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NEWS

ADVANCED TECHNOLOGIES | ATMOSPHERIC SCIENCES | BUILDING TECHNOLOGIES | ENERGY ANALYSIS | INDOOR ENVIRONMENT

ENERGY EFFICIENCY AND INDOOR ENVIRONMENTAL QUALITY IN RELOCATABLE CLASSROOMS

School districts in California and throughout the U.S. are increasingly using relocatable classrooms (RCs), also known as modular or portable classrooms, because of a growing student population and state and federal mandates for class-size reduction. California schools are estimated to have 85,000 RCs, and this number is increasing at a rate of 4,000 to 10,000 per year.

Lawrence Berkeley National Laboratory, Davis Energy Group, American Modular Systems (a manufacturer of RCs), and two California school districts collaborated to perform a field study of four new, high-performance RCs. The results of this study indicate that it is possible to engineer solutions that simultaneously increase the indoor environmental quality (IEQ) and energy efficiency of RCs.

The benefits of energy efficiency are well known, and energy-efficient design is becoming increasingly important as building codes and standards require it. High IEQ in buildings is expected to improve occupant health and work performance and reduce absenteeism.

Figure 1. This HVAC system was designed for the relocatable classroom study.

This study of high-performance RCs demonstrates technologies that can simultaneously improve energy efficiency and IEQ and quantifies the results. RCs are well suited to this demonstration because they are self-contained and have dedicated heating, ventilation, and air-conditioning (HVAC) systems and well-defined occupancies.

Design Considerations

Operating costs, electricity demand, and other constraints influence HVAC design decisions, including equipment configuration, energy efficiency, and fuel source. HVAC systems must also be capable of providing adequate outdoor air ventilation because natural ventilation is often infeasible and may be inadequate. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 62-1999 (ASHRAE 1999), as well as the State of California Building Standards and Occupational Safety and Health Codes (CCR, 1995; CCR, Title 8) specify a minimum ventilation rate of 7.5 liters per second (L/sec) per person in non-residential buildings. Ventilation delivered at this rate will typically maintain indoor-occupant-generated carbon dioxide (CO_2) at less than 1,000 parts per million (ppm).

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EETD 30th

Energy Efficiency and Indoor Environmental Quality in Relocatable Classrooms

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Design of the High-Performance RCs

The design for the high-performance RCs used in this study incorporated currently available energy-efficient construction materials and methods, including additional wall, floor, and ceiling insulation; ceiling vapor barrier; "Cool Roof" reflective roof coating; low-emissivity window glazing; and efficient (T8) fluorescent lighting. Each of the four study RCs is equipped with two HVAC systems: a standard 10 Seasonal Energy-Efficiency Rating (SEER) heat-pump air conditioner (HPAC) system and an energy-efficient hybrid system with an indirect/direct evaporative cooler (IDEC) and a natural-gas heating system (see Figure 1). The IDEC supplies continuous ventilation at ≥7.5 L/sec per person even when heating or cooling is not required. Compared to the standard heat-pump system, the IDEC consumes as much as 70 percent less cooling energy, and, because it has a quieter fan and no compressor, its noise output is lower. The IDEC hybrid system includes an 85-percent-efficient (annual fuel utilization efficiency) gas-fired hydronic space-heating system and an efficient inlet filter system.

The Field Study

To test the high-performance RC designs in different climates, we located RCs at schools in two distinct regions: the California Central Valley (extreme climate) and the San Francisco Bay Area (moderate climate). The manufacturer placed two high-performance RCs at an elementary school in the Modesto school system in the Central Valley and two RCs at a school in the Cupertino Unified School District (CUSD) in the San Francisco Bay Area.

The high-performance RCs were sited side by side at each of the schools prior to the fall 2001 semester and used during the semester by 3rd- and 4th-grade classes of 20-30 students; each class had one teacher. During nine weeks of the 2001 summer/fall cooling season (August to October 2001) and nine weeks of the heating season (January-March 2002), the two RCs at each school were simultaneously operated with either the standard heat pump or the IDEC unit; the systems in use were switched weekly. Each RC was instrumented to measure a range of IEQ and energy parameters, including humidity, temperature, air velocity, sound level, indoor and outdoor CO_2 concentrations, particulate matter (PM) counts, volatile organic compound (VOC) and formaldehyde concentrations, and energy use.

Results

The patterns of HVAC system operation by the teachers directly influenced classroom IEQ parameters during the school day. As currently designed, both systems must be turned on to provide the required ventilation. The control requirement for the IDEC hybrid system is simply that the system be on when the space is occupied because the fan provides continuous 100 percent outside air when it is operating. The teachers reported that the IDEC system was quieter in operation than the HPAC system. In some cases, the decision to not turn on the HVAC system is based on a desire to save energy. For example, one teacher in the study regularly opened the RC windows during the morning instead of running the HVAC. In general, doors and windows were left open more frequently during the cooling season.

Table 1 summarizes indoor CO_2, indoor-outdoor formaldehyde and indoor PM concentrations. Indoor sound level and daily HVAC operation costs are also shown. These data are averaged across the study RCs by cooling and heating seasons and by HVAC system type. The PM concentrations are presented as mass concentrations in three nested size bin ranges: 0.3 µm, 0.3 – 1.0 µm, and 0.3 – 5.0 µm. These ranges were chosen to facilitate assessment of the inlet filter effectiveness and system operation.

