Lawrence Berkeley National Laboratory

Spring 2003
Volume 4 Number 2

Environmental Energy Technologies Division

NEWS

Advanced Technologies | Atmospheric Sciences | Building Technologies | Energy Analysis | Indoor Environment

Saving Energy Through Improved User Interfaces

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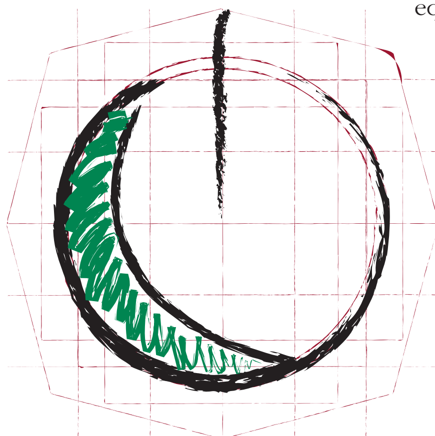
Environmental Energy Technologies Division

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



Electricity saved through power management of office equipment has been one of the premier success stories for the energy-efficiency community. The U.S. Environmental Protection Agency and Department of Energy's Energy Star program was largely responsible for creating aggressive low-power—or "sleep"—modes in nearly all forms of office equipment. The devices can automatically shift into a sleep mode after a user-determined length of inactivity and then quickly recover for use when needed.

Despite this success, many devices that have power management features are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by hardware or software conflicts. The number of products in use that have power management turned on vary widely with the kind of equipment and situation. Surveys have found that the great majority of PCs do not have power management turned on. For monitors, printers, and copiers, the enabled rates are above 50%, but significant improvement is still possible.

A comprehensive study of office equipment energy use conducted at EETD presents a snapshot as of 2000. This study found that the "power management gap" for office equipment in the U.S. was about $1.3 billion per year—energy that could be saved if power management was enabled on all devices that have this feature. Although it is difficult to predict what the actual savings from improved interfaces will be, we estimate that 35% of the potential savings could plausibly be realized, resulting in a savings of $470 million annually (Table 1).

Designing the power management interface for all office equipment so that users clearly understand which symbols mean "on," "off," and "sleep" and which state is currently active, can maximize the energy savings from power management. We believe that an interface standard, tested on users and agreed to by equipment manufacturers, can realize the predicted energy savings.

The Problem and the Research Process

With funding from the California Energy Commission's Public Interest Energy Research Program, we have, in consultation with the private sector, developed and tested a new interface standard that could capture some of the savings now being lost.

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Table 1. Office Equipment Energy Consumption and Savings from Power Management

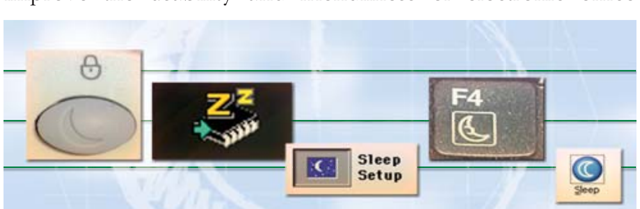
	United States
Total Office Equipment Electricity Use *(GWh/year)*	71,100
Potential Savings — 100% Power Management *(GWh/year)*	16,700
Likely Impact of the User Interface Standard *(GWh/year)*	5,800
Savings of each 1% of Potential *(GWh/year)*	170
Total Office Equipment Electricity Cost *($mil/year)*	5,700
Potential Savings — 100% Power Management *($mil/year)*	1,300
Likely Impact of the User Interface Standard *($mil/year)*	470
Savings of each 1% of Potential *($mil/year)*	13

Notes: From Kawamoto, 2001. All figures annual for end of 1999. Electricity rate is 8 cents/kWh. The "likely savings" figure is based on achieving 35% of the potential energy savings from increased use of power management. The existing savings from power management are 22.8 TWh/year for the U.S., with a dollar value at the above electricity rates of $1,800 and $380 million/year. The existing savings are with respect to no use of power management, and the "potential savings" reflect 100% enabling of power management — both with no change in manual turnoff rates.

