Lawrence Berkeley National Laboratory

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Environmental Energy Technologies Division News

Air Quality Advanced Technologies Building Technologies Energy Analysis Indoor Environment

EETD Study Explores Electricity Use of Office and Network Equipment

How much electricity is used to power information technology in the U.S.? EETD's End-Use Energy Forecasting Group, led by Jonathan Koomey, has released a new study estimating office and network equipment energy use as of the end of 1999. The last major study examining energy consumption by this group of products was also conducted by this group and was published in 1995, just before the explosive growth of the Internet and the Web. The new study, "Electricity Used by Office Equipment and Network Equipment in the U.S.," was coauthored by Kaoru Kawamoto, Jonathan Koomey, Bruce Nordman, Richard Brown, Mary Ann Piette, and Alan Meier, all of Berkeley Lab.

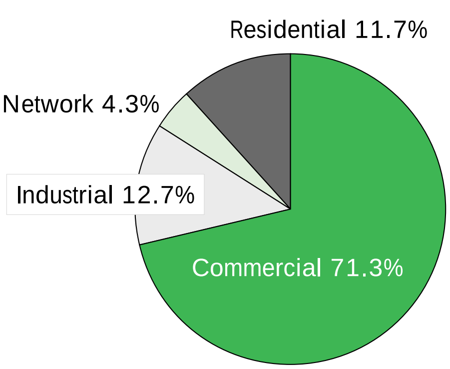
The EETD team divided office equipment into 11 types. For each type, they estimated the annual energy consumption for residential, commercial, and industrial use by combining estimates of stock, power requirements, usage, and saturation of power-management technology. They also estimated annual energy consumption for six types of network equipment.

Table 1. Best estimate of annual electricity used by U.S. office equipment in 1999, TWh/year.

Equipment Type	Residential	Commercial	Industrial	Total
Portable Computer	0.14	0.13	0.02	0.29
Desktop Computer	2.67	10.21	1.46	14.34
Server	0	1.60	0.23	1.83
Minicomputer	0	8.86	2.95	11.81
Mainframe	0	5.62	0.63	6.25
Terminal	0	1.83	0.61	2.44
Display	3.13	9.82	1.40	14.35
Laser Printer	0.10	5.36	0.77	6.23
Inkjet/Dot Printer	1.10	1.56	0.22	2.88
Copier	1.10	5.71	0.82	7.63
Fax	0.44	2.26	0.32	3.02
Total	8.7	53	9.4	71

The latest analysis shows that the total electricity used by office and network equipment is about 74 TeraWatt-hours (TWh) per year, about two percent of the total electricity use in the U.S. More than 70 percent of this total is used by office equipment in the commercial sector. Network equipment uses less than five percent of the total electricity consumed by office and network devices, or about 3 TWh. Power-management features found on many devices including computers, printers, and fax machines currently save about 23 TWh/year. Complete saturation and proper functioning of power management would save an additional 17 TWh/year, and shutting down all equipment not required to operate at night would save an additional 7 TWh/year beyond this. Table 1 summarizes the results for the 11 categories of office equipment, and Table 2 for network equipment.

Figure 1. Percentage of total annual office and network equipment electricity use (74 TWh) attributable to each sector at the end of 1999.



Results Challenge Current Thinking

In 1999, Mark P. Mills published a report for the Greening Earth Society, "The Internet Begins with Coal" (summarized in an article in *Forbes* magazine), that attempted to calculate the "Internet-related" portion of electricity use. The Mills study differs in a

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

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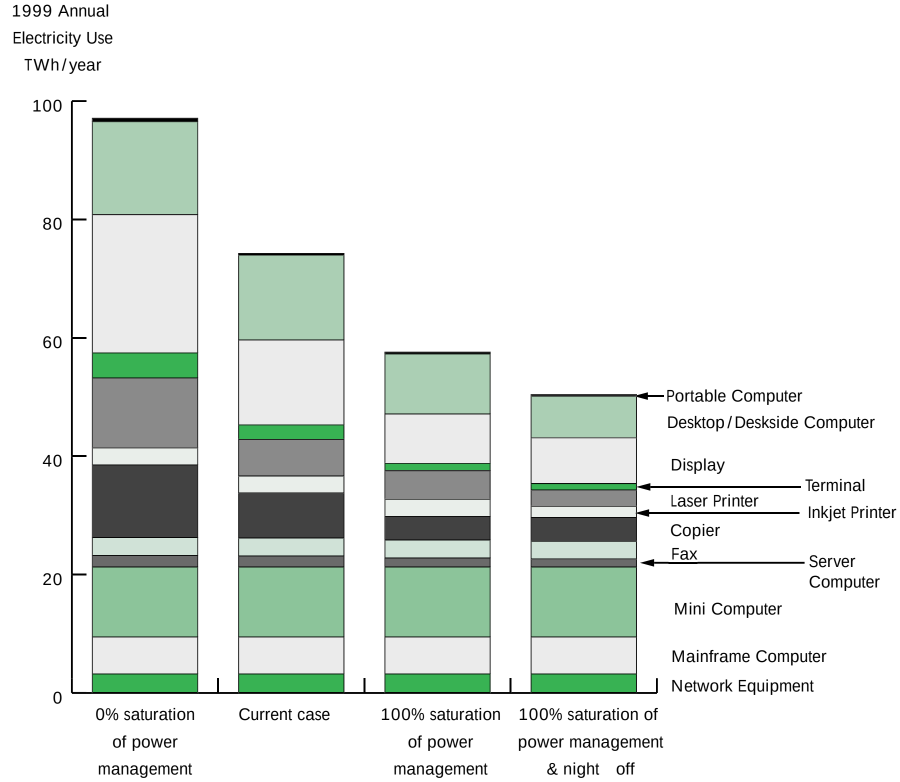
number of ways from the EETD study. One significant difference is its attempt to isolate the electricity use associated with just the Internet, not the total electricity use of office equipment such as PCs and laptops which may or may not be connected to the Internet.