Table 1. Summary school-day statistics averaged across four occupied high-performance relocatable classrooms monitored during nine to 10 weeks in the cooling and heating seasons in Northern California during the 2001-2002 school year. "10 SEER HPAC" refers to heat pump air conditioner weeks and "IDEC" refers to Indirect/Direct Evaporative Cooler weeks of operation, respectively.

COOLING SEASON		10 SEER HPAC			IDEC		
Measurement	Units	Mean±Std	Max	95th %	Mean±Std	Max	95th %
Indoor Temperature	∞F	72±3.9	82	78	71±3.8	80	76
Outdoor Temperature	∞F	82±8.7	104	98	77±8.0	104	88
Indoor CO_2	ppm	960±480	2,770	1,950	830±530	2,880	2,163
HCHO[1]	ppb	21±5	28	28	8.0±2.8	19	19
PM[2](0.3 – 5 µm)	µg m^{-3}	240±260	1,500	830	360±380	3,000	1,100
PM (0.3 – 1 µm)	µg m^{-3}	20±17	140	51	28±35	270	76
PM (0.3 µm)	µg m^{-3}	5.0±3.4	17	11	6.6±6.1	49	18
Indoor Sound Level	dBA	55.7±9.7	84.2	69.1	55.9±10.5	90.8	70.8
HVAC Energy Cost[3]	$/day	0.96±0.39	1.65	1.65	0.40±0.27	1.23	0.88
HEATING SEASON		10 SEER HPAC			IDEC		
Measurement	Units	Mean±Std	Max	95th %	Mean±Std	Max	95th %
Indoor Temperature	∞F	70±5.4	88	80	71±5.1	92	82
Outdoor Temperature	∞F	59±9.5	86	76	59±7.5	88	73
Indoor CO_2	ppm	1370±630	3,140	2,379	760±370	2,600	1,527
HCHO[1]	ppb	14±9	34	34	4.5±1.3	8.5	8.5
PM[2] (0.3 – 5 µm)	µg m^{-3}	74±72	580	210	48±49	640	130
PM (0.3 – 1 µm)	µg m^{-3}	11±7.7	48	26	8.3±6.4	130	19
PM (0.3 µm)	µg m^{-3}	3.8±3.2	16	10	3.2±2.8	15	8.0
Indoor Sound Level	dBA	55.5±9.6	78.0	68.3	55.9±10.5	86.8	70.7
HVAC Energy Cost[3]	$/day	1.54±0.79	3.60	2.90	1.03±0.61	3.53	2.12

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CLASP's International Success

mpressed with the large-scale energy savings demonstrated in North American and European nations, Lawrence Berkeley National Laboratory (Berkeley Lab) joined with two other organizations in the late 1990s to germinate a collaboration that would assist developing nations in creating, implementing, and enforcing energy-efficiency standards and labels. Energy saved by efficiency standards not only benefits the environment but also frees up capital that developing countries can put to other uses as their economies grow.

How CLASP Came To Be

In spring 1996, Stephen Wiel, head of the Energy Analysis Department in the Environmental Energy Technologies Division (EETD) at Berkeley Lab convened a general meeting for those at the Lab interested in working with developing countries to formulate energy-efficiency performance standards. His interest was in sharing the best technology and policy experience from the U.S.'s most successful energy-efficiency program—appliance standards and labeling—with the rest of the world. The initiative received internal start-up funding and then more funding from the U.S. Agency for International Development (USAID).

In 1999, the Alliance to Save Energy (the Alliance), the International Institute for Energy Conservation (IIEC), and Berkeley Lab formed the Collaborative Labeling and Appliance Standards Program (CLASP) to promote energy-efficiency standards and labels (S&Ls) for appliances, equipment, and lighting products outside the U.S. CLASP received a significant grant from the UN Foundation (UNF) through the UN Department of Economic and Social Affairs (UNDESA). CLASP is now an international partnership of governments and non-governmental organizations (NGOs) throughout the world.

Standards and Labels Save Energy

Worldwide, energy in buildings, including power used by appliances, equipment, and lighting, accounts for 34 percent of total energy consumption. Building energy use also accounts for about 25 to 30 percent of energy-related carbon dioxide (CO_2) emissions, and 10 to 12 percent of the net contribution to climate change from all greenhouse gases. "In the developing world, the increase in power demand is straining the energy infrastructure, causing environmental damage and hindering economic growth," says Wiel, who is Chair of CLASP's Governing Board. "Demand for major appliances and equipment—ranging from refrigerators and clothes washers in homes to copiers and lighting equipment in office buildings—will continue its steady growth. Efficiency standards and labeling programs can help meet this rising energy demand."

In the U.S., energy-efficiency standards for nine residential products show substantial benefits over product lifetimes. For the $2 spent so far by the federal government for each household in the U.S., the standards will, by 2020, have stimulated spending of $900 per household on additional energy-saving features and saved each household $2,400 in energy bills. The net savings to the U.S. economy by 2020 will be $1,500 per household, with a cumulative net dollar savings of $150 billion. Standards will reduce primary energy use by eight percent of 2020 residential energy use and carbon emissions by 27 million metric tons in 2020 (nine percent of total emissions).

