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Five-Lab Study Examines Carbon-Reduction Strategies

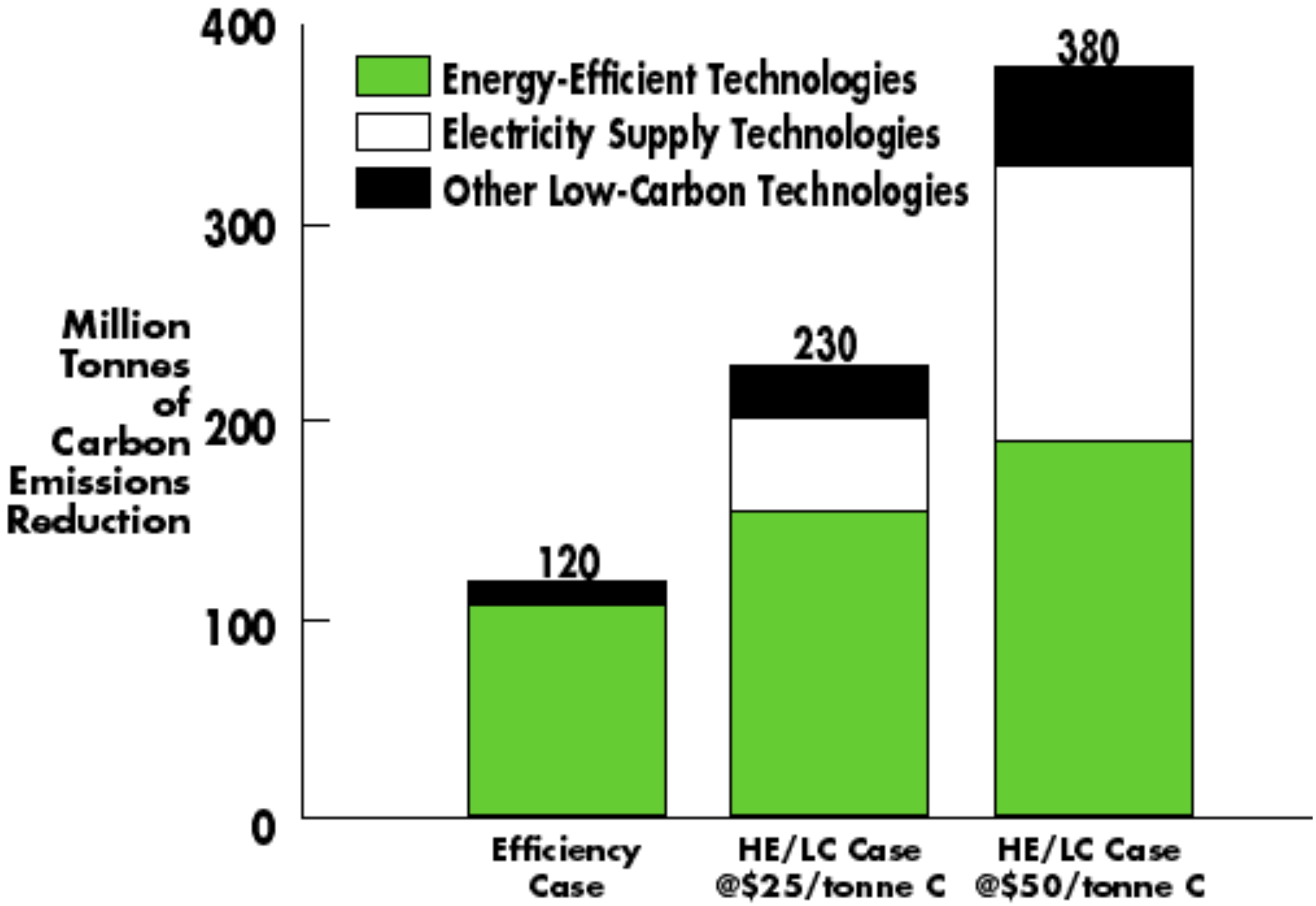

Figure 1. Reductions in carbon emissions from each scenario in the U.S.

As the world steps up its efforts to reduce emissions of greenhouse gases, policymakers and international negotiators are looking to the scientific community to provide answers to some important technical questions. What technologies exist or need to be developed to reduce carbon emissions? How much can these technologies reduce emissions? What will they cost?