The Mills report claimed that electricity use associated just with the Internet totaled about 8 percent of all U.S. electricity use in 1998 and that it would grow to half of all electricity use in the next two decades. The EETD research team examined the assumptions and conclusions of the Mills report in a technical memorandum (LBNL-44698), and raised a number of questions about its methodology and starting assumptions. One of the questions focused on possible overestimates of the power used by particular kinds of equipment. Mills assumes, for example, that the active power of a personal computer plus monitor is 1000 W, when the measured data for a Pentium III PC with a 17" monitor show total active power use of 135 W. Of course, most PCs and monitors bear the ENERGY STAR label, which further reduces the power use when

Figure 2. Effect of power management on office and network equipment electricity use.



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Lawrence Berkeley National Laboratory

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 laboratories, LBNL is located in the hills above the campus of the University of California, Berkeley.

With more than 4,000 employees, LBNL'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, LBNL has had nine Nobel laureates. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of more than 300 and a budget of $36 million.

Table 2. Best estimate of annual electricity use for network equipment in 1999 (TWh/year).

	Equipment Type	Annual Energy Use
Wide-Area Network (WAN)	Router	0.05
	Switch	0.24
Local-Area Network (LAN)	Router	0.68
	Switch	1.31
	Access Device	0.29
	Hub	0.65
Total		3.2

the computer is in standby mode.

The EETD group concluded that Mills significantly overestimated electricity use, in some cases by more than an order of magnitude. Adjusting the Mills estimates to reflect measured data and more accurate assumptions reduced Mills' overall estimate of total Internet-related electricity use by about a factor of eight. "The explosive growth in electricity demand that Mills alleges simply does not show up in the data, either at the micro level as estimated for each type of equipment, or at the macro level as measured by aggregate statistics on total electricity use," says Koomey. Various other researchers, including Jay Hakes, formerly of the Department of Energy's Energy Information Administration, the Rocky Mountain Institute's Amory Lovins, and Joseph Romm, Executive Director of the Center for Energy and Climate Solutions, have also raised serious questions about the Mills study's methodologies and results. Beyond estimating the direct energy use of office and network equipment, Koomey's group is beginning to assess the indirect effects of the Internet on resource use in the U.S. economy. These effects include structural changes (where new institutional arrangements and technological capabilities become possible because of the Internet) and substitution effects (where the new technologies substitute for established energy uses). An example of a substitution effect would be the use of Internet shopping in place of routine trips to the grocery store or the mall, which might reduce personal transportation energy use. A structural change scenario might involve a decline in brick-and-mortar retail stores in favor of warehousing of retail goods for direct home delivery.

The End-Use Energy Forecasting Group is currently analyzing energy use of emerging technologies such as Web phones, handheld computers, and Internet terminals, which are not currently included in the Berkeley Lab estimates.

—Allan Chen

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To download copies of EETD papers mentioned in this article, go to: http://enduse.lbl.gov/Projects/InfoTech.html

The Web site of the Network for Energy, Environment, Efficiency, and the Information Economy is: http://n4e.lbl.gov/

EETD Researchers Form Network to Study Energy Use, Environmental Impacts of Information Technology

EETD researchers are studying the energy use and environmental impacts of PCs, networks, and other technologies of the new economy. They are doing this work with the primary tool of the new economy—the Internet—in collaboration with researchers at universities and private corporations. The Network for Energy, Environment, Efficiency, and the Information Economy (N4E) is the brainchild of Environmental Energy Technologies Division scientist Jonathan Koomey, head of a research group that studies the energy consumption of end-use technologies such as office equipment and household appliances.

"N4E conducts research on the physical aspects of information technology, focusing on resource flows, energy use, and environmental impacts associated with computing and network equipment," says Koomey. "We are tracking equipment sales, materials use and reuse, energy use, and emissions. We also estimate stocks of equipment based on lifetimes and survey data.