"The challenge," says Wiel, "is that standards and labeling require decades in order for benefits to accrue, so they require a mid- to long-term perspective on energy policy. It's most effective to focus on new products—85 to 90 percent of energy used 20 years from now will be used by products that have not yet been manufactured."

Standards and labeling programs help consumers see that an energy-efficient appliance costs less money in the long run (see Table 1). Without energy labels, consumers are more likely to choose a cheaper model of an appliance, which is likely to have a higher long-term overall cost (energy plus purchase costs). When labels show products' average annual energy cost, consumers can see that the cost of an appliance plus the cost of energy to operate it is substantially lower for efficient products.

Table 1. S&L overcome market barriers. Model A is a pair of linear-tube T-12 fluorescent lamps with a conventional ballast in Mexico, and Model B is a pair of T-8 lamps and an electronic ballast.

How people choose without energy labels		
	Model A	**Model B**
Purchase price	$81	$137

An informed choice with an energy label		
	Model A	**Model B**
Purchase price	$81	$137
Energy cost	$1,064	$561
Total price	**$1,145**	**$698**

CLASP's work

CLASP's role as a major force in proliferating energy-efficiency standards and labels worldwide entails forming partnerships with governments and NGOs to give technical assistance to individual countries and regions. CLASP

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CLASP's International Success

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associates provide market analysis and research for baseline studies as well as monitoring and evaluation of program impacts.

USAID funding for CLASP has expanded so that the organization is currently playing a key role in the agency's South Asia Regional Initiative (SARI) energy program. CLASP has also joined with the U.S. Department of Energy for the Efficient Energy and Sustainable Development (EESD) partnership, which is the energy-efficiency component of America's energy commitment to the World Summit on Sustainable Development. In addition, CLASP helps Asian Pacific Economic Cooperation (APEC) provide access to codes and standards information through a web-based information network called the Energy Standards Information System (ESIS).

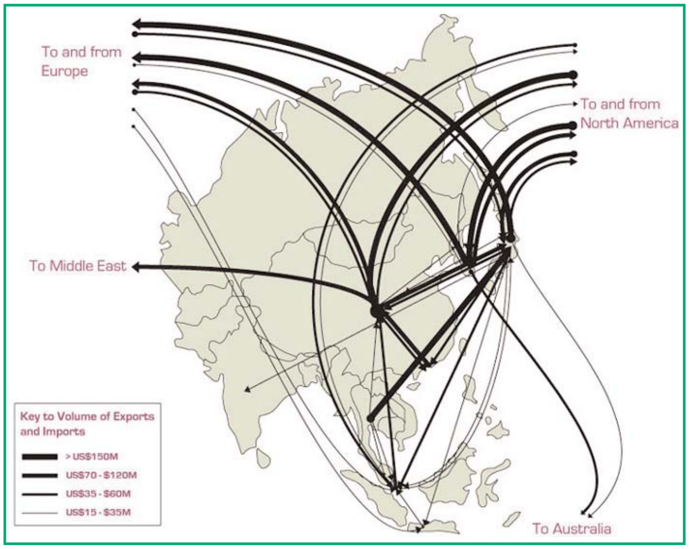

Figure 1. Example of a CLASP information product: refrigerator product flow in Asia.

Another CLASP project is assisting the United Nations Development Programme/Global Environmental Facility (UNDP/GEF) in developing a series of regional S&L initiatives to foster cooperation and harmonization among S&L programs in different regions. In addition, CLASP has provided significant technical assistance to Chinese government agencies developing energy-efficiency labels and standards for nine products, including refrigerators, room air conditioners, clothes washers, color televisions, central air conditioners, and motors.

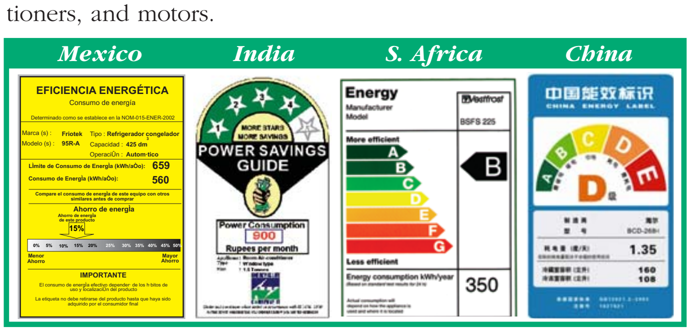

Figure 2. Proposed energy labels evaluated with the assistance of CLASP.

In India, CLASP participates in the S&L process led by the Indian Bureau of Energy Efficiency. CLASP is also in the early stages of providing technical assistance to the Brazilian government.

Tools for Training and Analysis

CLASP develops training materials and technical tools that explain the common elements and strategies of successful standards and labeling programs worldwide and that also help calculate potential program benefits. A significant recent example is *Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment and Lighting,* which was designed for officials in developing countries. This guide has been translated into Chinese, Korean, and Spanish and distributed to more than 1,000 people in 60 countries. CLASP also hosts information exchange events, including regional standards and labeling training workshops in Latin America and in Asia.

