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The Future of Buildings Research at LBNL

An Interview with Mark Levine, Director of the Environmental Energy Technologies Division

Mark Levine

Mark Levine is the newly appointed Director of Berkeley Lab's Environmental Energy Technologies Division (formerly Energy & Environment). He was the head of the Energy Analysis Program from 1986 until his appointment in March. Levine received a B.S. in chemistry from Princeton, and a doctorate in chemistry from the University of California, Berkeley. Before joining Berkeley Lab in 1978, he was a staff scientist at the Ford Foundation Energy Project, and a senior energy policy analyst at SRI International in Menlo Park, Calif. His current research interests include energy efficiency in China and global energy-demand studies. Levine is on the boards of several organizations, including the American Council for an Energy-Efficient Economy and the Center for Clean Air Policy. He has recently been elected Chairman of the Board of the Center for Resource Solutions, a new nonprofit organization at the Presidio in San Francisco that will promote energy efficiency and renewable energy in developing countries.

Three of EETD's programs-Building Technologies, Energy Analysis and Indoor Environment-focus heavily on buildings research. In the following interview, Levine discusses the future of buildings research in the Division.

R&D activities relating to buildings have been a central focus of the Environmental Energy Technologies Division since its origin in 1973. What role will buildings play during your tenure as Division Director?

I want to build on the Division's 20-year history of leadership in the buildings arena. We've played a central role in the development of advanced energy-efficient windows, electronic ballasts for compact fluorescent lamps, and DOE-2, the de facto standard building energy simulation program. We have also led the development of cost-effective policies to promote energy efficiency in buildings, as well as the creation of market-based programs to achieve the same ends.

In the next ten years, there are many opportunities for us to continue our pre-eminent role. For example, I view the field of advanced computing applications applied to energy in buildings to be an especially exciting and fruitful area. Advanced computing could, through the development of visualization tools for building design or sophisticated computer control systems, dramatically change the way we work in and operate buildings, with significant impacts on the use of energy. An ability to accurately model the flow of air and pollutants in buildings will make possible a significant reduction in health risks from indoor air pollution.

"...I think we have to be leaders in our field to attempt to influence, in a positive way, the directions of research in the country..."

Our electrochromic window research program is a significant area of technology research. Combined with electronic controls to respond to the fluctuations in daylight from the exterior, these windows will result in significant energy savings once they reach the market. There are also good opportunities for us in areas we haven't been involved with yet, such as lighting based on semiconductor technology and developing innovative techniques for producing energy-efficient manufactured housing.

What about the future of the Energy Analysis and Indoor Environment Programs?

The Energy Analysis Program, which I used to lead, will continue to be a vital area. I anticipate that the program's work will continue to exert considerable influence on key decisions in energy and the environment taken by governments and international organizations, including the Intergovernmental Panel on Climate Change. I expect that we will be working more with the World Bank and regional banks in creating new energy-efficiency programs in developing countries. I also hope that the program will be an important presence in new domestic energy-efficiency initiatives, including the development of market-based programs such as Motor Challenge and federal procurement programs. As the United States begins to look again at new ways of promoting energy efficiency, I believe we can play a valuable and creative role in assessing new policy approaches. I am personally very interested in seeing revenue-neutral feebates (fees and rebates) used to promote energy efficiency. I am eager to see the Energy Analysis Program apply many of the tools that we have used to analyze energy in buildings in assessing the energy efficiency of industry, in both domestic and international markets.

Regarding indoor air quality, a large area of opportunity exists in advancing our ability to understand and predict air pollutant flows and deposition in buildings. Because of the work we have already done in modeling and gathering field data, we are in a strong position to develop the leading next-generation computer model. As I suggested earlier, this work could play an important role in helping to diagnose and remediate indoor air-quality problems. The improved productivity from a better indoor environment could save billions of dollars.

How do you plan to address the challenge of adequate funding for buildings-related research in the Division?