The Berkeley Lab study determined that, from device to device, many terms, symbols, and indicators are used differently or are not clear to begin with. On many devices, power management controls are difficult or impossible for the average user to find. Many PCs don't indicate to the user when the equipment is in a low-power mode, so many users are unaware that the PC can "sleep." Users can't always tell whether PC power management is working, and many don't realize that PC power management is distinct from the monitor power management. An important example is the "standby" problem. The term can mean anything from a "fully on" state to a low-power mode or the amount of power used by a device when it is functionally off.

We conducted research in two phases. We first gathered a wide variety of data about products and related topics such as existing standards, cultural issues, and accessibility, and drew on the literature of user interface design. Next, we developed and tested proposed interface standards.

We worked closely with an industry advisory committee. Industry is interested in the user interface because it seeks to improve the usability and friendliness of electronic office equipment, which reduces customer service requests and may increase product sales. A Professional Advisory Committee, of equipment manufacturers helped refine the project plan for our research.



In devising a proposed standard, we developed a simple vocabulary of user interface elements that are adaptable to a wide variety of devices. What we had to work with was a large number of power-related symbols, colors for indicator lights, and device modes and states—with a bewildering variety of labels, including such words as *Ready, Sleep, Active, Energy-Saver, Power-Save, Idle, Suspend, Doze, Stand-by, and Low-Power.* Our goal was to reduce the possibilities to a single, simple set of easily understandable terms.

Results—A Recommended Standard Interface

We developed various interfaces and tested them at Berkeley Lab, UC Berkeley and Cornell to determine how well users understood various types of symbols, indicators, and equipment states (e.g., "sleep" versus "off"). From this work, we wrote the draft standard summarized in Table 2.

Table 2. Key Elements of the User Interface Standard

Static Interface
- Use only three basic power states when possible: *On, Off,* and *Sleep.*
- Use the word "Power" for terminology about power.
- Redefine the ⏻ symbol to mean "power" as for power buttons and power indicators; use the ⏼ symbol (on/off) only when necessary.
- Use the "sleep" metaphor for entering, being in, and coming out of low-power states; use the moon symbol—☾—for *sleep.*
- Adopt "green/amber/off" color indications for power-state indicators.
- Present PC "hibernate" modes as a form of *off.*

The standard also covers "dynamic behavior" or how devices behave over time and in response to input or activity. For example, the standard specifies using "power up" to mean turn on or wake up, "power down" for turn off or go to sleep, with flashing green on the power indicator for powering up and flashing amber for powering down.

Next Steps

In September 2002, the Institute of Electrical and Electronic Engineers (IEEE) created a working group (#1621) for a "Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments." This group is being formed now to adapt the User Interface Standard content into an IEEE standard. In the long term, we hope to work with international standards organizations. The standard is intended to be voluntary, and updated as power manangement technology changes.

We need to explore other areas in which user interface improvement and standardization could save energy,

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Berkeley Lab Helps the City of Oakland Meet Energy Costs

Reporters talk with Colleen Chadsey (l) of the Metrovations Building, Jim Flanagan of Quantum Consulting, and Oakland Mayor Jerry Brown.

The California electricity crisis has receded from the headlines, but energy costs are still high in the state. So there was anticipation in the audience when Oakland's Mayor Jerry Brown announced the start of the Oakland Energy Partnership at a news conference early this year.

Developed with the help of researchers from Lawrence Berkeley National Laboratory, Quantum Consulting, and others, the new $6 million partnership has set up six programs to help Oakland businesses and residents become more energy efficient. The program is funded by the California Public Utilities Commission (CPUC) and implemented by Quantum Consulting for the City of Oakland.

"The partnership will put four million dollars a year in energy cost savings back in the pockets of Oakland businesses and residences," said Brown, "It will strengthen the city's economy by moving it closer to sustainability."