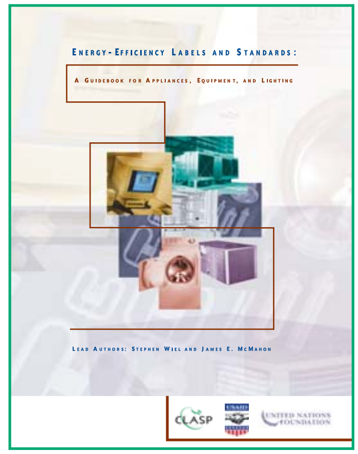

Figure 3. The CLASP energy-efficiency standards and labeling guidebook.

"CLASP's near-term vision," says Wiel, "is to provide in-depth and tailored technical assistance and training to at least 15 priority countries while supporting up to 50 others through information dissemination, harmonization discussions, and training forums. Our long-term vision is a future where standard-setting and labeling are routine government functions around the world."

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A Tool to Predict Exposure to Hazardous Air Pollutants

The Clean Air Act Amendments of 1990 authorized the regulation of 189 hazardous air pollutants (HAPs) that cause cancer, reproductive harm, or other serious health problems. Current regulations set source-specific limits on emissions, but the U.S. Environmental Protection Agency (EPA) plans to develop future rules that focus on reducing human exposure to these compounds. To develop these rules, it will be necessary to predict exposures. Even though most HAPs are emitted by outdoor sources such as vehicles and industrial facilities, Americans spend about 90 percent of their time indoors, so most human exposure to these pollutants takes place after they have entered buildings. Predicting exposure thus requires an understanding of the processes that can affect pollutants indoors. Toward this goal, researchers in the Atmospheric Sciences and Indoor Environment Departments of the Environmental Energy Technologies Division (EETD) at Lawrence Berkeley National Laboratory (Berkeley Lab) are developing a computer-based modeling tool that simulates the key processes, including ventilation, chemical reactions between gases, and sorption of pollutants on material surfaces.

In this context, *sorption* is the reversible attachment of gas molecules to indoor materials. *Adsorption* describes the process by which the gas molecules stick to surfaces. *Desorption* is the reverse process, in which molecules that were previously sorbed to a surface are reemitted into the air. In a sealed room, these two processes will eventually reach equilibrium, with a fraction of the pollutant remaining in the air and the rest sorbed to surfaces.

Experiments to Study Sorption of Pollutants Indoors

To acquire a detailed understanding of sorption in realistic settings, Berkeley Lab researchers conducted experiments in a room-sized test chamber constructed and furnished to simulate a residential environment. The room is finished with painted gypsum wallboard and padded carpet and furnished with wood and veneer tables, desks, and bookcases; upholstered chairs; and cotton draperies. Twenty air pollutants, including many HAPs and key components of environmental tobacco smoke, were released into the chamber, and their concentrations were monitored over time.

The typical observed pattern is shown in Figure 1 for xylene, a compound that exhibited a moderate amount of sorption. With the room initially sealed, the observed decay in gas-phase concentrations reflected adsorption of compounds to material surfaces. After several hours of adsorption, concentrations stabilized, indicating that equilibrium had been reached. The room was then ventilated (flushed) at a very high rate to quickly remove all gaseous pollutants. Rising concentrations after the room was resealed at hour 25 resulted from desorption of the previously sorbed mass. Time-concentration patterns for all 20 compounds were fitted to mathematical equations to determine the simplest

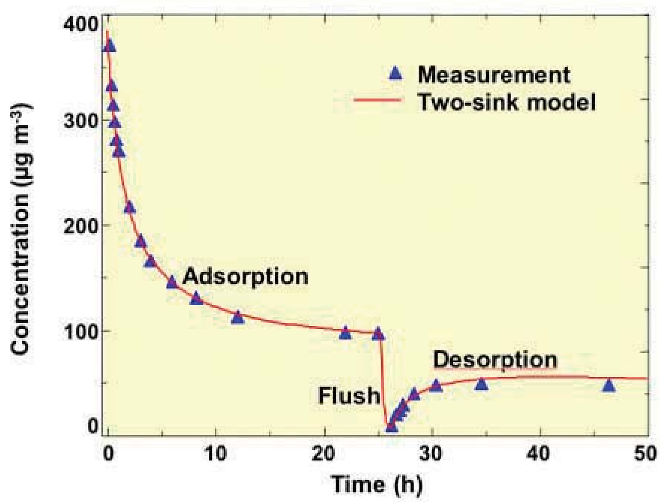

Figure 1. Gaseous concentrations of xylene in a furnished room. Room was sealed during adsorption and desorption periods. Changes in concentrations during these periods are from sorption to/from materials in the room.

model that could explain the observed behavior of each compound. Specifically, the goal was to understand the rates of adsorption and desorption and the overall sorption tendency (i.e., equilibrium) for each compound in the furnished room.

Indoor Sorption Alters Pollutant Exposure

Experimental and modeling results indicate that many important HAPs adsorb to surfaces at rates equal to or faster than ventilation rates in typical homes. This means that once a pollutant enters a residence along with outside air, a substantial fraction of the pollutant may stick to surfaces before it can be removed with air leaving the building. When outdoor pollutant concentrations are high, sorption will reduce the concentrations encountered indoors. However, desorption later on will means that indoor levels will be higher than those outdoors for a time as some pollutant returns to the indoor atmosphere. The consequence is a difference in the temporal pattern of indoor versus outdoor concentrations, which has important implications for human exposure. Figure 2 shows the results of a simulation using our sorption model with a repeating outdoor concentration profile. The indoor concentration pattern for toluene, a compound that does not sorb readily, is similar to the outdoor profile but lags behind the outdoor concentrations because of the time it takes for air to enter buildings from outdoors. The pattern is markedly different for the highly sorbing pollutant cresol. The implication is that indoor cresol exposures will be approximately constant throughout the day and not depend significantly on the outside concentrations.