The Department of Energy's energy technology research budget has declined from $10 billion to less than $2 billion in the last 15 years. Our biggest challenge will be to try to turn this around. I think we have to be leaders in our field to attempt to influence in a positive way the directions of research in the country. DOE's budget for buildings is our bread and butter. These areas of research are so vital to the country that in the long run, I think we will see them grow.

I see significant opportunities for new funding sources for our buildings work. The state of California, in its new public-interest R&D activities, is one major new source. I am hopeful that we can build a significant program for California. I believe that there is interest in many of our activities in the private sector and I expect we will pursue some ventures internationally. For example, there is considerable interest in research on advanced energy-saving technologies for buildings by several large private companies in Europe and Japan, and we may be able to gain support for our longer-term research efforts from them.

How do you view the future of energy efficiency?

I am extremely excited about the prospects for energy efficiency in the coming decades. There was a great interest in energy efficiency-resulting in our contributing to the national effort by developing new technologies and designing and analyzing policies-from the mid-1970s through the late 1980s. I believe that the efforts to deal with the long-term risk of climate change will likely spur another period of innovation in energy efficiency. If this happens as I expect, I believe that the next fifteen years could surpass the achievements of the earlier period. I can see much more sophisticated and effective technologies, especially based on advanced electronics, playing a major role. And I can foresee new policy and market approaches that will bring the technologies to market more effectively.

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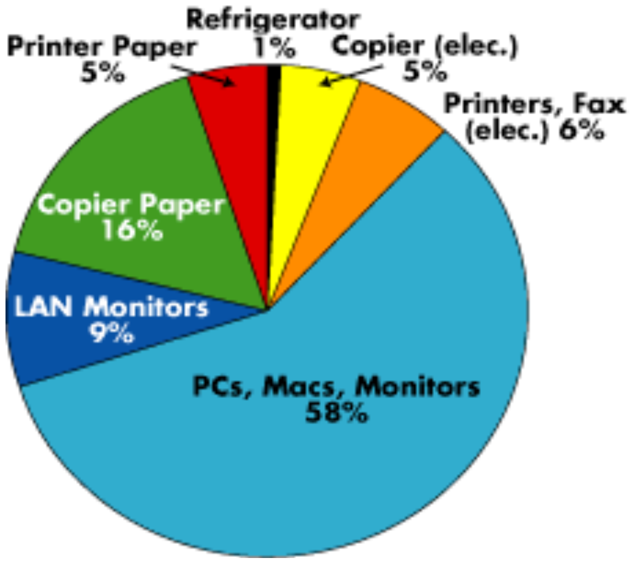
News From the D.C. Office

Energy-Saving Office Equipment, Part 1

More on the DC Office efficiency up-grade: Lighting, Office Equipment: Part 2

Designing an energy-efficient office involves more than "real estate" features, such as an efficient building envelope, windows, lighting, and space conditioning. In today's offices, the other uses of electricity-mainly for computers and other plug-in office equipment, lunchroom appliances, and conference presentation equipment-can use at least as much electricity as office lighting, typically 30 percent of the total office electricity. Careful selection and operation of this office equipment translates into significant energy and cost savings.

In setting up Berkeley Lab's Washington, D.C. Project Office, we paid close attention to the choice of office equipment and kitchen appliances. As a result, we are currently saving about $1,180/year in energy and paper costs (see figure). During the first two years of operation, we have also learned some important practical lessons about achieving real energy savings while maintaining the performance and services that users expect. The following results are based on spot-monitoring our equipment and operating practices.



Annual cost savings from energy efficiency and duplex printing or copying in the D.C. office.