On hand at the news conference was Public Utilities Commissioner Loretta Lynch, who thanked Mayor Brown for working to turn Oakland into a showcase for energy-efficiency. "Oakland received the largest single sum of money given to any city in California by the CPUC for energy-efficiency programs," she said.

Scientists from EETD, including Mary Ann Piette, Philip Haves, Stephen Selkowitz, Charles Williams, and Division Director Mark D. Levine, provided the city with technical assistance in designing the programs and submitting proposals to the CPUC. California Energy Commissioner and former Berkeley Lab scientist Art Rosenfeld and the Rocky Mountain Institute's Amory Lovins, two world-renowned energy-efficiency experts, also provided support and guidance during development of the partnership.

"We helped develop the programs in the partnership, and we'll be providing technical assistance in the area of commercial building system tune-ups and street lighting," said Mary Ann Piette, deputy leader of EETD's Commercial Buildings Group. "This is a great opportunity for us to apply some of the new procedures, tools, and technologies we are developing in our research program."

EETD has a large commercial buildings R&D program supported by the California Energy Commission's Public Interest Energy Research program and by the U.S. Department of Energy. Piette said, "Field testing the research results enhances the impact of our R&D and provides the city with the latest and most cost-effective techniques for energy savings."

Commissioning Large Buildings

"This building, one of the first to participate in the partnership, shows what energy efficiency can do," said Quantum's program director Jim Flanagan of the Metrovations building, a site near the city's Jack London Square where the press conference was held. "We've performed an energy audit which shows that the building can save $26,000 per year by implementing a series of energy-efficiency measures that will pay for themselves in three years. Just adding a programmable thermostat will save this building about $2,000 a year in heating and cooling costs."

The Large Commercial Building Tune-Up is one of two Oakland Energy Partnership programs in which Berkeley Lab is directly involved. It will adjust building systems for maximum energy efficiency, which can reduce operating costs by up to 15 percent. Its goals are to capture 16.5 gigawatt-hours (GWh, or billion watt-hours) of electrical energy savings and to reduce electricity demand by 4.6 megawatts (MW, million watts) by "tuning up" building systems in public and privately owned office, medical, hotel, educational, and retail buildings in Oakland.

Measures that save electricity or natural gas are both eligible for this program. The building tune-ups, also called "building commissioning," make sure that all systems are operating at their rated efficiencies. Berkeley Lab research has shown that most buildings operate more efficiently after commissioning.

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Thermal Distribution Systems in Large Commercial Buildings

Large commercial buildings are known to waste energy through their thermal distribution systems. Previous research by Mark Modera and members of EETD's Energy Performance of Buildings Group has shown that heating, ventilation, and air conditioning (HVAC) distribution systems in commercial buildings suffer from thermal losses, such as those caused by duct air leakage and poor duct location. Because of a lack of metrics and data about the potentially large energy savings from reducing these losses, the building industry has mostly overlooked energy-efficiency improvements in this area.

With support from the California Energy Commission and the U.S. Department of Energy, we conducted research to obtain the technical knowledge needed to properly measure and understand the energy efficiency of thermal distribution systems in commercial buildings. We expect that this new information will assist the California and U.S. building industry in designing better thermal distribution systems for new commercial buildings and in retrofitting existing systems to reduce their energy consumption and peak electrical demand.

There were three technical objectives:

1. Develop metrics and diagnostics ("yardsticks" and measurement techniques) for determining the efficiencies of commercial thermal distribution systems.
2. Develop information that the California and U.S. building industry (e.g., HVAC system design engineers and installers) can use to design new thermal distribution systems, estimate energy efficiency, and prevent or reduce the incidence of problems that have been identified in existing commercial systems.
3. Determine the energy impacts associated with duct leakage airflows in an existing large commercial building that could be mitigated by applying duct retrofit technologies.

