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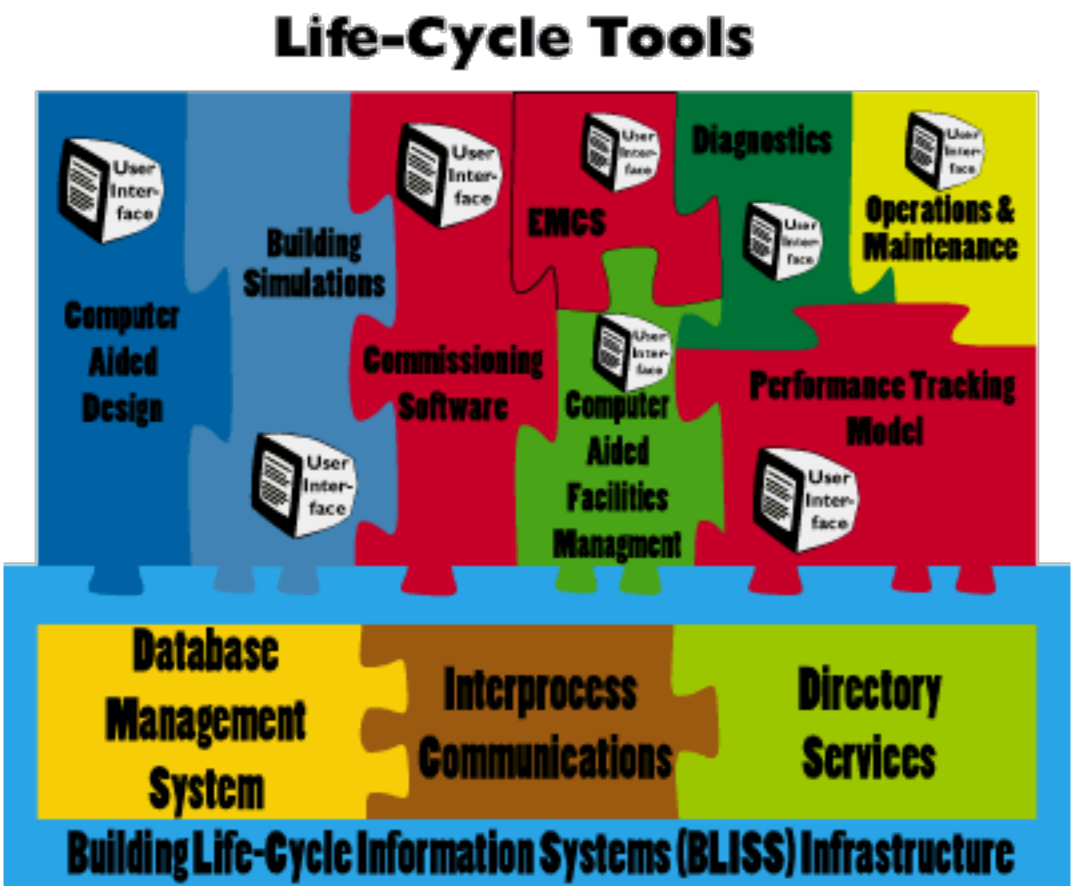
Assuring Building Performance: Creating BLISS



Software tools will link to the BLISS infrastructure

Despite significant advances in building technology and tighter building codes, buildings consume one-third of all energy used in the U.S. at a cost of $200 billion/year. Half of this energy is wasted if one considers the cost-effective measures now achievable. Assuring the highest possible building performance (in health and productivity as well as energy) ought to be a national goal in an increasingly competitive world. Providing designers, builders, and operators with consistent information throughout the life cycle of a building opens opportunities for reaching performance potential. LBL recently initiated an internally funded project to explore these issues, with the goal of creating public-private partnerships to develop workable, cost-effective solutions to assuring building performance.

Commercial building performance consistently falls short of its potential, with costly results to people and institutions. Energy use in commercial buildings accounts for $85 billion per year, more than half of which could be saved if the experience of a few unique, carefully designed and operated buildings could be widely replicated. Occupant health and comfort also suffer in poorly ventilated and conditioned spaces, resulting in lost productivity and a growing incidence of lawsuits.

The goal of the LBL project is to develop and standardize an interoperable set of software tools to correct these problems. The tools will respond to the needs of each phase of a building's life cycle and will be linked by a shared informational infrastructure, the Building Life-cycle Information Support System. BLISS will serve as the backbone of a dynamic data archive for each building. Once the BLISS data archive is established, the marginal cost of supplying additional tools with building data should be small compared to current practice. Interoperable tools that share information should provide considerable efficiencies and cost savings throughout the building life cycle. The tools developed in this project will not be limited to commercial buildings, but because of the existing infrastructure of building operators, computer-assisted design and EMCS, large commercial buildings are the logical first target. The same principles can be applied across the spectrum to single-family residential buildings.

LBL's early effort will focus on three projects:

1. BLISS,
2. commissioning information tools (CITs), and
3. performance evaluation and tracking tools (PETTs).

Building Life Cycle Information Support System

The goal of this effort is to create a software infrastructure that can be used to share information across disciplines and to link interoperable software tools throughout the building life cycle.