Computers and LANs. Some of the most important choices to be made in any office, from the viewpoint of both energy efficiency and user requirements, involve personal computers and the local area network (LAN). Our requirements included compatibility with both Macintosh and DOS-based machines, easy access to email and files for staff on travel or working at home, and close linkage with the network at our main Berkeley site. A starting point was to specify computers and monitors with a low-power sleep mode (maximum 30 watts), as required by the EPA ENERGY STAR label. For the Macs, we added an external "Power Key" that automatically shut off the computer and monitor at night after the system backup. Rather than replace one of our older monitors (not ENERGY STAR), we used an external control switch to shut it off when there was no keyboard or mouse activity. However, this system worked only with Windows 3.1 and had to be disconnected when we upgraded to Windows 95. Perhaps the single most effective measure was free: shutting off the two LAN monitors except for a few hours a month when they are needed for specific diagnostic or maintenance tasks. Where email is not appropriate, we use desktop LAN-based faxing wherever possible; this saves paper and electricity, and it improves staff productivity. For a fully occupied office suite, the total electricity savings from computers, monitors, and LAN operations amount to about 9970 kWh/year, a savings of 65%.

Other office equipment. We chose a copier that already meets the ENERGY STAR Tier-2 requirements (scheduled to take effect in July 1997), including two-sided copying as the default mode. This copier also shuts off at night after a pre-set delay and offers a choice of six possible low-power "sleep" modes, with different combinations of standby power and recovery time.

Waiting time for the user is further reduced by a people sensor that starts the warm-up process as soon as one approaches the machine. An on-board toner recovery system recycles toner particles that would otherwise be wasted. By far the most important energy-saving feature is default two-sided copying. While power management features save an estimated 720 kWh ($58) per year, the duplex feature saves another 570 kWh of off-site (manufacturing) energy embodied in the paper and reduces annual paper costs by $190.

Similarly, we chose shared LAN printers (a laser and a color inkjet) and an office fax machine that all meet ENERGY STAR requirements. The laser printer also has a duplex printing option that is easily controlled from the desktop. Power-saving sleep settings on the fax and printers save about 815 kWh ($65) per year, with the same amount in additional paper cost savings from duplex printing.

Kitchen appliances. The refrigerator we selected is an 18 ft^3 model with ice maker that uses only 520 kWh, or about 20 percent less than a base-case model meeting the then prevailing (1995) federal efficiency requirements. We have a small storage-type electric water heater, and recently changed the factory settings to lower water delivery temperature by about 20°F. The lower tank temperature reduces standby losses, lowers cooling loads, and eliminates the chance of being burned by hot tap water.

—Jeff Harris and Avis Woods

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More on the DC Office efficiency up-grade: Lighting, Office Equipment: Part 2

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Building Software Tools with Interoperability

Vladimir Bazjanac (left) chairs the open IAI research advisory committee meeting held at San Diego in June. Next to him are Ricardo Goncalves, UNINOVA, and Manfred Koethe, DEC.

Recently, architects and engineers (A&E) have begun to make building design and energy simulation software an indispensable part of their toolbox. Most A&E firms now use commercial, off-the-shelf design assistance programs. An increasing number of building professionals are also using software developed at the Center's Building Technology Program: the whole-building energy simulation program DOE-2 to design more energy-efficient structures, RADIANCE for simulating lighting designs, and WINDOW for calculating the thermal performance of window systems. A number of other energy-related programs for buildings are also on the market. However, all of these face a barrier to wider distribution: their inability to exchange data easily. Each program defines a building differently. To use building data generated by one program in another, the user has to re-create the building specifications in a new data format-a time-consuming process.

A new organization, the International Alliance for Interoperability (IAI), is working to change this. "The aim of the IAI is to create an environment of interoperability for building software tools," says Vladimir Bazjanac, a scientist in the Center's Building Technologies Program who has been involved with IAI since its early days. "We are working to establish a standard data model of a building which can serve as common ground for the exchange of information among all parties involved in the conception, design, construction, operation and use of the building."

