robust technology solution suitable for larger building applications. It is both an R&D facility to help answer research questions and a limited proof-of-concept test, designed to eliminate practical "bugs" from an innovative building system. Side-by-side energy and environmental quality comparisons of prototype versus conventional design will prove the design. Negotiations are under way to form a partnership with Pacific Gas & Electric and a major U.S. commercial developer and owner of a 24-story commercial office building in downtown Oakland, California.

Efforts in 1995 will focus on deployment, getting industry feedback on demonstrations of the two prototypes, and continued work on tools for integrated design, including quick, accessible reference materials.

—Eleanor Lee

Eleanor Lee
Building Technologies Program
(510) 486-4997; (510) 486-4089 fax

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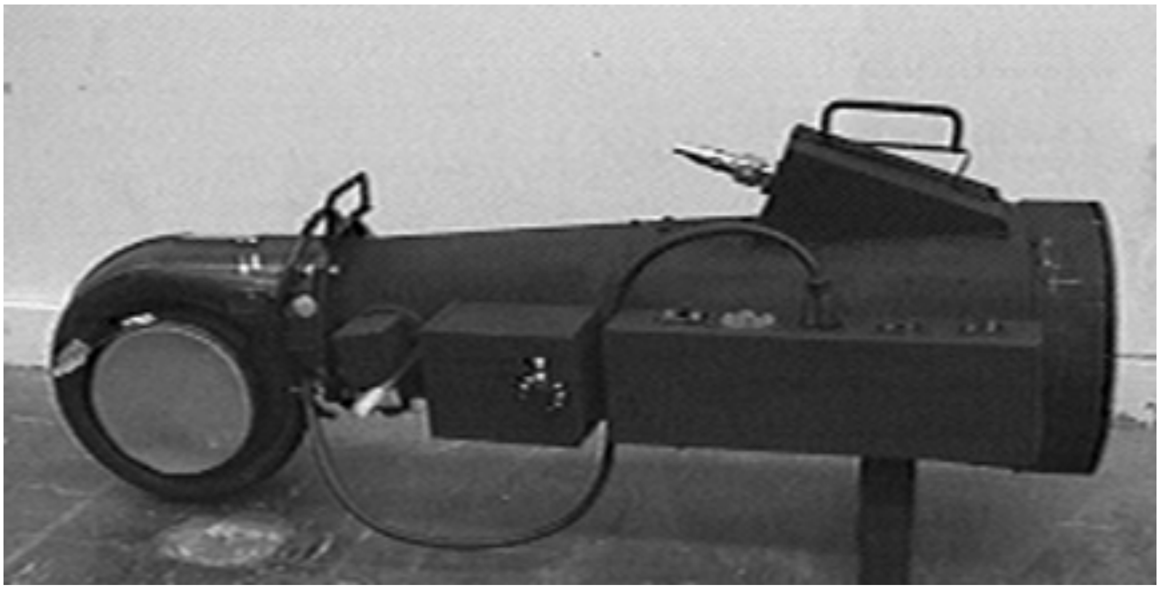
Aerosol-Based Duct Sealing Technology



During the past five years, research has quantified the impacts of residential duct system leakage on HVAC energy consumption and peak electricity demand. A typical house with ducts located in the attic or crawlspace wastes approximately 20% of heating and cooling energy through duct leaks and draws approximately 0.5 KW more electricity during peak cooling periods. A 1991 study indicated that sealing leaks could save close to one Quadrillion Btus per year.

(see also *Commercializing a New Technology*)

Because the major cost of sealing leaks in existing air distribution systems is the labor for the location and sealing process, reducing the labor could greatly improve the cost-effectiveness of such a retrofit. Field studies of duct sealing programs performed by HVAC contractors show that labor costs vary between three and six times material costs. Another conclusion of these studies is that in many instances it is virtually impossible to get to the leaky ductwork. Between 1992 and 1994, we obtained laboratory proof-of-concept of a technique to seal duct systems remotely using an internally injected aerosol. Our tests have shown that holes in the ducts, as well as leaks between duct joints, can be sealed remotely and that even those leaks beyond bends and junctions in the ductwork can be sealed.