To contribute some of the answers, the U.S. Department of Energy recently released a study called "Scenarios of U.S. Carbon Reductions: Potential

Impacts of Energy Technologies by 2010 and Beyond."[1] Five national laboratories and dozens of researchers contributed to the study, which was led by Berkeley Lab's Mark Levine, Director of the Environmental Energy Technologies Division and Oak Ridge National Lab's Marilyn Brown.

Several Center for Building Science researchers participated in the work. Jonathan Koomey was lead author for the 2010 analysis of the Buildings chapter. Nathan Martin carried out detailed calculations underlying the 2010 scenarios. Many scientists from the Center reviewed and made comments on the longer-term buildings R&D section that was prepared by staff at Oak Ridge National Laboratory.

The first two chapters in the report describe the analysis results and relevant background for the study; other chapters discuss results for the buildings, industrial and transportation sectors, and the technologies that apply in these sectors. Two chapters examine the effect of upcoming changes in the structure of the electricity industry, and advanced electricity supply technologies, on carbon emission reduction.

The 200-page report reaches three major conclusions. The first is that "a vigorous national commitment to develop and deploy energy-efficient and low-carbon technologies has the potential to restrain the growth in U.S. energy consumption and carbon emissions such that levels in 2010 are close to those in 1997 for energy, and 1990 for carbon." That such a reduction is possible is suggested by three simulations of growth in energy consumption (see Figure 1). In the first, the efficiency case, the U.S. adopts policies and enhanced private-sector efforts to encourage energy-efficient technologies, with the result that it reduces carbon emissions by 120 million metric tonnes of carbon (MtC) by 2010.

The second case includes energy-efficient policies and a $25/tonne carbon permit price (tonne=metric ton), reducing emissions by 230 MtC/yr in 2010; and the third includes the policies and a $50/tonne carbon permit price. This last case reduces emissions by 390 MtC/yr by 2010-to the 1990 level of carbon emissions. The last two cases assume a major effort to reduce carbon emissions through federal and state programs and policies, active private sector involvement, and a focused national R&D effort. The study cautions that the third case-emissions reductions of 390 MtC/yr, sufficient to approximately meet 1990 levels in 2010-would take dramatic changes in U.S. commitments to energy efficiency and low-carbon technology. Its feasibility is not demonstrated.

The study's second conclusion is that, if feasible ways are found to implement the carbon reductions described here, all the cases (with reductions varying between 120 and 390 MtC) can produce energy savings that are roughly equal to or exceed costs. For the most part, the technologies exist in the marketplace and perform well technically and economically, and there are substantial increases in the economic viability of carbon reductions in electricity generation at the $50/tonne carbon charge. The challenge will be to find satisfactory ways to have the technologies accepted in the market. This is particularly the case for end-use energy efficiency technologies.

Finally, the report asserts that a new generation of energy-efficient and low-carbon technologies can continue the aggressive pace of carbon reductions after the U.S. has realized the potential of existing technologies. "Maintaining low carbon emissions beyond 2010 will require the development of new technologies," says Levine. "We describe many examples of needed R&D to illustrate the technological opportunities. And the R&D has to start soon, because the time from lab to market is often long." A variety of advanced technologies in the report could become cost-competitive in the 2010 to 2020 time frame, if an enhanced and expanded R&D program-along the lines recommended by the recent report on energy R&D by the President's Council of Advisors on Science and Technology (PCAST)-is begun soon.

The technologies that provide these carbon reductions through 2010 include efficient end-use technologies for residential and commercial buildings; industrial processes and transportation; and less-emitting supply-side technologies such as fuel cells; biomass, wind and other forms of renewable energy. Substantial near-term carbon reductions come from the retirement of coal-powered plants or their conversion to natural gas, and from efficient grid dispatch of electricity. In addition to assessing the carbon reduction effects of efficient technologies that are available now, the report discusses the potential of more advanced technologies in the post-2020 era.