This project has three major elements:

1. to specify the distributed systems software architecture,
2. to build a life-cycle database, and

3. to develop a mechanism to capture design intent.

The distributed systems architecture will describe how various building software components will communicate with each other. The building database schema will specify the structure and semantics of the database, providing a common vocabulary for the software components. The data structures will be able to accommodate both object-oriented building descriptions and extensive time-series data from performance tracking tools. BLISS will also be able to capture and represent design intent (goals, specifications, and decisions), a critical set of information that will be updated as the building design evolves. Data on design intent will provide information that is necessary later in the life cycle for successful building commissioning and operations.

Commissioning Information Tools

Commissioning is the process of inspecting and testing a building to ensure that it operates as intended. A cost-effective commissioning process will produce buildings that have lower operating costs while providing a healthier indoor environment that will increase productivity and user satisfaction.

The initial project goals are:

1. to develop the conceptual design for a complete CIT, and
2. to develop an operating software module for one building system that is ready for field testing.

The software will specify procedures for commissioning, monitoring guidelines, and electronic documentation requirements, along with methods to continue using this information in the operations phase of the building life cycle. The initial focus will be on developing a chiller commissioning module. A new building on the UC Berkeley campus will provide a living laboratory for developing and testing these new tools.

Performance Evaluation and Tracking Tools

The goal of this project is to develop information collection and interpretation systems that allow the building's performance to be continuously evaluated and tracked as part of normal building operation. The first-year effort to produce PETTs will have two elements. The first is development of information resources that describe how the building should perform. This will be accomplished through performance metrics and accessing and updating the design intent and commissioning results inherited from earlier life-cycle phases. The second element will capture how the building does perform, based on real-time data acquired from the building EMCS.

Partnerships

This program cannot succeed without involvement from building-sector partners-as financial sponsors for the next phase of work; as research collaborators; as sources of information where LBNL does not have experience or expertise; and, most importantly, as development partners for the tools and processes in this program. LBNL is actively seeking interested partners to expand this program.

Overall Project:
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- Max Sherman, (510) 486-4022

BLISS:
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- Frank Olken, (510) 486-5891

CIT and PETT:
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News From the D.C. Office

Seminars Explore Energy Policies & Technologies

As part of our effort to communicate with customers and colleagues in the Washington area, the LBNL-D.C. office sponsors a series of breakfast seminars on research and policy topics of current interest. We've held six seminars this spring, each attended by 15 to 25 invited guests from the Department of Energy, the Environmental Protection Agency, the Agency for International Development, nongovernmental organizations, Congressional committee staff, and D.C. staff of other national laboratories.

On March 2, Jim McMahon of LBNL's Energy Analysis Program described LBNL's important contribution to national energy-efficiency standards for appliances. LBNL has provided analytical support to DOE for more than 15 years, contributing significantly to the program's success. LBNL analyses of expected impacts on consumers, manufacturers, utilities, and the environment have improved DOE's understanding of the appliance market and technologies. These detailed analyses will become more valuable to policymakers as some DOE standard-setting shifts to a negotiated rulemaking process. For more information, contact Jim McMahon at 510-486-6049.

Bill Fisk of the Indoor Environment Program presented a talk on March 23 addressing the enormous potential benefit of improving indoor environmental quality in commercial and public buildings. There is considerable evidence that improved indoor environmental quality can reduce infectious diseases, symptoms of allergies and asthma, the symptoms associated with sick building syndrome, and the failures of electronic equipment while enhancing workers' physical and mental performance. The potential productivity gains are on the order of $40 billion per year in the U.S. LBNL is a national leader in laboratory and field research on how to improve indoor environments in an energy-efficient manner. High-quality indoor environments can be attained through a variety of practical, energy-efficient measures, such as better ventilation and air filtration and well-designed lighting. If you'd like more information, you can reach Bill Fisk at 510-486-5910.

"Sustainable transportation" was the topic of Lee Schipper's seminar on April 26. Co-leader of the International Energy Studies group in the Energy Analysis Program, Lee described sustainable transportation systems as an elusive but critically important goal that involves far more than energy concerns. Transportation has a tremendous impact not only on energy use and pollution, but also on the quality of life in urban and rural areas. This clearly applies to industrial countries, but it is increasingly an issue in developing countries as well. Long-term solutions must be market-based as well as technological. Fuel taxes, "feebates" and other policies that internalize environmental externalities are needed to reduce fuel use and travel growth. Lee sparked a lively discussion of possible market-based pricing policies that the U.S. and other countries could adopt to reduce low-occupancy vehicle use. Contact Lee Schipper at 510-486-5057.

Jim Cole, Director of the California Institute for Energy Efficiency, along with Anthony Sebald of UC San Diego and Eng Lock Lee, of Supersymmetry, Inc., presented a seminar on April 28 on CIEE-funded research to improve building energy performance through better diagnostic information and operator feedback. This new collaborative project will explore and demonstrate ways to improve monitoring, data archiving, analysis, and data visualization so that operating problems can be diagnosed quickly and this information can be more usable by building operators. For more information contact Jim Cole at 510-486-4123.