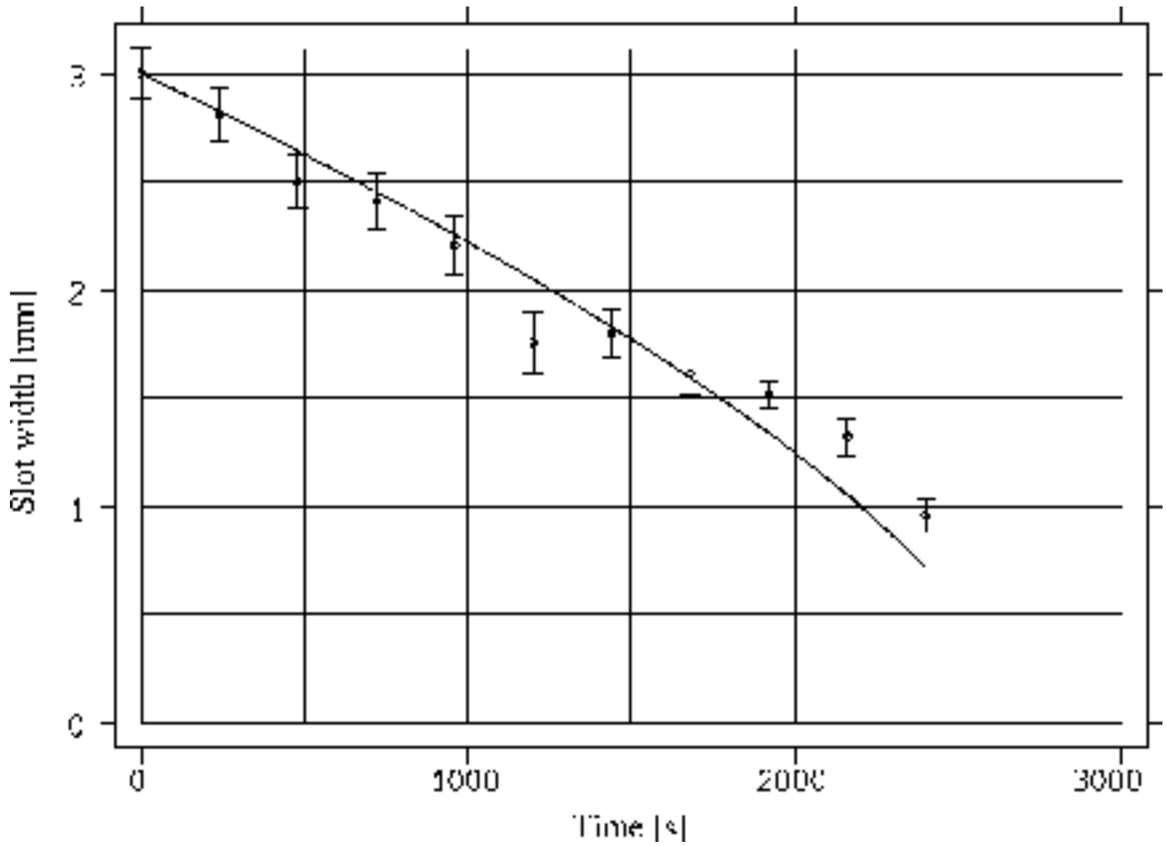


Figure 1. Predicted (solid line) and measured slot width over the course of the sealing process for a 3 mm by 40 mm leak.

Aerosol Sealing

To develop a successful technology for remotely sealing leaks with an aerosol, we needed to solve two fundamental problems: how to deposit aerosol particles preferentially at the leaks to be sealed rather than on the walls of the duct, and how to have the particles span and ultimately seal the leaks completely. The solution to the first problem involved two steps: first, choosing an aerosol that is small enough to reach the leaks before settling out of the flow stream but large enough to leave the airflow streamlines at the leaks; and second, choosing and controlling the flow rate and pressure in the duct system so as to expand the range of usable aerosol sizes that can seal the leaks capable of achieving the sealing. The solution was to use turbulent flow to minimize particle transit time through the duct system and to use particles of 2 to 20 μm in diameter. (Turbulent air generates higher velocities and therefore a shorter time in the ductwork.) We solved the problem of spanning the leaks by ensuring that the particles were essentially in solid phase; therefore, they did not deform when they were deposited at the leak boundaries. Controlling the flow rate and relative humidity of the pressurizing airstream evaporates all the carrier liquid within a short distance of the aerosol injection point, preventing large wet particles from hitting the walls of the injection chamber.

A simplified model of the rate of particle deposition on the leak boundaries helped us understand and predict the efficiency of the sealing process. This model predicts the fraction of aerosol passing through the leak that will be deposited on the leak's boundaries as a function of particle size, pressure and flow conditions, the size of the leak, and the thickness of the leak boundaries (see Figure 1). Videotaping the sealing process verified the model-it was shown to work remarkably well over the range of our experiments (see Figure 2).