The project involved an extensive *in situ* characterization and duct leakage intervention study at a 25-story office building in Sacramento, California. In particular, we characterized the performance of the variable-air-volume (VAV) duct systems on two floors of the building. One floor was our control floor; the other was the intervention floor, where we could study the effects of duct leakage on system performance.

Metrics and Diagnostics

The most important metric is transport energy—the total energy used to transport air per unit of thermal energy delivered. This metric is useful for comparing the relative performance of various types of thermal distribution systems. We recommend that California's Title 24 (energy code) compliance process for large commercial buildings include quantification of this metric.

Our field tests of diagnostics focused on measurements of duct leakage airflows, fan airflows, and fan power. In particular, of the two duct leakage diagnostics that we tested, only one reliably determined duct leakage airflows. It involves accurately measuring airflows entering and exiting the duct system: the difference is the duct leakage. With further development and testing, we expect this diagnostic will be useful in developing a database that characterizes the distribution of duct leakage airflows in California's large commercial buildings.

Dust System Characterization

Because there has been very little characterization of the actual performance of thermal distribution systems in large commercial buildings, we carried out an extensive characterization of one of these systems. The test building showed every indication of a "tight" thermal distribution system: good application of mastic, metal bands at joints, and overall high quality. To demonstrate duct leakage impacts, we installed temporary calibrated leaks and monitored their effects on system energy consumption and demand.

Energy Impacts

The principal finding from this project is that duct leakage airflows can have a significant energy impact in large commercial buildings. Our measurements indicate that adding 15% duct leakage at operating conditions leads to an increase in fan power of about 25 to 35% (see Figure). These findings are consistent with the impacts of increased duct leakage airflows on fan power that have been predicted by previous simulations. The primary benefit from having tight duct systems is reduced electricity use. We estimate that eliminating duct leakage airflows in half of California's existing large commercial buildings could save about 560 to 1,100 gigawatt-hours (GWh) annually (about $60-$110 million per

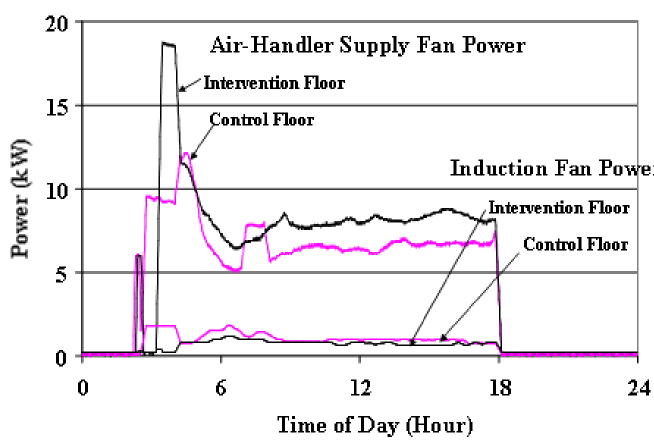

Figure. Measured fan power from the supply air handler (top curves) and induction fans (lower curves) for two floors in the test building. The difference in fan power (25 to 35%) is due to leakage in the duct system.

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Cal-Arch: A California Building Energy Tool for Owners and Operators

Researchers in EETD's Commercial Buildings Systems Group have developed an interactive, web-based diagnostic tool that enables California building owners and operators to compare energy use in similar buildings. Their work is part of a three-year program to analyze energy use in California's commercial buildings.

Commercial buildings account for about one-third of all electricity consumption in California and consume about $18 billion in energy costs. Efforts during the past 20 years have brought about significant increases in building energy-efficiency, but the savings are still well below technical and economic potential.

Cal-Arch, the web-based diagnostic tool, was developed by EETD's Mary Ann Piette, Saki Kinney, and Brian Smith. Based on another EETD benchmarking tool called Arch, this localized version uses a data set compiled from California commercial building energy use data. The data set, the Commercial End-Use Survey (CEUS), was developed from 2,500 commercial on-site surveys, monthly energy use bills, and load research data from California utilities Pacific Gas & Electric and Southern California Edison. The CEUS data provide annual energy-use estimates and hourly load profiles for the commercial sector.