Both the rates of adsorption and the potential extent of sorption at equilibrium varied widely among the pollutants

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Testing New Battery Materials in Standard Cells

Building a better battery is a key goal for those who would like to see electric and hybrid electric vehicles (EVs and HEVs) become viable options in the car market. However, progress toward this goal has been slow. Many labs are seeking battery anode (negative electrode) and cathode (positive electrode) materials that will last longer, suffer less degradation, and operate safely over wider temperature ranges than is currently possible.

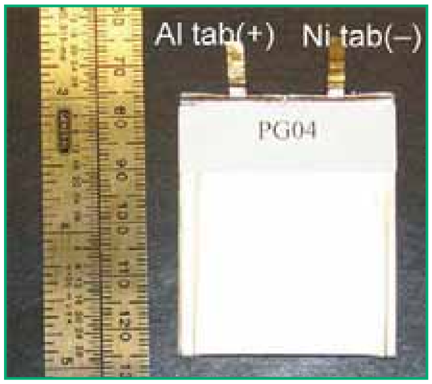

Figure 1. Pouch-type lithium-ion test cell.

As part of this battery research effort, a unique cell development program has been under way at Lawrence Berkeley National Laboratory (Berkeley Lab) for the past three years, led by Kathryn Striebel, a scientist in the Lab's Environmental Energy Technologies Division (EETD). This project uses standardized cells to assess, in a working battery, the performance of promising new materials. The project aims to bridge the gap between materials research and transfer to a battery developer.

EETD has long studied advanced materials for batteries. The work is currently funded by the U.S. Department of Energy (DOE) Batteries for Advanced Transportation Technologies (BATT) program of the Office of FreedomCAR and Vehicle Technologies. BATT, which is administered by EETD for DOE, consists of six research tasks involving Berkeley Lab and a number of other institutions and national laboratories.

Standard Cells Test Realistic Conditions

"The idea of this research element," says Striebel, "is to take new materials from labs and build them into test cells for new batteries. We build new materials from different sources into these test cells and run a set of standard tests to see how they perform under realistic conditions. Then, we disassemble the test cells, and, after some additional electrochemical testing of our own, we send samples to the Berkeley Lab researchers focusing on diagnostic techniques, such as Raman and Fourier Transform Infrared Spectroscopy [FTIR] and many others." The testing helps determine why electrode materials fail or degrade. Experimental materials come from labs all over the world, including EETD's own electrochemistry labs.

To be successful, a battery for automotive applications must meet DOE criteria for features such as weight, cost, power density, and operating temperature range. These criteria include a 10-year life, $150/kWh cost, ability to operate between –40° and 50°C, and a lifetime loss of capacity of no more than 20 percent. Batteries for HEVs differ slightly from those for EVs in that they also need to be able to provide numerous pulses of power for acceleration and accept charge during regenerative braking.

Currently, lithium-ion-based cells are promising canditates for meeting these performance goals. One option is based on lithium iron phosphate ($LiFePO_4$) and natural graphite (NG).

"The central goal for us," Striebel says, "is to determine which materials work the best, and, when they fail, to answer the question 'why?'"

$LiFePO_4$ material has some advantages: it is stable and flame retardant, it has a long cycle life, and it shows promise for meeting the goal of no more than 20-percent capacity degradation over the battery's lifetime. However, the capacity of $LiFePO_4$ batteries is currently insufficient for use in vehicles.

No material currently meets all of DOE's goals for automotive batteries. One important reason is that the performance of existing materials degrades significantly after many charge-discharge cycles. EETD's "strength is in our understanding of degradation mechanisms in battery materials," says Striebel. "If we can nail down the mechanisms of degradation, it will be a great help to everyone working in the field."

Test Pouches

Figure 2. Electrode casting device.

Test cells are small, thin pouches: 12 square centimeters and just larger than an inch (about 3.5 cm.) on each side (see Figure 1). They can store an average of 12 milliampere-hours of charge. The effort to make a cell starts with 5 to 20 grams of an experimental material—an amount that is considered large for a new material that may exist in only tiny quantities in a single lab. The material is mixed with carbon, a binder polymer, and a solvent to form a slurry. This slurry is cast in thin layers onto a foil current collector and dried extensively (see Figure 2). One anode and one cathode are placed in a flexible pouch with a porous

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Testing New Battery Materials in Standard Cells

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Figure 3. Cell test apparatus.

separator and transferred to a helium-filled glove box for finishing. At this point, electrolyte is added, and the pouch is sealed to protect the cell from water vapor during testing. The pouch is then compressed and mounted on a test device (see Figure 3), usually along with many other cells that are undergoing testing.