To accomplish this, the IAI is developing a standard object-oriented model of buildings. IAI members include the companies and institutions that develop and distribute major building design and energy simulation software programs, and they are working to adapt their software to comply with this standard. The IAI's standard data model is called Industry Foundation Classes (IFCs). By incorporating IFCs into their own software, design software manufacturers are giving their products a common data format that will allow users of different programs to exchange information easily.

Among the IAI's 400 members are the major CAD vendors: Autodesk (AutoCAD), Bentley (Microstation TriForma), and Nemetschek (Allplan FT). Berkeley Lab, through Building Technologies Program Head Steve Selkowitz, Bazjanac, and others, was one of the 11 founding members of the IAI. The Pacific Northwest National Laboratory, the General Services Administration, the Department of Defense and the Department of Energy, through the national labs, are also participants. Selkowitz is on the Board of Directors of IAI's North American chapter.

The Center's Building Technologies Program became involved in 1994, when Autodesk began working with other software manufacturers to address the interoperability problem. Another founding member, Honeywell, approached Selkowitz, proposing a partnership to develop components of the software that would demonstrate the value of the IFC concept. After the demo was judged a success at the 1995 Architecture Engineering Construction Systems Show in Atlanta, the founding members reformulated the IAI as a non-profit, open consortium which now has 400 members organized in six chapters around the world.

Design software manufacturers are giving their products a common data format that will allow users of different programs to exchange information easily.

Working with their industrial partners, programmers at Berkeley Lab meet to write an interface to building simulation programs developed here, including DOE-2 and RADIANCE, so that they are IFC-compliant. Then it will be possible to take the description of a building designed using AutoCAD, for example, transfer it to DOE-2, and test the design's energy efficiency. "All of our simulation tools depend heavily on the description of a building's geometry," says Bazjanac, "and 80 percent of the simulation effort is describing the input. Thus IFCs could save us a lot of time and make it possible for an energy consultant to do the work for a lot less money. Also, these tools can improve the accuracy of the simulation by eliminating human error from the process of translating the building description."

IAI has released Version 1.0 of IFC, which contains the building geometry model; the three most widely used commercial CAD programs are in the process of becoming IFC-compliant. The IAI plans to release Version 2.0 later this year. Through regular releases, IAI expects eventually to bring all new software into compliance as it appears on the market.

—Allan Chen

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Visit the IAI Web site.

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

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Improved Productivity and Health from Better Indoor Environments

Recently completed analyses suggest that improving buildings and indoor environments could reduce health-care costs and sick leave and increase worker performance, resulting in an estimated productivity gain of $30 to $150 billion annually.

The research literature provides strong evidence that characteristics of buildings and their indoor environments influence the prevalence of several adverse health effects. These include communicable respiratory disease (e.g., common colds and influenza), allergy and asthma symptoms, and acute sick building syndrome (SBS) symptoms such as headaches, and irritation of the eyes, nose, throat, and skin. For example, in six studies, the number of respiratory illnesses in building occupants varied by a factor of 1.2 to 2.0 as a function of building characteristics such as rate of ventilation with outside air, type of ventilation system, and occupant density (see table). Allergy and asthma symptoms are often a consequence of indoor exposure to allergens that may originate indoors or outdoors. Several methods can be employed to reduce allergen exposures. Changeable building factors such as ventilation rates, indoor pollutant concentrations, and quality of building cleaning can influence the frequency and severity of SBS symptoms. In addition to influencing health, research suggests that the indoor environment, especially temperature and lighting, can affect worker performance directly by a fraction of a percent to a few percent.

We estimated the costs of the building-influenced adverse health effects from statistical data and published papers. The annual (1993) health-care costs for acute respiratory infections are about $30 billion. These respiratory infections result in about $35 billion in annual sick leave plus restricted activity at work. The health-care costs and productivity decreases from allergies and asthma are about $13 billion per year. Productivity losses from SBS symptoms are quite uncertain but were estimated to be around 2 percent among office workers, costing an estimated $50 billion annually.