Cal-Arch (http://poet.lbl.gov/cal-arch/) makes it possible for building owners and operators to see how their buildings, stack up against other buildings of the same type. After entering data in a few fields on a web page—building activity, floor area, energy consumption, and ZIP code—and clicking a "comparison" button (see Figure), the user receives a graphic representation comparing the building's energy use with that of similar buildings. The histogram is interpreted for the user on subsequent web pages. Additional information includes a summary table, which shows data for the corresponding energy-use intensity. The data can be viewed in both site or source energy units.

"Cal-Arch provides an easy-to-use tool that allows building owners and operators to quickly compare how their building's energy use compares with others. We have found it to be of great interest to this audience," says Mary Ann Piette.

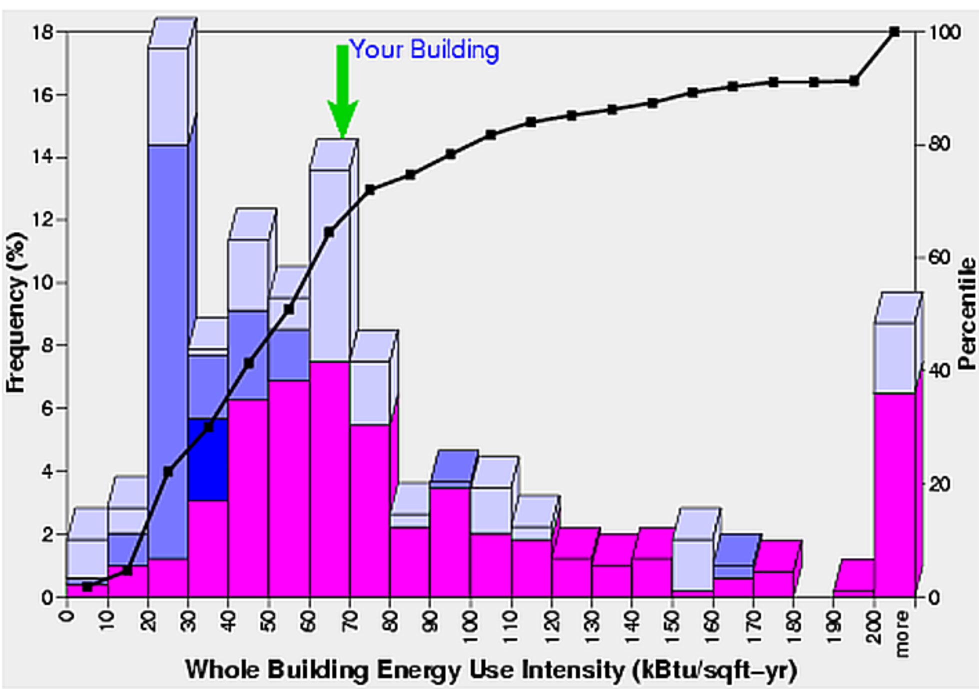

Figure. The x-axis shows the values of the histograms bins, which, in the figure above, have a width of 25 kbtu/sqft-yr. The left-hand y-axis corresponds to the vertical bars and is displayed as percent frequency, that is, the percent of all buildings displayed in a given bin. The right-hand y-axis corresponds to the black lines and gives the cumulative percent frequency, that is, the percent of all buildings to the left of a given point.

In the figure above, the percent frequency corresponding to Your Building is about 22%. In other words, approximately 22% of buildings in the comparison data set use between 25 and 50 kBtu/sqft-yr. The corresponding cumulative percent frequency is about 30%, i.e., 30% of the comparison buildings use less than 50 kBtu/sqft-yr. Although the building is not inefficient, the histogram suggests that there is room for energy-efficiency improvements to make a difference. See http://poet.lbl.gov/cal-arch/results.html for more information.