Levine argues that the R&D for these new technologies requires "a strong, steady build up of capabilities-with serious efforts to maintain growth over a long period of time. While there are important differences in the opportunities for R&D success in end-use sectors and low-carbon supply technologies, I believe that overall growth in R&D efforts of 15 to 20 percent per year for the next five years, leading to a doubling in the R&D budget, makes a lot of sense. The PCAST report says much the same thing. Some programs need higher growth. Examples are: longer term R&D for energy efficiency, and for alternative fuels for vehicles (beyond the timeframe of the Partnership for a

New Generation of Vehicles); low-emission diesels; lighting; information technologies applied to buildings to monitor and control buildings' operations; biomass as an energy source; and advanced control systems for a variety of industrial processes."

"We can play many roles in this work," he adds. "There are major projects here in the buildings field that need more extensive R&D-new lamp technologies [Fall 1996, p.6; Spring 1997, p.4], including a critical need to find a relatively low-cost replacement for incandescents; electrochromic glazings for windows; techniques to reduce heat islands in urban areas [Spring 1994, p.6]; and hardware and software to monitor and control commercial buildings [Summer 1994, p.6; Summer 1995, p.1]. Also, there are areas that need demonstration support in addition to research in order to move into the market sooner-for example, the duct sealant technology [Winter 1995, p.8]. And it is extremely important that we obtain information about and begin to find ways to reduce the explosive growth of a wide variety of miscellaneous energy uses in buildings, including "leaking electricity" (demand by devices that are not in active operation) that Alan Meier has made widely known." [See page 4.]

Previewing work at EETD that is in early stages of development, Levine says: "we are aggressively exploring technology development for industry and transportation, as well as new efforts for buildings. For example, we are looking into taking advantage of extensive work in electrochemistry to apply to batteries and fuel cells. And we are just beginning new efforts assessing industrial energy efficiency technology."

With the five-laboratory carbon-reduction study and the greenhouse gas treaty negotiations in the public eye, the coming year should see further evolution in plans for R&D on carbon emissions reduction technology.

—Allan Chen

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The report "Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond" is available on the Web.

This work was supported by the Department of Energy's Office of Energy Efficiency and Renewable Energy.

[1] Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Argonne National Laboratory, Pacific Northwest National Laboratory.

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News From the D.C. Office

Energy-Efficient Office Equipment Around the World...

Energy consumption from office-equipment use continues to grow unabated because of the strong growth in sales of these products in every region of the world. By the year 2001, the global installed base of computers is expected to exceed 500 million units. The energy consumption of imaging equipment will also expand as new, fully networked digital products, which require more energy to operate, proliferate in the market place.

The staff of the D.C. Office is working to support the Environmental Protection Agency's efforts to address this challenge. To date, the EPA has recruited hundreds of office-equipment manufacturers from around the world to design, manufacture, and sell products that meet the Energy Star® guidelines for energy efficiency. This was initially a U.S. program, but other countries are now interested in promoting Energy Star products in their own markets as a low-cost way to reduce energy consumption.

Manufacturers have also played a significant role in the spread of Energy Star office equipment abroad. They can benefit from economies of scale by standardizing entire product lines to meet the Energy Star specifications for diverse markets, reducing a wide range of manufacturing and related costs. These cost savings are easily realized, since most models are essentially identical from one market to another.

To foster production efficiencies that let manufacturers meet a single set of specifications for multiple markets and to build on existing worldwide consumer recognition of the Energy Star label, EPA is working on several international office-equipment projects.

International Cooperation

EPA signed a Letter of Intent to coordinate its efforts on the Energy Star Office Equipment Program with the Japanese Ministry of International Trade and Industry (MITI) in 1995. The D.C. Office coordinates many aspects of this informal agreement; for example, staff members work with MITI, which plays a consultative role with EPA by reviewing current specifications and planning new office-equipment product areas for the Energy Star program. Through MITI's contacts with Japanese manufacturers, we gain insights into the potential for new energy saving technologies in the Pacific Rim, while MITI's work in implementing these technologies and fostering greater consumer awareness gives EPA useful information on designing programs that work in other markets.

Energy Star-labeled office equipment is showing up in more places than Japan. Surveys show that market penetration of labeled equipment is quite high in many European countries-as much as 80% for some products. Recognizing the advantages of building on an existing program and working with an internationally known label throughout its 15 member countries, the European Union has proposed to EPA that it, too, join the program. To develop the more formal intergovernmental agreement requested by the EU, the EPA has been working with the D.C. Office to solicit the involvement of other key U.S. government agencies: the Departments of Energy, State, and Commerce, as well as the U.S. Trade Representative's office. The Lab is helping EPA evaluate all the questions that should be addressed as this program expands internationally, and to establish a system for other interested countries to join the program.