On May 24, Willett Kempton of the University of Delaware spoke on his recently published book Environmental Values in American Culture coauthored by James Boster of UC Irvine. In late June, Alex Bell of LBNL and UC

Berkeley led a seminar called "Enhancing the Durability of Automobile Emission Control Catalysts." For details on either talk, call the LBNL-D.C. office at 202-484-0880.

—Nancy Casey-McCabe and Jeffrey Harris

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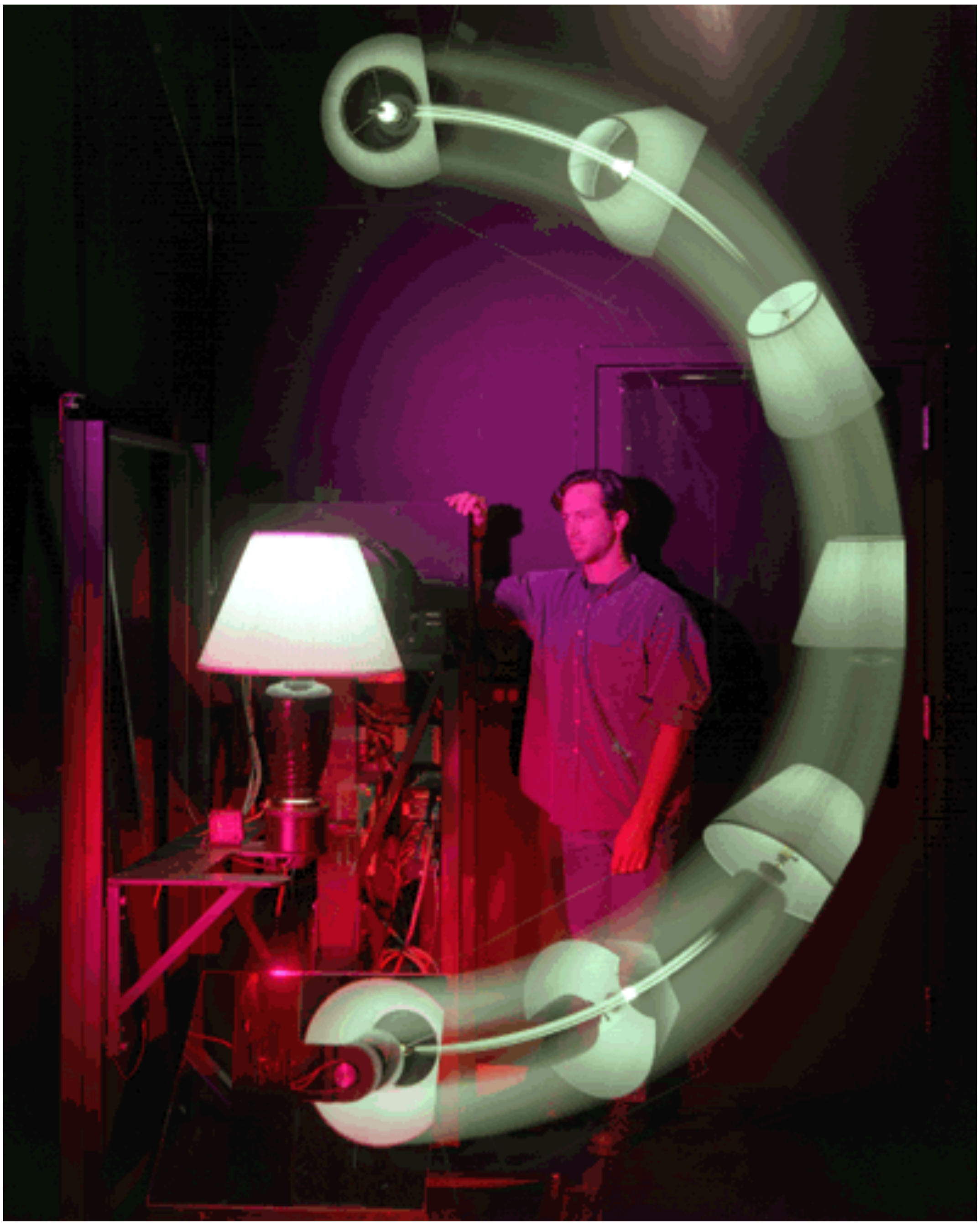
New Research Tool for Energy-Efficient Residential Fixtures