Field studies of respiratory disease as a function of building characteristics.

Setting	Populations Compared	Health Outcome	Results
U.S. Army Barracks	Residents of modern (low-ventilation) vs. older barracks	Respiratory illness with fever	50% higher incidence in modern barracks
Finnish Office	Workers with one or more roommates vs. no roommates	Common cold	20% more colds with roommates
Antarctic Station	Residents of smaller vs. larger quarters	Respiratory illness	100% more illness in smaller quarters
NY state schools	Fan-ventilated vs. window-ventilated classrooms	Respiratory illness, absence	70% more illness, 18% more absence in fan-ventilated rooms
Gulf War troops	Troops housed vs. never housed in different types of buildings	Symptoms of respiratory illness	Significantly more symptoms in air-conditioned building
U.S. jail	> 7.5 m^2 vs. < 7.5 m^2 space per person and high vs. low CO_2	Pneumococcal disease	Significantly higher incidence if < 7.5 m^2; 95% higher incidence in high-CO_2 group

The most difficult step in the analysis was to estimate the percentage decrease in adverse health effects and the percentage of direct improvements in productivity that could be obtained by improving indoor environments. These estimates were based in part on the strength of reported associations between health effects and indoor environmental factors. The estimates also reflected the degree to which it is practical to improve relevant indoor environmental conditions such as ventilation rate and pollutant concentrations. Based on these and other considerations, we estimated the potential decreases in adverse health effects from improvements in indoor environments to be 10 to 30 percent for infectious respiratory disease, and allergy and asthma symptoms and 20 to 50 percent for SBS symptoms. The potential direct increase in office workers' performance was estimated to range between 0.5 and 5 percent. For the U.S., the corresponding annual health-care savings plus productivity gains are $6 to $19 billion from reduced respiratory disease, $1 to $4 billion from reduced allergies and asthma, $10 to $20 billion from reduced SBS symptoms, and $12 to $125 billion from direct improvements in worker performance that are unrelated to health.

Because worker salaries exceed building energy, maintenance, and annualized construction costs by a large factor, the cost-effectiveness of improvements in indoor environments will be high even when the percentage improvements in health and productivity are small. The costs of increasing ventilation and improving air filtration in a large office building were estimated and then compared to the value of projected health and productivity benefits. The resulting benefit-to-cost ratios were very high, approximately 50 to 1 and 20 to 1 for increased ventilation and improved filtration respectively.

Very strong evidence that better indoor environments can cost-effectively increase health and productivity would justify changes in building codes and in company and institutional policies related to building design, operation, and maintenance. Available data are not sufficiently specific and compelling to motivate these actions. The existing evidence of potential productivity gains is, however, clearly enough to justify an expanded program of research. A research investment on the order of $10 million per year for five years would answer many of the key questions. The total cost of this multiyear program of research would be only 0.2 percent of the most conservative estimate of annual productivity gains from improved indoor environments.