The device tester can charge and discharge up to 64 test cells simultaneously, according to any specification. For example, it can run through continuous charge-discharge cycling at constant current, letting the cells rest between half-cycles, which is the procedure for determining baseline cell performance, or it can charge and discharge with short, high-current pulses, simulating the conditions that an HEV battery might encounter.

The tester measures current, voltage, and other parameters, and, for each test cell, provides impedance characteristics, capacity, and power as a function of cycle number or time. After a cell reaches a pre-determined end-of-life limit (low capacity or power), additional diagnostic cycles are carried out before the cell is removed to the glove box for disassembly.

Once the cell is disassembled, Striebel and her colleagues might subject the experimental material to a range of additional tests to investigate its degradation mechanisms. These tests might use Raman, FTIR, and other spectroscopic methods; X-ray diffraction; or transmission electron microscopy.

"The testing is an ongoing program," says Striebel. "We continue to test new materials as they are developed. The results allow us to compare the performance of different materials with one another. We have also been working with John Newman's group [of EETD and the University of California, Berkeley], which develops computer models of the performance of batteries. This really helps us isolate why these materials perform the way they do."

Test results are presented at U.S. and international meetings and published in peer-reviewed journals, so the data are available to the scientific community as well as battery developers. "Recently, we used the computer modeling directly to help in the comparison of six different sources of $LiFePO_4$ from around the world. This approach generated a lot of interest at the most recent meeting of The Electrochemical Society, in Orlando Florida," says Striebel.

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Battery test material information:
http://isswprod.lbl.gov/battdatasite/

BATT program information:
http://berc.lbl.gov/BATT/BATT.html

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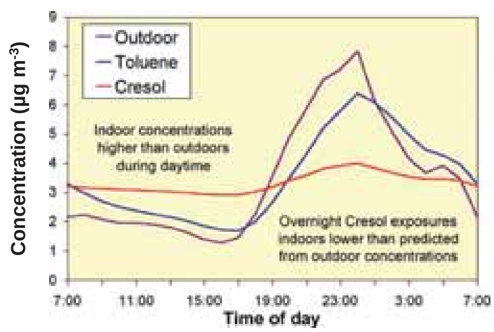

Figure 2. Model-predicted indoor concentration patterns for toluene and cresol resulting from outdoor profile shown.

studied. The most rapidly sorbing compounds tested were gas-phase polycyclic aromatic hydrocarbons (PAH), cresols, and the tobacco smoke constituent nicotine. These compounds sorbed much faster than ventilation air exchange rates and were more than 95 percent sorbed at equilibrium (i.e., less than five percent remained in the air). Two of the HAPs that have generated the most concern to date, benzene and acrolein, were observed to adsorb at relatively slow rates, suggesting that indoor exposure patterns for these compounds may not be greatly affected by sorption.

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Buildings Technologies Information Gaps Filled by New Sources

A new pair of information sources—a website and a recently published book—fill gaps in knowledge about building façades and daylighting. Although materials abound that show photos and drawings of modern building façades, little has been written about the actual performance of modern buildings; the Environmental Energy Technologies Division's (EETD's) new High-Performance Commercial Buildings Façades website (http://gaia.lbl.gov/hpbf/) contributes much-needed knowledge in this area. Another recently completed effort, *Daylight in Buildings: A Source Book on Daylighting Systems and Components*, written and edited in part by EETD Building Technologies scientists, promotes advanced daylighting technologies and daylight-conscious building design.

High-Performance Commercial Building Façades Website

Modern office buildings are often constructed with all-glass façades, a trend associated with buildings that have "green" design goals: energy efficiency, occupant comfort, and optimized operations and maintenance. A variety of energy-efficient technological solutions, including daylighting, solar heat gain controls, and advanced ventilation and space-conditioning devices, are incorporated in these commercial building façades. The intensive use of glass and coatings in these buildings can raise construction costs considerably, but the claims that these façade elements save energy remain largely unsupported because there has been little critical examination of the actual performance of these buildings. In addition, some designs are so site- and climate-specific that reproducing them elsewhere can lead to unexpected results.

Figure 1. High-Performance Commercial Building Facades Website

The primary goal of the High-Performance Commercial Buildings Façades website (Figure 1) is to clarify what is known about the performance of advanced building façades so California building owners and designers can make informed decisions about the value of these building concepts for meeting energy-efficiency, ventilation, productivity, and sustainability design goals.

The website contains links to information about technology, design, building performance, case studies, and resources. The case studies section includes further links to photos, plans, and other technical information about recently constructed buildings.

Daylighting Source Book Published

The importance of lighting in office and other non-residential buildings cannot be disputed. In particular, the quality, spectral composition, and variability of daylight strongly affect occupants' reactions to the indoor environment, from creating pleasant conditions that provide adequate illumination for tasks to creating uncomfortable conditions such as solar glare. The many possible effects of daylight need to be considered when daylighting systems are designed.