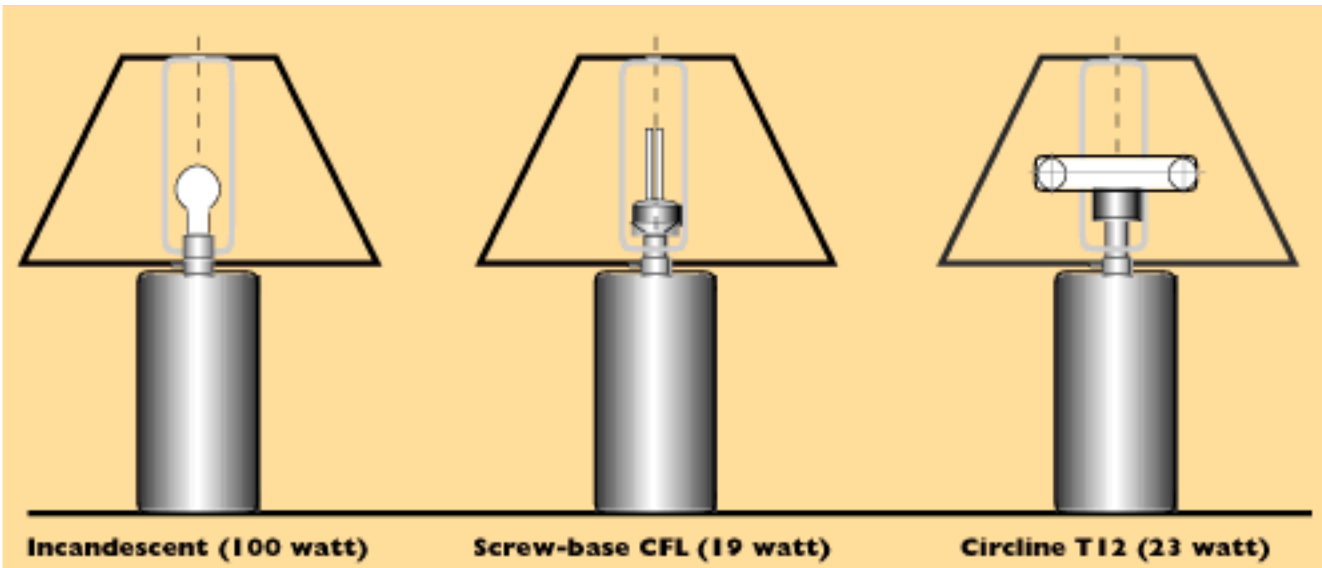


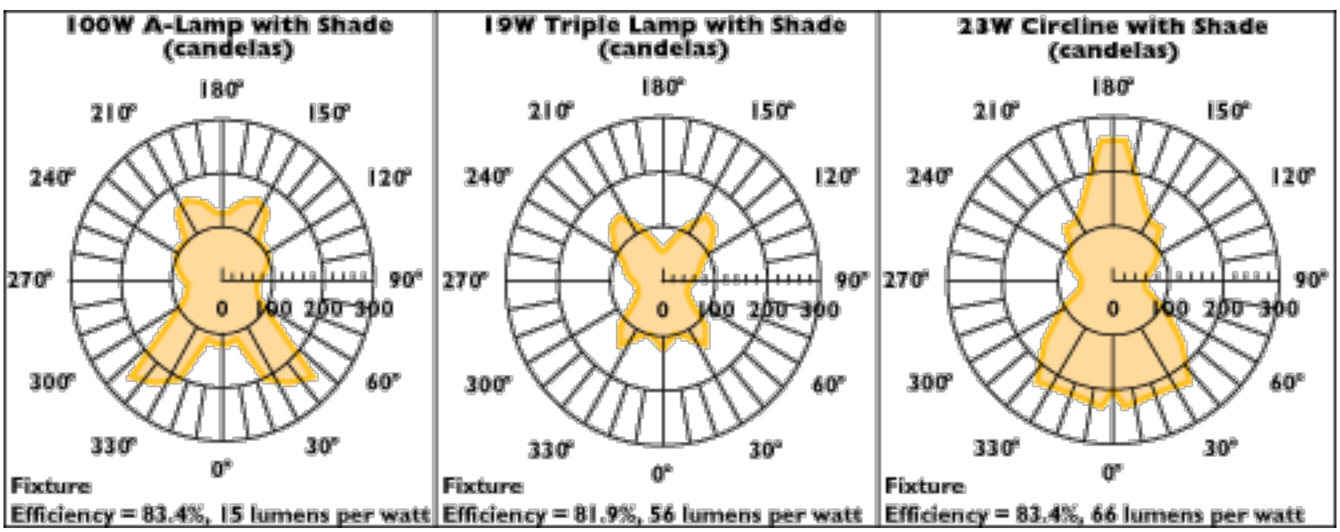
Lighting Group researcher Erik Page stands next to the new goniophotometer, shown in a multiple-exposure photo that represents a complete sensor sweep around a table lamp. The lamp is seen reflected in a mirror mounted on a swing arm, aimed at a photocell used for data acquisition.

The residential lighting sector represents a significant opportunity for energy conservation because it currently uses inefficient incandescent sources almost exclusively. Compact fluorescent lamps (CFLs) have the potential to transform this market by using one-fourth as much power as an incandescent to provide the same amount of light. While technical advances such as triphosphors and electronic ballasts have addressed issues of color rendition, flicker, and hum, CFLs still face significant market barriers, particularly because of their perceived brightness level in traditional fixture applications. When operated in fixtures originally designed for incandescents, a CFL with total light output equal to an incandescent can appear dimmer because of differences in its light distribution. One type of fixture, the common table lamp, is typically operated for more than 3 hours a day, and thus represents a significant opportunity for energy savings.