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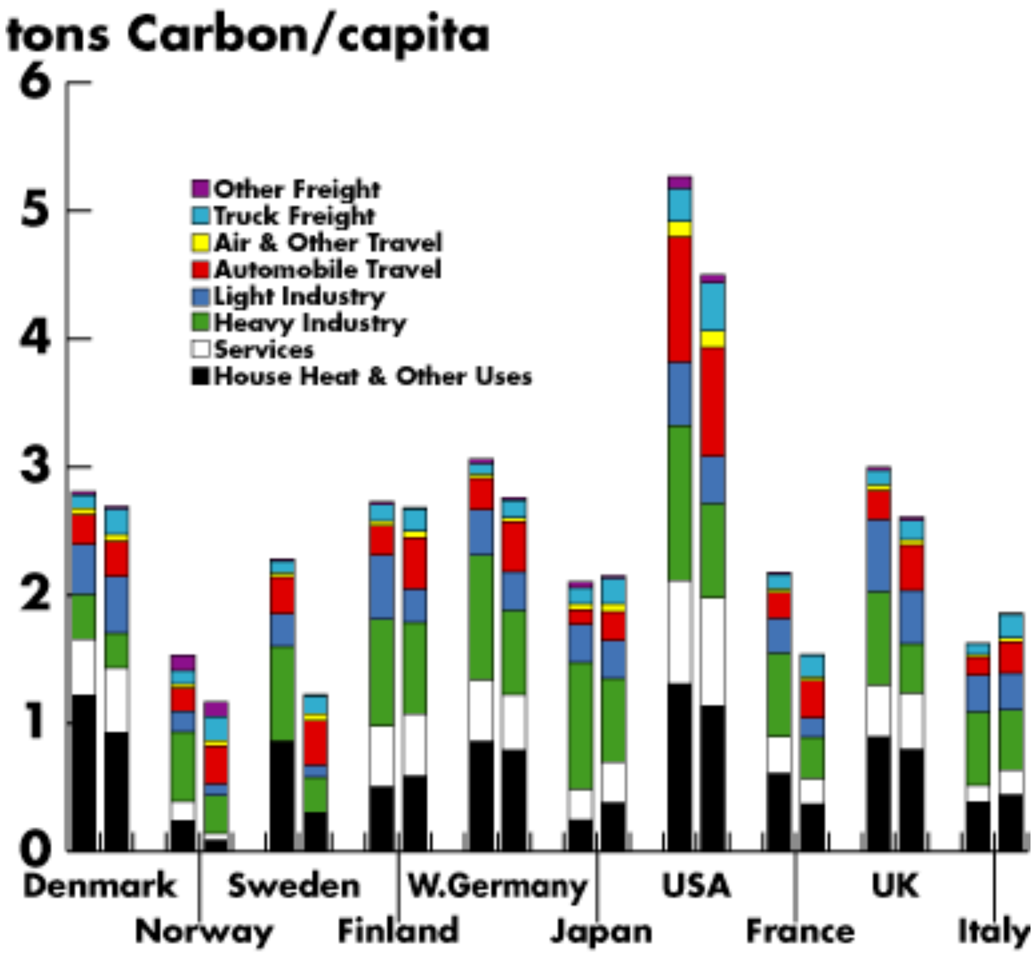
Carbon Dioxide Emissions from Industrialized Countries

Extended discussion here



Carbon emissions per capita 1973 vs. 1991 by major end use. (Denmark comparison is 1972 and 1991)

With the third Conference of the Parties (COP-3) in Kyoto approaching, there is a great deal of excitement over policies designed to reduce future carbon dioxide (CO_2) emissions from fossil fuels. At COP-3, more than 130 nations will meet to create legally binding targets for CO_2 reductions. Accordingly, we have analyzed the patterns of emissions arising from the end uses of energy (and electricity production) in ten industrialized countries, with surprising and, in some cases, worrisome results. The surprise is that emissions in many countries in the early 1990s were lower than in the 1970s in an absolute sense and on a per capita basis; the worry is that factors that reduced emissions in the past are not having the same effect in the mid-1990s.

We traced the evolution of economic output and human activities from 1970 to 1993 and analyzed emissions from nearly three dozen energy uses or economic subsectors. The figure shows our first-stage results, CO_2 emissions by end-use sector or subsector for ten countries in 1973 and 1991, normalized to each country's population. In these calculations, electricity is reported at the annual average rate of CO_2 emissions per unit of electricity delivered to the economy (excluding exports or imports).

The lesson of the figure is that emissions per capita fell in most countries we studied. Even in absolute terms, emissions from the major energy end uses and associated power and heat production fell in most countries. In general, manufacturing showed the most consistent decline relative to activity, with emissions/output (carbon intensity) falling between 25 percent (Denmark) and 67 percent (Sweden). Lower energy intensities were the main reason, but shifts away from solid fuels and oil also aided this decline. Emissions per capita from the residential sector fell in all but two countries, while emissions from services generally declined relative to output, depending on how much space heating intensity fell and how much CO_2 was released in producing electricity.