Next: Creating Demand for New Technologies

Beyond Energy Star labeling, LBNL Staff are helping EPA with another international effort: creating sufficient market demand to stimulate the introduction of a new generation of advanced energy-efficient photocopiers. This project, part of Annexe III of the International Energy Agency's Demand Side Management Agreement, will involve securing commitments from purchasers of copiers who agree to a common set of specifications. The D.C. Office will help identify large buyers, work with them to define specifications, and coordinate with manufacturers and the other six countries (Finland, Korea, the Netherlands, Sweden, Switzerland, and the U.K.) participating in the copier working group to see that these advanced, high-efficiency copiers reach the market and offer superior performance.

—Alison ten Cate, LBNL D.C. Office, and Andrew Fanara, U.S. EPA Energy Star Office Equipment Program Manager

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Reducing Leaking Electricity

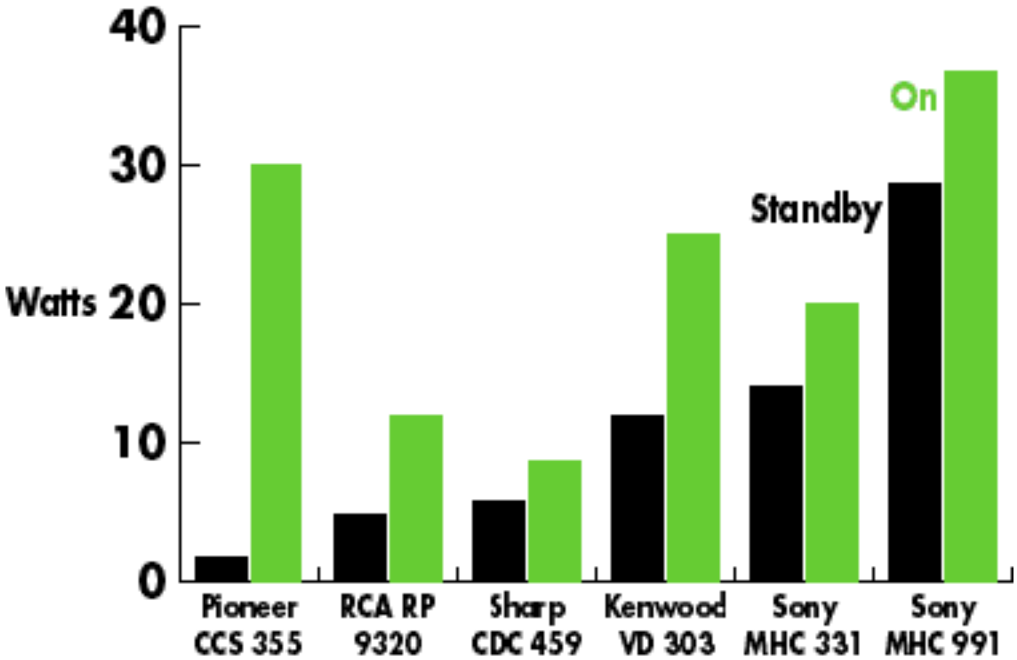

Figure 1. Full and standby power draws of some compact audio systems.

A surprisingly large number of appliances-from computer peripherals to cable TV boxes to radios-consume electricity even after they have been switched off. Other appliances, such as cordless telephones, remote garage door openers, and battery chargers don't get switched off but draw power even when they are not performing their principal functions. The energy used while the appliance is switched off or not performing its primary purpose is called "standby consumption" or "leaking electricity." This consumption allows TVs, VCRs and garage-door openers to be ready for instant-on with a remote control, microwave ovens to display a digital clock, and fax machines to switch on when the telephone rings. An example of "leaks" from compact audio systems is shown in Figure 1; Figure 2 shows the increasing number of shipments of these systems.

Each appliance leaks anywhere from less than one to more than 20 watts, and a typical house draws about 50 watts from leaking appliances. For comparison, a new refrigerator consumes on average about 60 watts. Nationwide, leaking electricity requires the operation of eight large power plants that emit roughly 12 million tons of carbon into the atmosphere. These leaks are not confined to the U.S.. Japan, Europe, and the less-developed countries also have hundreds of millions of appliances with similar standby losses.