Researchers in LBNL's Lighting Systems Research Group have been conducting a series of distribution studies on a wide cross-section of CFL fixtures using a newly built apparatus known as a "goniophotometer" (see photograph, above), which can map the amount of light emitted from all angles around a light fixture. The custom-built goniophotometer rotates a large mirror around all angles of a test fixture, allowing light to be reflected from the fixture to a centrally located light meter. The apparatus is fully automated and computer-controlled, enabling researchers to generate highly accurate goniometric light intensity maps of a fixture in less than half an hour. We have collected goniometric data on different light sources (including incandescent bulbs and CFLs of various shapes) operated in standard table-lamp fixtures.

Goniometric results show that CFL orientation plays a significant role in a fixture's perceived brightness. This is illustrated by the chart at right, which shows the candlepower plots of a 100W incandescent, a vertically-oriented 19W triple-tube CFL and a 23W horizontal Circline fluorescent lamp. The plots represent one measurement sweep around the lamp and map out the candlepower distribution in a single vertical plane. Nadir is shown as 0° on the plot and corresponds to readings directly under the lamp, while zenith occurs at 180° and represents readings directly above the fixture. The incandescent lamp in the graph transmits more than 77% of its light straight into the lamp shade (typically in the range from 50° to 140° above nadir). While some of this light is transmitted through or reflected by the shade, much of the light is absorbed, adding to fixture losses. The horizontal Circline lamp sends only 64% of its light into the shade and demonstrates the advantages of focusing output vertically. Horizontally oriented lamps distribute the majority of their flux vertically because of a predominance of horizontal illuminating surfaces. While the incandescent lamp has the larger total bare-lamp light output, the Circline has a much more intense output at the crucial nadir and zenith angles. In effect, fewer total lumens are required to produce sufficient illuminance where it is most needed: at nadir for task lighting and zenith for indirect lighting.





Candlepower plots of incandescent, ordinary CFL, and Circline table lamps

Goniometric results explain why CFLs have traditionally suffered perceived brightness problems. The most common CFLs for table-lamp retrofits have not been horizontal sources that focus flux vertically, but vertical sources that focus flux horizontally. These CFLs direct over 82% of their flux into the shade and suffer associated fixture losses, resulting in a failure to match the lumen output of the incandescent lamps they are intended to replace.

Optimizing fixture geometry and lamp position can significantly increase the efficiency of these CFL fixtures. Ongoing research with the fixture industry seeks to identify and develop efficient source/fixture configurations.

—Erik Page, Michael Siminovitch and Carl Gould

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Energy and Ventilation Research in Highrise Apartments: The Chelsea Public Housing Study

More than 30 million Americans live in multifamily housing. A disproportionate number of them are poor, renters, minority, single parents, and children. While buildings with five or more units account for only 9% of residential energy end-use in the United States, the energy burden—i.e., the percent of household income spent for energy—is several times higher for these households than for single-family households. Historically, multifamily buildings have been the most neglected building sector for retrofit activity in utility and federal programs, but the last ten years have seen impressive advances in improving the energy efficiency of these buildings.

Figure 1. The Margolis Apartments in Chelsea, Massachusetts, was designed in 1973 and is typical of high-rise construction from that period. This USHUD

project is the site of ventilation and infiltration measurements to improve comfort and energy performance.

A new book, *Improving Energy Efficiency in Apartment Buildings*, by John DeCicco, Rick Diamond, Sandy Nolden, and Tom Wilson, funded by the U.S. Department of Energy and the Energy Foundation and to be published by the American Council for an Energy Efficient Economy in early 1996, documents much of this work. It is the result of collaboration by practitioners and researchers active in multifamily retrofit research. One area that continues to block retrofit efforts has been our lack of understanding of how ventilation and infiltration occurs in these buildings. Unlike single-family buildings, where our knowledge of ventilation and infiltration has benefited from such tools as blower doors and tracer gas measurement, the more complex configurations of multifamily buildings challenge our ability to measure and model the air flows and their resulting energy costs.

We have been working for the past two years at the Margolis Apartments (Figure 1), the site of a collaborative venture among DOE, HUD, the Boston Edison Company, and the Chelsea Housing Authority, to demonstrate energy-efficient retrofits of public housing as part of a utility DSM Program.

We made a series of visits to the building in which we performed ventilation and air-leakage measurements using tracer gases and blower doors to determine the performance of the energy-saving retrofits and to determine if adequate levels of ventilation for air quality were being met throughout the building. Following these measurements, we modeled the air flows in this building using the computer simulation program COMIS, which allowed us to understand the complex air flows under different weather conditions.