Site results need to be interpreted with caution. Low energy use does not mean that a building is efficient, nor does high energy use mean it's inefficient. Factors such as structure, level of service, and occupancy affect energy use. However, even buildings considered efficient can have significant energy-savings potential. A tool such as Cal-Arch can be a valuable resource for building owners and operators looking for methods to cut back on energy use and save money.

—Ted Gartner

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This work is funded by the California Energy Commission's Public Interest Energy Research (PIER) Program, and the Department of Energy.

Measuring Emissions from Heavy Oil Storage Tanks

Two EETD scientists, Donald Lucas and David Littlejohn, have developed a method to measure air pollution emissions from heavy oil storage tanks. The method measures hydrocarbon emissions using a simple oil-sampling device fashioned from parts available at hardware stores for less than $20 (see Figure). Older measurement methods that were developed for lighter oils overestimated emissions from heavy oil tanks by orders of magnitude.

The researchers were approached by the Heavy Oil Storage Tank (HOST) Committee, which represents three air quality districts in Southern California, the U. S. Environmental Protection Agency (EPA), the California Air Resources Board, as well as members from the industry that these agencies regulate: oil companies and the Western States Petroleum Association. HOST was seeking new, accurate methods to inexpensively measure emissions from heavy oil storage tanks. By working with industry, they hoped to develop a consensus method for measuring these emissions.

Inexpensive Components

The new technology consists of a simple sampler built from off-the-shelf parts and used with the Tank Atmosphere Perturbation method, which measures the total gas emissions (reactive organic compounds, carbon dioxide, water vapor, methane) from a tank. The method involves blowing air into a tank headspace to perturb the concentrations of gases there and then taking measurements as the concentrations return to their equilibrium state. The samples are collected and then analyzed in the lab.

Thousands of oil storage tanks dot the landscape of oil-rich counties in southern and central California. Typically 30 feet high and 40 to 50 feet across, they store the crude oil extracted by pumps scattered across numerous oil fields, which can be as small as a few acres. HOST approached EETD seeking an inexpensive, reliable, and accurate method of measuring the emissions from these storage tanks to address the various concerns of its members. The region's air quality districts needed a way of determining the magnitude of the contribution that these tanks made to air pollution problems in the region, particularly the Central Valley, which has one of the worst air pollution problems in the nation today, including high levels of ozone and particulates. The oil industry stood to lose tens of millions of dollars mitigating a problem whose magnitude was unknown because the standard Reid Vapor Pressure (RVP) method, which is well-suited for liquids like gasoline, does not work at all for heavy crude oil. For example, one of the steps in the RVP method calls for cooling the liquid in an ice bath and transferring it to the analysis system. Existing tests fail because crude oil thickens like peanut butter once cooled.

The Berkeley Lab researchers went into the field to study oil tanks made available to them by HOST members and developed the test method. HOST issued no mandates in how to proceed; the Lab team took a leadership role in conducting the research, and meetings were run by a mediator who ensured that all parties reached consensus as the work progressed.

Transferring the Technology

After developing the oil sampler and measurement method, Lucas and Littlejohn made numerous measurements of tanks operated by HOST members. Their measurements demonstrated to regulators that the approach yielded accurate results. Oil industry members were satisfied that the new technology was accurate, inexpensive, and could be used reliably by the private firms that provide measurement services. The Lab team worked with all local and state regulators to gain official approval from local air districts, the California Air Resources Board, and the U.S. EPA for the testing methods. Then they taught commercial vendors, selected by HOST, to use the test method and technology; Aeros Environmental, Zalco Laboratories, Oilfield Environmental & Compliance, and Genesis Environmental Services participated.

Figure. Oil-sampling device developed for heavy oil tank emissions test.

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User Interfaces

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including lighting, space conditioning, and real-time pricing. Research has shown that thermostat controls are poorly understood by many users; making these devices easier to use will substantially increase the energy they save.