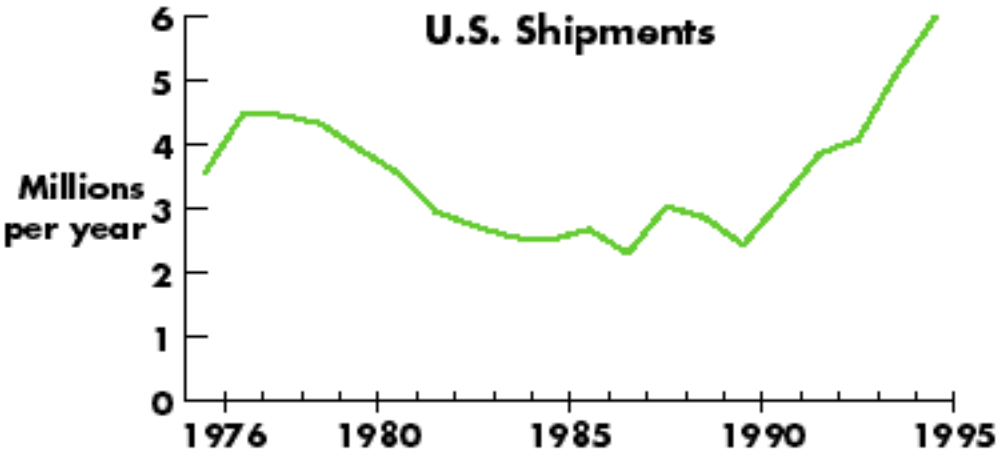

Figure 2. U.S. shipments of all makes of compact audio systems are on the rise.

Several strategies substantially reduce leaking electricity in appliances while still providing the services that consumers expect from them. They range from simply repositioning the off-switch to designing special chips that let small appliances manage and store power. We are proposing that standby losses be limited to one watt per appliance. The one-watt target can be achieved with little or no extra cost to manufacturers and will lead to modest cuts in consumers' utility bills, along with increased peace of mind that appliances are truly off or consuming the absolute minimum necessary amount of electricity. We are planning to collaborate with Europe, Japan, and less-developed countries so the energy savings and reductions in global emissions will be many times that from the U.S. alone.

Instead of relying on government regulation, we expect to use a combination of voluntary programs, special awards and labels, and other incentives to achieve our one-watt objective. One key form of recognition will be the Energy Star® label, from the U.S. Environmental Protection Agency/Department of Energy program, to identify appliances that meet minimum energy-efficiency standards. Government purchasing specifications may be another path. In the end, however, the benefits to both manufacturers and consumers will be the strongest motivation. And the environment will be the biggest winner.

—Alan Meier, Karen H. Olson

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Visit the Leaking Electricity web site.

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

Reference to any specific commercial product by its trade name or manufacturer does not constitute endorsement or recommendation by the University of California or the U.S. Government.

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The Efficient Window Collaborative

http://www.efficientwindows.org

Energy-efficient windows make up only about 35% of the U.S. residential window market, even though they are cost-effective in approximately 80% or more of all applications. To ensure that efficient windows reach their optimum potential in homes throughout the U.S., the Department of Energy and key players in the U.S. window industry have formed the Efficient Window Collaborative (EWC). The EWC's goal is doubling the market share of efficient windows by 2005. With 31 charter members from the window and glass industries, the EWC is managed jointly by the Washington, D.C.-based Alliance to Save Energy and the Center for Building Science's Windows and Daylighting Group. The EWC serves as a focal point for voluntary public/private-sector efforts to promote energy-efficient products.

The Alliance to Save Energy will lead communications and marketing activities, and the Windows and Daylighting Group will lead technical support efforts. Members of the collaborative have made a commitment to promote energy-efficient products through specific actions, including labeling a majority of their products with objective, accurate, credible ratings provided by the National Fenestration Ratings Council (NFRC) [Spring 1994, p.8], supporting the recently unveiled U.S. Environmental Protection Agency/Department of Energy Energy Star® Windows program, and participating in EWC sponsored initiatives and sales staff training.