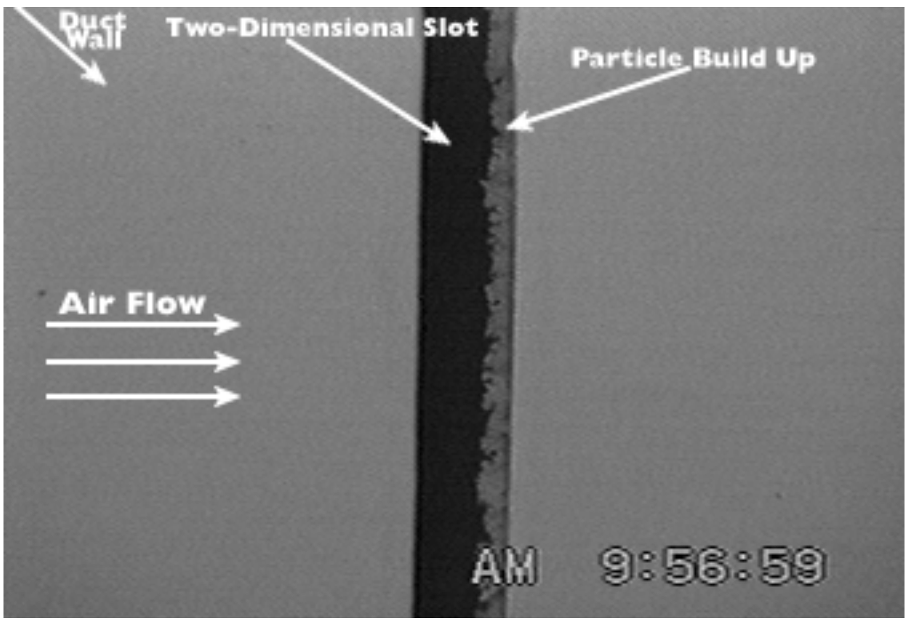


Figure 2. Top view of a 3 mm by 40 mm slot after 20 minutes of injection.

In-Situ Sealing Apparatus

In 1994, we designed, built and field-tested an in situ aerosol sealing apparatus (see Figure 3). Designed for portability and ease of use. Besides performing the sealing process, the field apparatus also measures the leakage of the duct system before and after sealing, eliminating the need for additional hardware.

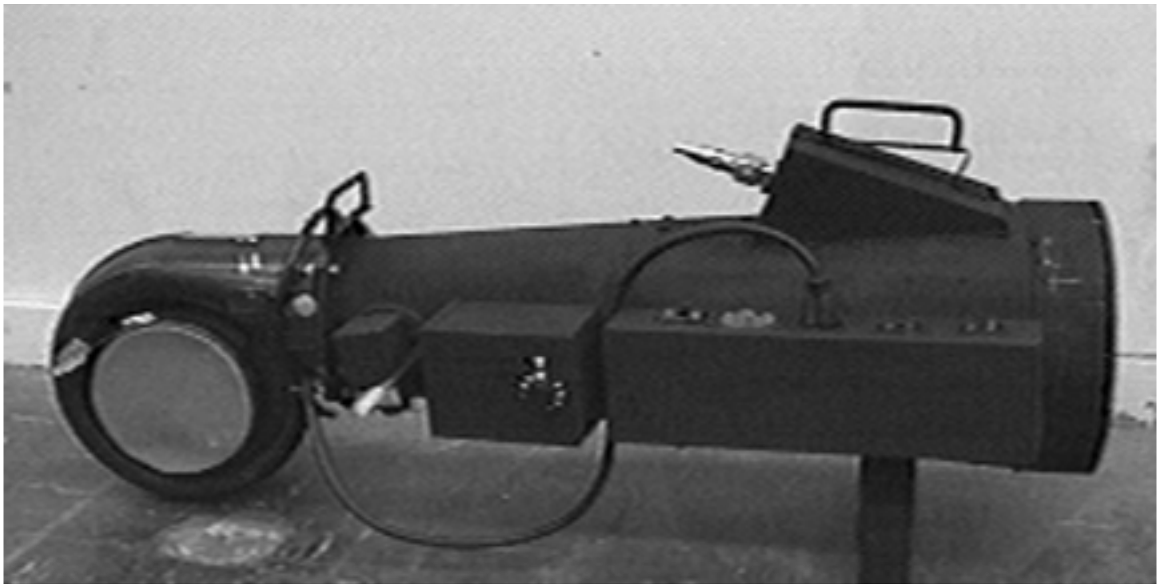


Figure 3. Video-frame capture of the first prototype of in situ sealing apparatus. Back to Commercializing a New Technology