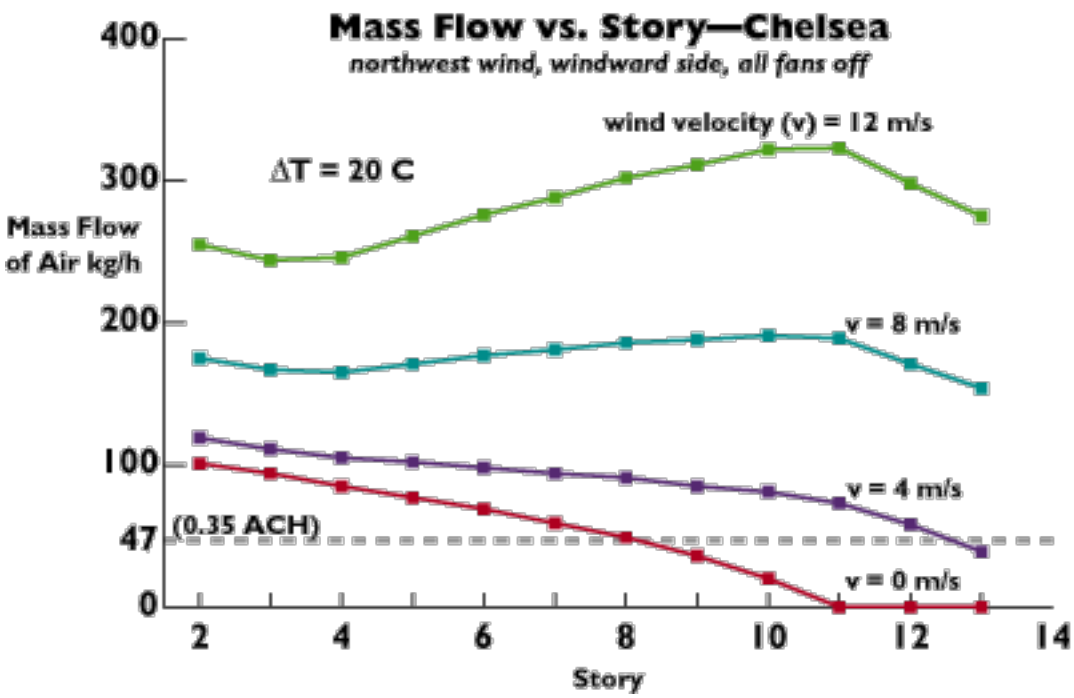

Figure 2. A simulation of the air flows in the Margolis Apartments under different wind speeds. The model shows that even apartments on the windward side of the building are not receiving sufficient outside air (according to ASHRAE Standard 62, see dashed line) during periods of low windspeed.

Our findings to date illuminate the asymmetric nature of the air flows in highrise buildings. Depending on the side of the building and the height above the ground, the unit may be under- or overventilated (Figure 2). We have also been studying the relative importance of the stair towers and elevator shafts and how they interact with both the mechanical and natural ventilation in the building. One disturbing finding is that the designed mechanical ventilation often performs poorly, both in exacting a greater energy penalty and in not providing adequate ventilation.

We plan to continue our study of ventilation in highrises by looking at additional buildings and making recomendations for both retrofits and new construction. One goal of this research is to develop protocols and guidelines for measuring and improving ventilation as efficiently as possible.

—Rick Diamond, Helmut Feustel, and Darryl Dickerhoff

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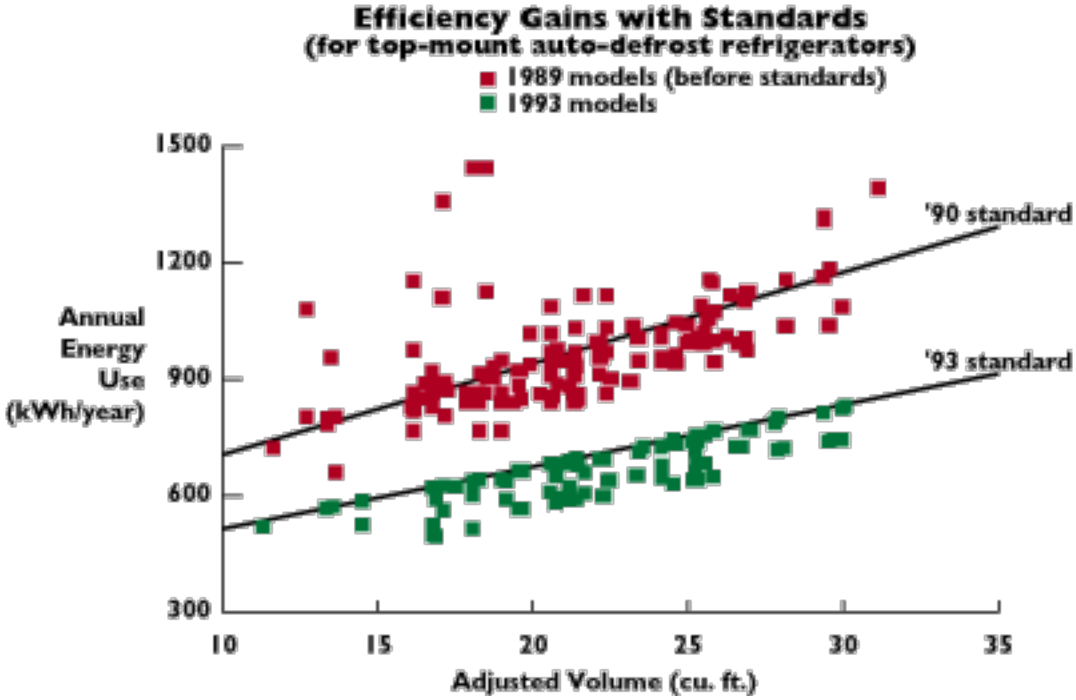
Appliance Efficiency Standards

Part 2 of 2: Policy process and consumer gains



Part 1 of this article (CBS News, Spring 1995) discussed LBNL's role in setting federal appliance efficiency standards and presented an overview of the net national benefits of standards. Here, we examine the broader policy context for appliance standards and consumer benefits.