Education a Key

Communications and education efforts aimed at window purchasers are a key activity of the EWC. Half of the residential window market consists of customers who retrofit their homes with new windows; consequently, the EWC will target both homeowners making decisions about window replacements and manufacturer sales staff promoting products to these customers. The EWC will promote energy-efficient mortgages to these buyers and salespeople, since these mortgages provide attractive financing packages for energy-efficient measures. Outreach activities to builders and contractors will focus on teaching them how to sell the energy and comfort benefits of energy-efficient products.

The EWC will work with other public and private entities who promote energy-efficient windows, including utilities launching market transformation programs and state government voluntary programs. An important step in developing ties to these groups will be establishing partnerships with federal agencies such as the Federal Energy Management Program (FEMP) [Spring 1995, p.1], whose goal is to ensure that all products purchased by the Federal sector are energy-efficient.

Technical activities by the Center's Windows and Daylighting Group in support of the EWC include:

- Developing the RESFEN computer program and other analytical support aimed at providing an accurate and uniform means of determining the most energy-efficient and cost-effective window product for a specific application;
- Creating content and maintaining the EWC Web site with the University of Minnesota, http://www.efficientwindows.org (see above), a focal point for educating and training audiences on the benefits of energy-efficient windows;

- Providing input about the Energy Star Program criteria, and development and proper use of the NFRC annual energy ratings;
- Documenting the benefits of energy-efficient windows by monitoring their use in homes and publicizing the energy savings that result;
- Developing tools and products such as a field verification kit for energy-efficient products;
- Performing market research and window assessment studies aimed at understanding which products need to be promoted in specific regions;
- Providing technical support for window-related changes to the Model Energy Code and state energy codes.

—Dariush Arasteh

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Efficiency of Exterior Exposed Ductwork

Most of California's commercial buildings have thermal distribution systems, the majority (63%) of which are air-based and distribute air through ductworks. Thermal distribution ductwork systems in small commercial buildings are similar to those in residential construction [Winter 1995, p.8] and have the same leakage and conduction-loss problems. The extent of these duct-related thermal losses depends on the location of the ductwork-the largest thermal losses occur when the ducts are entirely outside the building envelope.

Leakage, conduction losses, direct solar radiation effects and solar reflection all affect the magnitude of thermal loss. Differences in the lengths of exterior ducts also affect a distribution system's energy efficiency, as well as the temperature of air delivered to interior spaces at the registers. When long duct runs are exposed to sunlight and high outdoor temperatures on roofs, the supply air can experience a significant temperature rise before reaching the registers during periods of demand for interior cooling. This configuration has a direct impact on interior thermal comfort conditions and can cause uneven temperature distribution within the building.

To examine the thermal energy issues of exposed exterior ductwork, we conducted a case study at a building on the campus of a community college in Sacramento, California. Most of the building's ductwork was located on the roof, providing an opportunity to evaluate the effects of duct leakage, conduction losses, and other issues on the energy performance and efficiency of the duct system.

The study building is a single-story brick structure with a 2,000 m^2 (21,500 ft^2) floor area containing classrooms, laboratories and office space. There is no shading from the south and east and some tree shading on the west side. The building is one of two served by a centralized chiller plant. Its systems were completely renovated in the 1980s with the installation of 15 roof-mounted, constant-volume air-handling units with chilled water coils and air-side economizers.

In 1995, the Sacramento Municipal Utility District conducted a "cool-roof" retrofit of the building, which involved improving the roof-deck insulation and increasing the surface reflectivity of the building's roof. (This strategy was developed as part of a joint research project between SMUD and Center researchers in the Heat Islands Project [Spring 1994, p.6]). A contractor sprayed a closed-cell polyurethane coating that added a 1.2- to 1.7-cm-thick coating to exposed ductwork and 10 to 15 cm to the roof. After the insulation, a highly reflective coating-reflecting up to 85% of incident solar radiation, according to the manufacturer-was added to only the top and sides of the ductwork.

For this experiment, we selected a building air-handler system serving a lecture hall with a floor area of 147 m^2 (1,580 ft^2). Diagnostic measurements included system duct leakage, system air flows, outside air flows and duct insulation and conduction efficiency. The study included short-term monitoring of temperature and solar radiation over two three-week periods in the summer of 1995.