Field tests in 1994 in a single-family house in Berkeley, California, demonstrated that the sealing apparatus performed well on its first outing. The device was found to seal approximately 60% of the leakage in the duct system within 15 minutes using about $6 worth of sealing material. The cost for tape to seal the registers temporarily during the sealing process was higher than the cost for sealing material, and the setup time far exceeded the sealing time. The field test included measurements of particle and volatile organic compound concentrations in the house before and after sealing. Total suspended particles were found to decrease after the sealing process, and there was no change in VOC concentrations detected after the sealing process. We are exploring the longevity of the seals by tracking the airtightness of the duct system. The degree of sealing has remained stable during the many months of nonoperation since the original sealing process. However, in a more difficult test during the winter months of 1994-95, the system will be made to cycle continuously in heating mode, creating larger stresses on the seals.

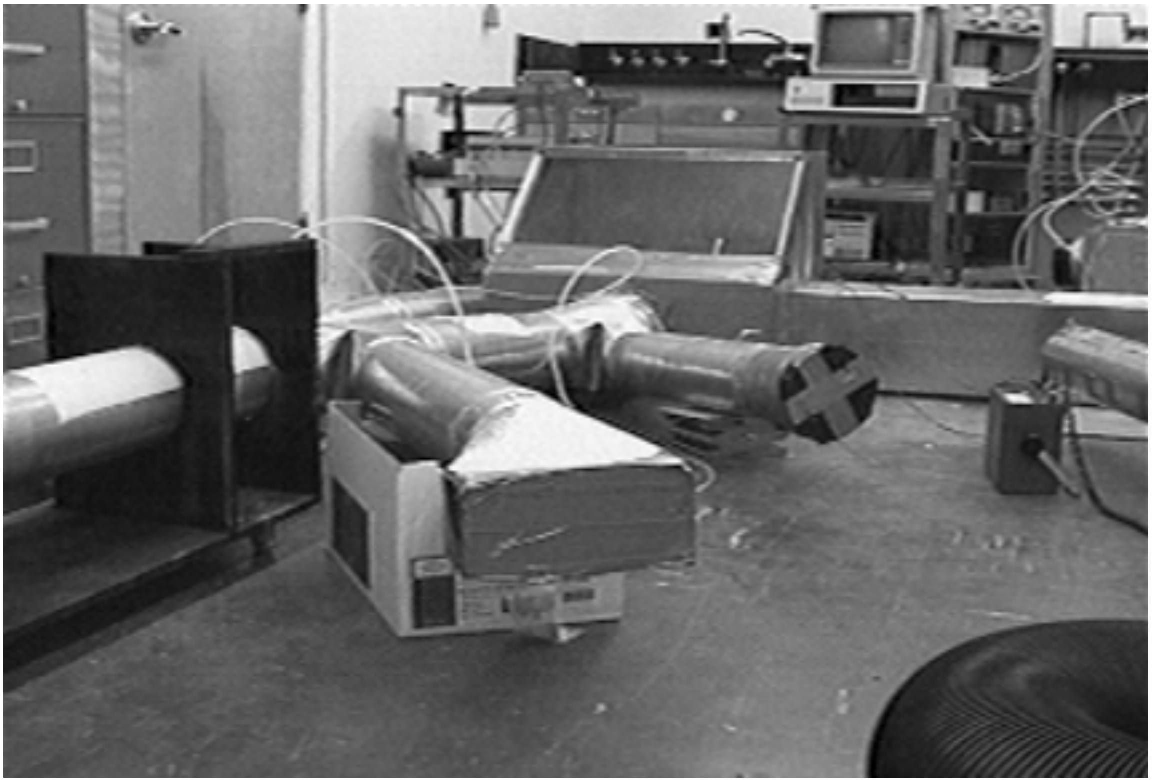


Figure 4. Video-frame capture of the apparatus used to test aerosol sealant effectiveness.

In 1995, our efforts are focused on accelerated laboratory testing of the seals produced by the aerosol, designing reusable, quick-installation seals for the registers and HVAC heat exchangers, larger-scale field testing, construction of a second prototype sealing apparatus, and the related activities required for the technique's commercialization.