The personal transportation sector behaved differently. Emissions from travel fell only in the U.S. and Canada, a result of the great decline in fuel use/km for cars. In Japan and Europe, there was increased motorization, modest declines in fuel use/km, and, in most countries, an increase in fuel use per passenger-km. The sum of these factors pushed per capita emissions up.

In all, falling energy intensities and changes in final fuel and utility fuel mix led to lower releases of carbon, while structural changes within sectors and increases in activity raised emissions. But the rate of decline in sectoral energy intensities has slowed in the 1990s; indeed, in the U.S. automobile fuel use/km has stopped falling and even rose slightly after 1991. This means that a key component that restrained or even reduced emissions weakened through the early 1990s.

The analysis also shows where per capita emissions differ from country to country. The most important differentiating factor is gross domestic product (GDP) per capita, followed by structural differences, energy intensity, and fuel mix (including utility fuel mix). The U.S. has a slightly higher-than-average ratio of CO_2 emissions to primary energy consumed; somewhat higher-than-average energy intensities in travel, services, and manufacturing; and above all, larger homes and more driving per capita, which account for higher emissions there.

These findings raise important issues for the Kyoto meeting. Should countries with higher-than-average GDP growth rates be expected to cut their emissions/GDP more than those with lower growth? Do past reductions in emissions that cannot be repeated easily (such as big reductions in fossil fuel use for electricity generation or very great cuts in the energy intensity of space heating) be taken into account in the discussion of future restraint or reductions? Should differences in emissions that arise because of climate, house size, or geography be subject to negotiation?

Reducing energy intensities by improving energy efficiencies is crucial to further emissions cuts. Now that most of the energy-efficiency programs of the 1980s have run their course and real energy prices are for the most part stable or falling, it is no surprise that the rate of intensity reduction has fallen. Just what combination of taxation, efficiency programs, and new technology will spark significant restraint or reductions in the face of continued economic growth continues to vex experts.

Extended discussion here

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This work is supported by the DOE's, Office of Building Technologies, State and Community Programs; and the Environmental Protection Agency, Climate Change Branch.

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A-Team Report

Multifamily Ventilation Guide

Multifamily ventilation experts meeting in Boston discuss ventilation strategies in apartment buildings. Photo credit: Larry Kinney

How do you use diagnostic equipment such as blower doors and pressure sensors to measure air flows in high-rise apartment buildings? What about low-rise buildings? What is adequate ventilation and how do you ensure it happens? What do we know about ventilation in apartment buildings, what do we need to know, and how do we put it into practice?

These were some of the questions tackled by a group of experts at a workshop organized by members of the Center's Applications Team in Boston on ventilation in apartment buildings. Sponsored by DOE's Rebuild America program, the November 1996 meeting, titled "Rebuild America Workshop on Ventilation and Infiltration in Apartment Buildings," brought together professionals from the U.S. and Canada. They spent three days discussing, debating, and trying to resolve conflicting issues in ventilation for multifamily housing. The participants included energy service companies, code officials, representatives of nonprofit organizations, researchers, practitioners, and equipment manufacturers.

Ventilation experts demonstrate a diagnostic technique for determining air flow in multifamily buildings. Photo credit: Larry Kinney

Meeting attendees drafted a preliminary version of a "Ventilation Guide for Apartment Buildings," and A-Team members Helmut Feustel and I edited and expanded this draft into a 75-page document that Rebuild America will publish and distribute. In April, the content of the draft was discussed at a session of Affordable Comfort '97 in Chicago titled "Indoor Air Quality in Multis: Fear, Facts, Fiction and the Future." With new insights from the continued discussion of issues in multifamily ventilation at this meeting, we are now revising the draft once again and expect to see it in print later this year.

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