The analysis of these measurements focuses on quantifying the magnitude of conduction losses and the effect of direct and reflected solar radiation on the ducts, the delivery effectiveness and efficiency, and the effect of the "cool-roof" retrofit on system performance and thermal-comfort issues. We developed and verified a simplified computer model to evaluate the effectiveness and efficiency of the delivery system.

The Table below summarizes conduction losses, expressed as capacity losses, measured at each air supply register studied. Conduction losses in the ducts, when in cooling mode, raise the supply air temperature. The capacity loss is the energy lost as a fraction of the capacity before cooled air reaches a room.

Despite the fact that the ducts started off with a conduction efficiency of 97%, the delivery efficiency was, on average, only 73%. (Conduction efficiency is a measure of how ducts behave as a heat exchanger; the higher the conduction efficiency number, the better. Delivery efficiency is defined as the ratio of energy delivered to the space divided by the energy put into the duct system.) This is because the ducts were located on the roof, where they gained heat from the ambient environment. The retrofit increased the delivery efficiency to an average of 89%, reducing the average energy use for conditioning by 22%. The model predicted these results, on average, within 10% or better of the measured results.

Table: Summary of average register conduction losses. Capacity loss is energy loss as a fraction of capacity before reaching the room.

	Uniformly Weighted Average			Capacity Weighted Average		
Supply Register	Pre-retrofit Capacity Loss	Post-retrofit Capacity Loss	Percent Change (post-retrofit in relationship to pre-retrofit)	Pre-retrofit Capacity Loss	Post-retrofit Capacity Loss	Percent Change (post-retrofit in relationship to pre-retrofit)
1	17%	9%	-46%	16%	9%	-47%
2	27%	16%	-41%	25%	15%	-40%
3	14%	5%	-64%	13%	5%	-64%
4	25%	13%	-48%	23%	12%	-45%

—Woody Delp, Nance Matson, Mark Modera

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An LBNL report, "Exposed Exterior Ductwork: Delivery Effectiveness and Efficiency," LBNL-39083, describes the methods and results of this study in detail.

This work was supported by the California Institute for Energy Efficiency and the Department of Energy's Office of Building Technology, State and Community Programs.

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A-Team Report

A Design Charrette at the Presidio of San Francisco

The 1480-acre Presidio of San Francisco, a historic military base for 200 years, is now a part of the Golden Gate National Recreation Area. With its sweeping views of San Francisco Bay and the Pacific, the Presidio is undoubtedly one of the most beautiful urban parks in the U.S.. The park has been administered since 1994 by the National Park Service (NPS) and has more than 800 buildings, many of which are architecturally and historically significant.

The Presidio's buildings have the potential to serve the public, but most need rehabilitation before they can be reused. In 1994, Building 102, a historic structure that now houses the Presidio's NPS offices, was the subject of a design charrette aimed at creating guidelines for the sustainable redesign of Presidio buildings. Organized by the Bay Area chapter of the Association of Energy Engineers®, and hosted by Pacific Gas & Electric and the NPS, the charrette drew on the expertise of the Center's Applications Team, as well as engineers, researchers, architects, government officials, and students from throughout the Bay Area.

Following the charrette, Applications Team head Dale Sartor, the California Institute for Energy Efficiency's Karl Brown, and Applications Team members including Steve Greenberg, Tai Voong, Doug Lockhart, and Dennis Kincy have provided the NPS with design assistance to bring energy-efficient building technology to Presidio facilities in synergy with the historical character of its buildings. Historical preservation itself fosters sustainability because the existing structures are reused and low-energy cooling techniques are reestablished within them.

Two documents are now available describing the charrette and the guidelines developed subsequently for the energy-efficient retrofit of the Presidio's historical buildings. "Guidelines for Sustainable Building Design: Recommendations from the Presidio of San Francisco Energy Efficiency Design Charrette," LBNL-38868, and "Tenant Guidelines for Energy-Efficient Renovation of Buildings at the Presidio of San Francisco" are available from the NPS. The documents' authors intend these references to serve as models for the development of sustainable design and energy-efficient retrofits of all types of facilities.

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LBNL Report 38868 is available on the Web.

"Tenant Guidelines" by Jeffery Warner, Dale Sartor and Rick Diamond is available on the Web.

This work is supported by the Federal Energy Management Program of the Department of Energy, the National Park Service and the Bay Area chapter of the Association of Energy Engineers.