Policy Context

Appliance efficiency standards provide a minimum requirement for energy efficiency at the point of manufacture (or import). These standards seek to overcome market failures—including price distortions and transaction costs—that have historically given rise to a gap between observed and attainable product efficiencies. In this way, appliance standards complement information programs, utility DSM and other incentive programs, and research on new technologies in improving energy and economic efficiencies.

The process of developing standards has evolved since the 1970s, with increasing participation by manufacturers and other interested parties in the early stages of the analysis of standards updates. This extensive participation promotes a standards process grounded in the best information, including proprietary data. Continued discussion between manufacturers and environmentalists, supported by objective analysis, reduces disagreements and helps resolve or bound uncertainties in the data.

The policy process has been especially inclusive for refrigerators—the product for which standards have been most successful. California set the first standards for refrigerators in the late 1970s. These standards were superseded, however, when national efficiency requirements were set in 1987 affecting refrigerators made in 1990. An updated standard, which became effective in 1993, further improved the efficiency of new refrigerators by 15%. A recent consensus agreement, if enacted into law, will improve refrigerator efficiency by another 25% for 1998 new units. This most recent consensus standard was the result of two years of active negotiation among industry representatives at the Association of Home Appliance Manufacturers, environmental advocates at the Natural Resources Defense Council, efficiency analysts at the American Council for an Energy Efficient Economy, and utility and regulatory representatives from the New York State Energy Office, the California Energy Commission, Pacific Gas and Electric, and Southern California Edison.

In energy terms, an average new auto-defrost refrigerator with top mount freezer in 1972 used about 2000 kWh/yr. A new unit in 1990 used about 900 kWh/yr, and in 1993 about 690. In 1998, a new unit will consume less than 500 kWh/yr.

Consumer Savings

For American consumers, energy-efficiency standards translate into dollar savings every time utility bills come due. Looking at refrigerators alone, the average consumer can expect to save about $140 over the 19-year life of a top-mount auto-defrost refrigerator meeting existing standards versus one only meeting initial federal standards (savings in 1993$ discounted at 7% real). Purchasers of models meeting the 1998 consensus standard can expect further savings. Moreover, market data indicate that refrigerator prices have not increased, and that consumer choice has not been restricted as a result of standards.

Adding savings from other appliances meeting federal efficiency requirements only increases the level of consumer gain. Table 1 gives a snapshot of annual energy consumption and cost savings for a list of typical home appliances. Values in the middle column are for appliance models meeting standards set in the National Appliance Energy Conservation Act of 1987 (NAECA).

Table 1. Annual energy consumption and cost comparison

Appliance	1990 stock average annual energy use (kWh)	1994 new unit annual energy use (kWh)
Refrigerator-freezer	1220	670
Freezer	1010	500
Clothes washer (1)	890	670
Clothes dryer (electric)	930	830
Dishwasher	620	500
Room air conditioner	970	830
Gas water heater	300 therms	270 therms
Gas furnace	610 therms	530 therms
Total Annual	5640 kWh	4000 kWh
Energy Use:	910 therms	800 therms
Total Annual Costs:	$1,090	$880
($0.082/kWh & $0.69/therm)		

(1) Includes electricity consumed in heating water in an electric water heater

The importance of the story told by these figures is that, as time passes, the U.S. stock of appliances will consume far less energy, even as their features and numbers increase. In this way consumers and the environment both benefit from federal appliance efficiency standards.