—Mark Modera and Francois Remi Carrie

Mark Modera
Indoor Environment Program
(510) 486-4678; (510) 486-6658 fax

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MoWiTT: Mobile Window Thermal Test Facility

The window has come a long way since the days when it was a single pane of glass in a wood frame. Low-emissivity windows were designed to help buildings retain some of the energy that would have leaked out of less efficient windows. Designing efficient window-and-frame systems requires accurate measurement of the flow of energy through windows in realistic conditions, a capability provided by the Mobile Window Thermal Test facility. Consisting of a pair of outdoor, room-sized calorimeters, MoWiTT measures the net energy flow through two window samples in side-by-side tests using ambient weather conditions. MoWiTT characterizes the net energy flow as a function of time and measures the temperatures, solar fluxes, and wind conditions to which the samples are exposed.

The net energy flowing through a window is a combination of temperature-driven thermal flows and transmission of incident solar energy, both of which vary with time. U-value and solar heat gain coefficient, the window properties that control these flows, depend partly on ambient conditions. Window energy flows can affect how much energy a building uses, depending on when the window flows are available to help meet other energy demands within the building. By using the solar gain available through a window, either for winter heating or for daylighting, buildings stand to save a significant amount of energy. To pursue this strategy successfully, we need to know more about the time-dependent energy flows.

Most window developers are interested in measuring the overall average or peak energy demands resulting from these time-dependent flows. They obtain energy demands from a complex set of calculations such as a building simulation model; in many cases, however, the information available to characterize a fenestration may be limited or inadequately described in available simulation models, or the user may be skeptical of the calculation's results. In these cases, direct performance measurements under well-characterized outdoor conditions provide performance information with higher confidence levels.

Most window developers are interested in measuring the overall average or peak energy demands resulting from time-dependent energy flows.

MoWiTT researchers at the Center carry out a DOE-funded program of research to characterize fenestration systems and develop publicly available calculation methods for predicting fenestration thermal performance. Their goals are to assess the performance of energy-efficient windows currently available or under development, such as the newly emerging superwindows; to identify opportunities for new development; and to create a knowledge base that will encourage the rational selection of optimal windows in the design process. Organizations that have collaborated on these projects include Andersen Corp., ASAHI Glass Co., ASHRAE, Cardinal IG, CIEE, LOF Glass Co., The Moore Co., PG&E, Rolscreen Co., and Southwall Technologies. In addition to its DOE-supported research, MoWiTT is also available for privately-funded studies of specific products or window improvement options. It can:

- provide direct comparisons of alternative systems
- determine effective U-values and solar heat gain factors under realistic conditions
- provide verification of energy-savings calculations
- measure the energy performance of windows for which calculations are unavailable or unreliable.

MoWiTT users under this arrangement have included the Bonneville Power Administration, LOF Glass Co., Cardinal IG, and Andersen Corporation.

Joseph Klems
Building Technologies Program
(510) 486-5564; (510) 486-4089 fax

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Energy Currents:

An Energy-Efficient Plan to Stop Cholera

Motivated by a 1993 cholera epidemic in Asia, Center for Building Science researchers have developed a simple, inexpensive ultraviolet-light-based water purification system ideal for villages in developing nations. In many rural areas, water is disinfected by boiling, an inefficient process that is hampered by fuel-wood shortages and contributes to deforestation, depletion of fuel-wood, and air pollution. Knowing that UV light sources can destroy organisms in water far more efficiently, Derek Yegian, University of California mechanical engineering graduate student, former Center Head Art Rosenfeld and myself investigated the technical and economic possibilities of UV disinfection. The result is a demonstration unit that can treat 30 liters (eight gallons) of water per minute using a 36-watt UV lamp similar in technology to a fluorescent lamp.

The purifier is based on the germicidal property of UV-C radiation (100 to 280 nm), which disrupts the DNA strands within the exposed virus, bacteria, or other waterborne pathogens. Less than one minute of exposure can disinfect contaminated water while costing about 1¢ per metric ton. The group's calculations suggest that the total cost to a village of 2,000 is 2.5 to 5¢ per capita annually-well below the medical costs of treating victims of cholera and other waterborne diseases. Yegian and I organized a workshop on this technology in Bhubaneswar, India, in May 1994. Indian nongovernmental organizations are now field-testing purification units that were manufactured privately in India according to an LBL design. The program received early support from USAID, DOE, UNICEF India, and the Joyce Mertz-Gilmore and Rockefeller Foundations. In addition, General Electric (USA) and Philips Lighting (The Netherlands) donated UV germicidal lamps for this project. Mexico, South Africa, and Brazil have expressed interest in the technology as well, and our research team plans to develop a UV unit that can be built locally for less than $200.

—Ashok Gadgil

Ashok Gadgil

AJGadgil@lbl.gov

Indoor Environment Program
(510) 486-4651; (510) 486-6658 fax