—Bruce Nordman

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http://eetd.lbl.gov/Controls/

For the project's final report and detailed recommendations, see: http://eetd.lbl.gov/Controls/1621/. This work is funded by the California Energy Commission's Public Interest Energy Research Program.

City of Oakland

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The tune-up program aims to commission 10.5 million square feet of buildings, which would result in potential energy savings of $2.4 million per year. The Lab's role will be to provide the technical assistance necessary to identify the most effective energy-efficiency measures for each building.

"Working with building owners and managers in this program will help us better understand the issues associated with identifying and implementing retro-commissioning and operational improvements in buildings," says Piette. "We'll identify the most important retro-commissioning opportunities: those which provide the largest savings at specific sites, the easiest to identify, the most common in all buildings."

Piette adds: "This work will also help us understand how we could apply advanced techniques such as model-based diagnostics and continuous performance-monitoring tools, which we are developing at the Lab."

More energy-saving programs

Another program, the Street Area and Lighting Demonstration, is a collaboration among the City of Oakland, private outdoor lighting system operators, and Berkeley Lab researchers to test more efficient municipal street-lighting systems. According to Flanagan, workers will install highly efficient electronic ballasts in 1,400 outdoor lights with 100-, 150-, or 200-watt lamps.

Yet another Oakland Energy Partnership program is Energy Efficiency Design Assistance, which gives designers, property owners, and developers free design expertise and energy audits to improve building efficiency. The Business Services Energy Team will analyze the energy use of businesses and suggest cost-effective energy-efficiency improvements. These services, plus 75 percent of total project cost, are covered by CPUC funding.

Two programs that provide small commercial and residential buildings with air conditioning tune-up and duct sealing round out the partnership's activities.

—Allan Chen

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http://www.oaklandenergypartnership.com/
This work is funded by the California Public Utilities Commission.

Thermal Distribution Systems

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year or the equivalent consumption of about 83,000 to 170,000 typical California houses) and about 100 to 200 MW in peak demand.

We are continuing our investigation, using our new diagnostic techniques to characterize duct leakage in a sample of large commercial buildings. We are also continuing to work with the CEC to introduce improved ways of characterizing energy-efficient ducts in the state energy code. The parallel story in the residential and small commercial sector has shown that it took approximately 10 years to move from the comparable stage in that research to maturity of technology adoption (e.g., commercialization and inclusion in standards). We conclude that a concerted effort will be necessary to make the same—or better—progress for the large commercial sector.

—Rick Diamond and Craig Wray

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This work was sponsored by the California Energy Commission and the U.S. Department of Energy.

Measuring Emissions

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One result of this work was that continued measurements demonstrated that oil tanks emission levels were much lower than expected. This helped both regulators, who, once they knew that the problem was not as large as they had feared, could free up resources to address other, larger pollution sources in their districts. The Industry also benefited by avoiding expenditures of tens of millions of dollars that would have been required to alter the tanks if they had been found to be a significant source of pollution.

—Allan Chen

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This work was funded by the Department of Energy and the Western States Petroleum Association.

Environmental Energy Technologies Division News

Published Quarterly

Vol. 4, No. 2

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This work was supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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LBNL/PUB-821 Vol. 4. No. 2, Spring 2003

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New DOE Building Energy Survey

Data collection begins in August 2003 for the Commercial Buildings Energy Consumption Survey (CBECS), the only national survey that collects information about the prevalence of energy-related characteristics in commercial buildings and the amount (and related cost) of electricity, natural gas, fuel oil and district heat used in the buildings.

Energy decision makers of approximately 5,500 sampled commercial buildings throughout the U.S. will be contacted by Westat, a survey research firm under contract to the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE), for information about the energy-related characteristics of their buildings. No information that would permit identification of respondents or their buildings is published. Previous CBECS results are available on the World Wide Web at http://www.eia.doe.gov/emeu/cbecs/. Additional information about CBECS is available from the survey manager, Martha.Johnson@eia.doe.gov or (202) 586-1135.

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