—Jim McMahon and Steve Pickle

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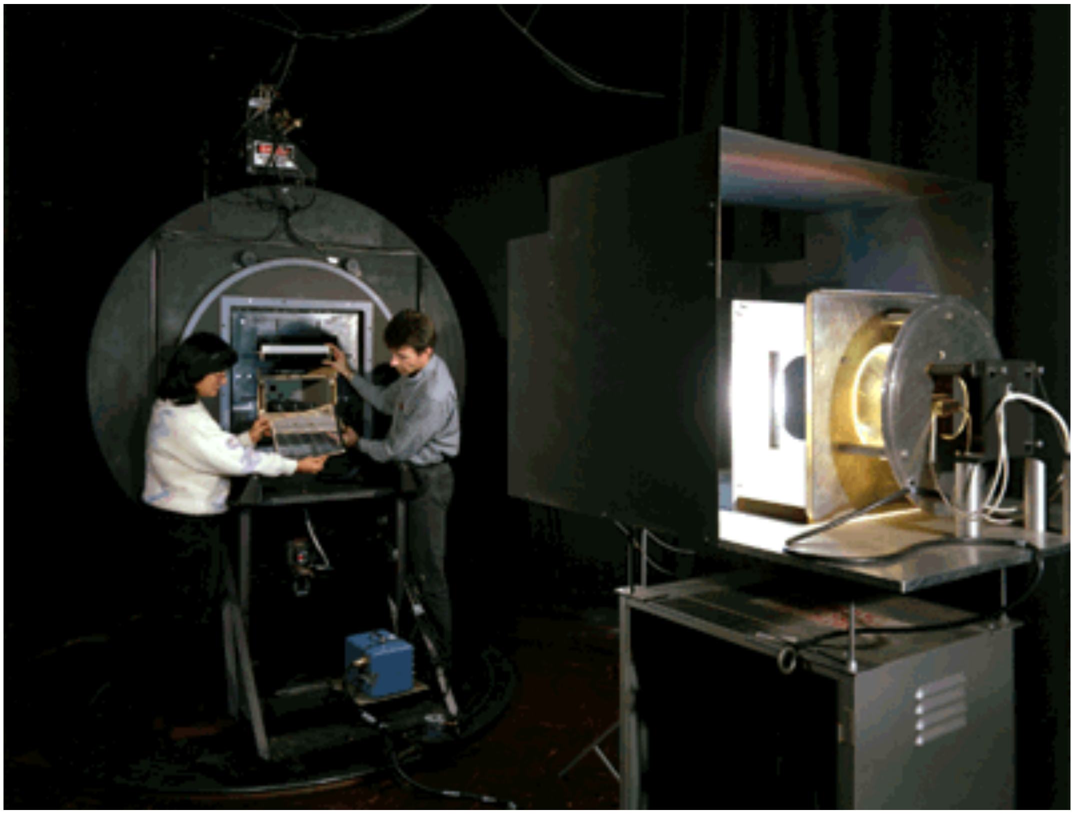
The Bidirectional Radiometric Scanner



Liliana Beltran and Konstantinos Papamichael (Building Technologies Program) prepare a sample for testing in the scanning radiometer.

Saving energy in buildings is increasingly a matter of balancing different efficiency strategies. A building uses less cooling energy during the summer when it has specially coated windows that reduce solar heat gain. But a building with increased daylighting and lighting controls uses less lighting energy throughout the year, suggesting that buildings can harvest significant energy savings with windows that transmit most of their incident visible light. During the winter, solar heat gain through windows also contributes to maintaining a comfortable indoor temperature. But the amount of energy that gets through is determined by the effect of the window plus any shading device, such as a venetian blind—classified as a complex fenestration system.

This complicated interplay of factors requires researchers to have an accurate method of measuring the solar heat gain of any window system, which can include shades, blinds, drapes, and a variety of glazings, tints, coatings, and glass thicknesses. Scientists in the Building Technologies Program developed a solar heat gain scanner to improve research on fenestration systems and to develop a universal rating system for fenestration solar heat gain.

The device, essentially a scanning gonioradiometer, consists of a fixed source of light and a sample mounted on a plane that rotates about a fixed vertical axis relative to the source. The sample also rotates about an axis that is perpendicular to this plane (see photo). An optical collection system is mounted on a semicircular arm that rotates about a vertical axis through the center of the sample. The three elements of this detector system are a collecting mirror, an integrating sphere, and a pair of sensors. Radiation is collected by the mirror and focused onto the entrance of the integrating sphere, which contains a radiometric and a photometric sensor. The sensors collect data on both the wavelength and intensity of radiation coming from the test sample. The data are then amplified and sent to a computer to be recorded.

Joseph Klems and colleagues have been using the scanner to develop a method of calculating solar heat gain that is more reliable than older, calorimeter-based methods. Using the old technique required testing the complex window system in every possible configuration—for example, every possible orientation of its venetian blinds—a prohibitively expensive procedure.

The Center researchers are testing a faster, simpler way to measure solar heat gain. During the 20-minute procedure, the detector system measures the radiation distribution over the outgoing hemisphere by continuously moving over the detector's vertical arc, which in turn steps through the horizontal outgoing angles; when the outgoing scan is completed, the sample plane is rotated 15° and the measurement repeated for another incident angle. For most systems, characterization over six incident angles is sufficient; for very complicated systems it may be necessary to repeat the 20-minute measurement for multiple rotations of the sample within its plane.

This work is sponsored jointly by ASHRAE and the U.S. Department of Energy, with the goal of establishing a standardized method for measuring solar heat gain analogous to the National Fenestration Ratings Council U-value method. The results to date suggest that this radiometer-based approach provides results at least as accurate as and considerably faster than calorimetric-based methods. Although still under development, the scanner facility can be used in collaborative work with outside organizations; when development is completed, the scanner should be available for privately-funded studies.

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Sponsors

Sponsors of research described in this issue include:

- Department of Energy
    - Office of Building Technologies
        - Existing Building Efficiency Research Program
        - DOE-HUD Initiative
        - Building Equipment Division
    - Office of Codes and Standards
    - Office of Energy Research
        - Laboratory Technology Transfer