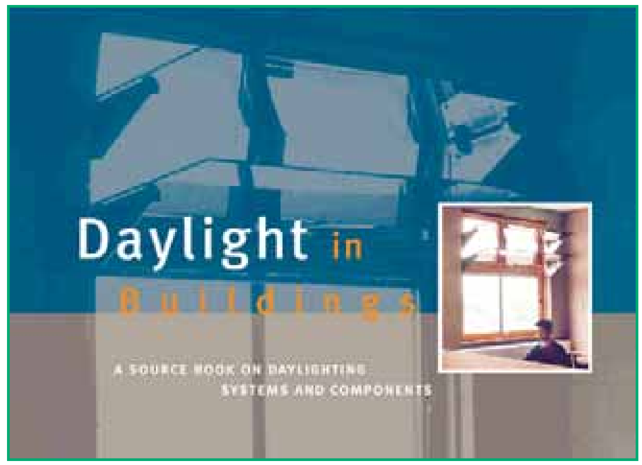

Figure 2. Daylight in Buildings: A Source Book on Daylighting Systems and Components

With the publication of *Daylight in Buildings: A Source Book on Daylighting Systems and Components* (http://gaia.lbl.gov/iea21/), lighting designers have a new planning resource to use when considering innovative daylighting concepts for non-residential buildings. The book (Figure 2), written and published by the International Energy Agency (IEA), lays out original observations related to daylighting-conscious building design and describes and assesses the performance of innovative daylighting strategies. Stressing that lighting needs to be included at the beginning of the design process, the authors of the *Source Book* use demonstrations from test rooms and models to make cases for sensible architectural solutions. Chapter topics include daylighting in building design, including rooms, windows and adjacent spaces; performance parameters for visual comfort, thermal comfort, building energy use (including lighting energy, space-conditioning energy use, and peak demand); as well as more advanced and complex concepts such as light shelves, louvers, prismatic panels, and laser-cut panels.

The *Source Book* is the result of IEA's Solar Heating and Cooling Programme Task 21. Among the authors are EETD scientists Eleanor Lee and Steve Selkowitz. Both also worked as editors for the book.

—Ted Gartner

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Energy Efficiency and Indoor Environmental Quality in Relocatable Classrooms

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[1]Indoor – outdoor formaldehyde concentration.
[2]PM = Particulate Matter in given instrument bin sizes, mass concentration calculated from particle count concentration, based upon bin size diameter and assumed density of 2 g cc^{-1}. Outdoor PM concentrations (0.3 – 5 µm) were 130±140 µg m^{-3} and 30±40 µg m^{-3} in the cooling and heating seasons, respectively.
[3]Assuming electricity cost of $0.14 kWh^{-1} and natural gas cost of $0.60 $therm^{-1}$.

During the cooling season, average school-day indoor CO_2 concentrations across study RCs were 960±480 ppm (average±standard deviation) and 830±530 ppm for HPAC and IDEC weeks, respectively. We observed that teacher operation of the HVAC systems was not based solely on thermal demand. Teachers did not always turn on the IDEC in the morning as instructed. When they did not, the CO_2 concentrations in the classrooms were observed to rise well above 1,000 ppm, with peaks reaching almost 3,000 ppm, irrespective of the type of HVAC system designated for operation. During periods of window-only use, indoor CO_2 levels often exceeded 1,000 ppm, indicating that windows alone may not provide adequate ventilation. The substantially lower CO_2 concentrations during IDEC operation weeks demonstrate the benefits of continuous adequate or enhanced ventilation.

The continuous ventilation provided by the IDEC system was effective for controlling the concentrations of indoor-generated pollutants, as demonstrated by the formaldehyde data. School-day formaldehyde concentrations in both the cooling and heating seasons were higher during HPAC weeks than during IDEC weeks.

The teachers' usage of the HVAC system during the heating season was similar to usage during the cooling season, but morning heating demands led to more consistent use of the IDEC. Mean heating season indoor CO_2 concentrations were 1370± 630 ppm and 760±370 ppm for HPAC and IDEC weeks, respectively.

Indoor PM concentrations were generally higher than outdoor concentrations, indicating that occupant activities were a source of particles. During the cooling season when doors and windows were frequently open, there was increased infiltration of PM from outdoors. Indoor PM concentrations were lower on average during HPAC operation across the particle-size distribution, but concentrations occasionally reached high levels with both HVAC systems.

Sound levels in the RCs were consistent across HVAC system and season, averaging about 56 A-weighted decibels (dBA). A comparison of occupied and unoccupied time periods showed that most of the noise increase above background in the occupied classrooms was from the occupants themselves, with HPAC and IDEC system operation contributing up to 14 dBA and 8 dBA, respectively.

Classroom total energy use and HVAC energy consumption were measured throughout the field study, and the energy data were used to calibrate a DOE-2 energy simulation model. Using the calibrated DOE-2 model for 16 California climate zones, we compared the energy use of the HPAC and IDEC, assuming that each HVAC system was operated to meet minimum ventilation standards. The resulting statewide average energy impacts per classroom included an 80 percent reduction in annual electricity use, more than 70 percent reductions in peak electricity requirements during both summer and winter, an increase in natural gas use (for winter heating), and a $220 annual energy cost savings.

These results overall suggest that it is possible to use efficient engineering solutions to simultaneously reduce energy consumption and improve indoor environmental quality.

This study was conducted by: MG Apte,[1] D Dibartolomeo,[1] T Hotchi,[1] AT Hodgson,[1] SM Lee,[1] SM Liff,[2] LI Rainer,[3] DG Shendell,[1] DP Sullivan,[1] and WJ Fisk.[1]

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http://buildings.lbl.gov/hpcbs/s_arc.html

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Research Highlights

Ventilation Standard for Residences Approved

In July 2003, the Board of Directors of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), approved publication of ASHRAE Standard 62.2, Ventilation and Acceptable Indoor Air Quality for Low-Rise Residential Buildings. The Board heard and rejected appeals to its decision to publish the standard in October, and the Board Policy Committee for Standards made ASHRAE Standard 62.2-2003 official on October 5. Max Sherman of the Environmental Energy Technologies Division (EETD) is the outgoing chair of Standards Project Committee (SPC) 62.2P, which worked for six years to develop this standard for maintaining acceptable indoor air quality in homes.

SPC 62.2P consists of three primary sets of requirements addressing whole-house ventilation, local exhaust, and source control. A large group of secondary requirements address implementation issues related to the primary requirements.

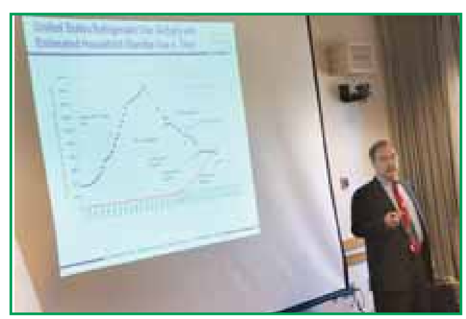
The standard provides alternate pathways to meeting its requirements, with the goal of giving builders flexibility. The requirements are performance based, and after prescriptive alternatives for achieving specified ventilation rates. Both mechanical and natural methods of achieving these rates are permitted.

"The intention of whole-house ventilation," says Sherman, "is to dilute the unavoidable contaminant emissions from people, materials, and background processes. Local exhaust is intended to remove contaminants from specific rooms like kitchens and bathrooms where these sources originate."

Secondary requirements include specifics such as sound and flow ratings for fans, as well as labeling, and guidance to help prevent the design of a building from being a factor in the failure of ventilation systems.

Mayoral Summit

U.S. mayors and their staffs, city council members, members of boards of supervisors, and renewable energy experts attended the second day of the Solar Cities Summit at Lawrence Berkeley National Laboratory (Berkeley Lab) on September 19. Convened by San Francisco Mayor Willie Brown, the mayors spent September 18 in San Francisco learning about solar energy's prospects and looking over the new photovoltaic (PV) panels and energy-efficiency improvements at the Moscone Convention Center. The following day, they came to Perseverance Hall where they heard practical talks about how to plan, implement, and finance solar PV projects in their cities. Environmental Energy Technologies Division (EETD) Director Mark Levine welcomed the group to Berkeley Lab with a talk about how energy efficiency complements the use of renewable energy sources by providing more bang for the renewable energy buck. The Mayors of Honolulu HI, Boulder CO,



Research Highlights

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Scottsdale AZ, and Montclair NJ were among those in attendance, along with mayors from California cities including Burbank, Campbell, Oroville, and Santa Ana. The meeting concluded with a mid-day visit to the Lab's new Advanced Windows Test Facility where attendees learned about electrochromic and other new efficient window technologies.

Environmental Energy Technologies Division is 30 Years Old

Figure. Andrew Sessler reminisces. Photo by Ted Gartner

Celebrating its 30th anniversary in style on October 30, the Environmental Energy Technologies Division (EETD) threw a birthday bash in the Lab's cafeteria, complete with nostalgic photographs, music performed by EETD staffers, and birthday cake. Current EETD staff attended the party along with a number of old friends, including retired staffers, former EETD Directors, and past Lab Director Andy Sessler.

Past Division Directors Jack Hollander, Bob Budnitz, and Elton Cairns attended as did current Division Director Mark Levine, Lawrence Berkeley National Laboratory (Berkeley Lab) Director Charles Shank, and Lab Deputy Directors Pier Oddone and Sally Benson. In his welcoming remarks, Director Shank praised the Division's accomplishments: "Thirty years ago, Andy Sessler worked with his [colleagues] to create this Division. In doing so, he created the Lab as it is today," he said, pointing to the Lab's evolution from a physics research facility to a multidisciplinary science laboratory.

Attendees viewed posters set up around the room with portraits and candid photos of 30 years of past and present-day staff. Maggie Pinckard and Greg Homan, both Division staffers, provided harp, flute, and keyboard music. In the cafeteria lobby, bulletin boards were covered with pictures, some dating back to the Division's beginnings, loaned by current employees.

Buildings Technologies Information Gaps Filled by New Sources

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EETD High-Performance Commercial Buildings Façades website:
http://gaia.lbl.gov/hpbf/
Website contents can be downloaded as a pdf.

Daylight in Buildings: A Source Book on Daylighting Systems and Components:
http://gaia.lbl.gov/iea21/
Copies of the book may be obtained from JeShana Dawson, JLDawson@lbl.gov

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Ernest Orlando Lawrence Berkeley National Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of the nine national laboratories, Berkeley Lab is located in the hills above the campus of the University of California, Berkeley.

With more than 4,000 employees, Berkeley Lab's total annual budget of nearly $400 million supports a wide range of unclassified research activities in the biological, physical, computational, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, Berkeley Lab has had nine Nobel laureates. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of 400 and a budget of $40 million.

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Sources

EREC: Energy Efficiency and Renewable Energy Clearinghouse

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