N4E also operates a discussion forum on its Web site, where analysts can post questions and receive responses from other experts in the field."

According to Koomey, this kind of information can help answer questions about the direct effect of the explosion in computing and communications technologies on electricity use in the U.S., and the net environmental effects of telecommuting and Web-based commerce.

Research members from universities and independent research organizations compile data and conduct technical analysis related to resource flows in the information economy. They gain access to the network's expertise and data, in exchange for contributing their own. Current research partners include scientists at the University of California at Berkeley, Carnegie-Mellon University, MIT, and AT&T.

"N4E is expanding its research and actively recruiting new members for its network of affiliated researchers," says Koomey. "Research affiliates contribute data, in-kind support, and technical expertise, in exchange for access to the most current research results as they emerge." To become a member, go to the group's Web site at http://n4e.lbl.gov/ and sign up (it's free).

Berkeley Lab's focus in N4E is on the direct energy and resource use of the information economy. More information is posted at http://enduse.lbl.gov/Projects/InfoTech.html. Ongoing research efforts among other N4E members include green design and manufacturing in industries such as electronics, computers, aerospace, cars, and construction; environmental implications of telecommunications services, computer recycling, environmentally conscious engineering, product and process design; and manufacturing and architecture.

—Allan Chen

In Memoriam—Joan Daisey

Dr. Joan Daisey passed away on February 29 after a long illness. This article is written by Dr. Rich Sextro, Dr. Daisey's long-term colleague and friend in EETD's Indoor Environment Department.

Joan Daisey's career as a chemist and atmospheric scientist took her from teaching undergraduate chemistry at Mount Saint Mary's College in New York state to, first, New York University Medical Center and then to a distinguished tenure at Berkeley Lab. During this 30-year period, Joan made an important difference. Following her death on February 29, 2000, many of the tributes and remembrances from colleagues and friends emphasized not only the exemplary quality of her science and leadership, but the gift of her personality and the quality of the relationships she formed. She was a mentor to many—students, postdocs, and young scientists—and was a much-admired role model for women in science. Joan was also a good friend to many of her colleagues and associates.

After receiving a Ph.D. in physical chemistry from Seton Hall in 1970, Joan began her teaching career at Mount Saint Mary's. It was during this time Joan developed an interest in airborne particles, especially the role of organic compounds—either as main components of the particles themselves or as sorbates on other aerosol substrates. She moved to NYU to work as a postdoc with Mort Lippmann, giving up a tenure-track teaching position to pursue research. At NYU, she investigated the composition of urban aerosols, identifying N-nitrosamines in the New York City air. She also developed thin-layer/gas chromatographic methods for the analysis of polycyclic aromatic hydrocarbons (PAH) in airborne particulate matter. Joan published more than 40 papers on the organic composition of atmospheric aerosols, including early work on the mutagenicity of some of these species. She was Principal Investigator for the Airborne Toxic Elements and Organic Substances Study, an important and comprehensive study of non-criteria air pollutants. This effort led to several significant papers on chemical composition and mutagenesis published in a book co-edited with Paul Lioy (1).

In collaboration with her long-time colleague and friend, Beverly Cohen, Joan examined the effect of liquid aerosol on exposure of workers to solvent sprays. The resulting paper (2) was one of the first to examine this effect.

One of her best qualities was a willingness to take on new projects and to learn new things. She collaborated with Phil Hopke in an early attempt at doing target transformation factor analysis on some of her ambient monitoring data from New York City. Although this effort didn't work out as planned, she came away with important insights into the methodology and mathematics that would lead to other, more successful applications of factor analytical methods. As another example of her willingness to take on new challenges—happily for her colleagues at Berkeley and for the larger field of indoor air quality—she came to Berkeley Lab in 1986 to lead the indoor air chemistry group. While there are a number of similarities between ambient and indoor air contaminants, there are also significant differences. Joan was quick to recognize these differences and successfully incorporated them into her scientific thinking, thus making the transition from "outdoors to indoors."

While all her associates benefited from her guidance, ready availability and wonderful scientific insights, her women colleagues were particular beneficiaries of her mentoring.

Appointed Head of IED

In 1989, Joan was appointed head of the Indoor Environment Department, a position she held until her death. Not only was she able to adopt a new field of study, but she proved to be a very successful leader and expert in the field. Under her guidance and leadership, the department grew to an annual budget of over $6 million and more than 60 staff.

Her research focused on a number of areas. She continued her interest in organic compounds as a constituent of air pollution—in this case, for indoor air contaminants. Working with her Berkeley Lab colleagues she led and contributed to a wide variety of research efforts on organic compounds, ranging from understanding sources of volatile organic compounds (VOC) in indoor air (3) to improved methods of determining phase distributions (4) to interactions among indoor air pollutants (5)

Adapting the science from several key studies of the transport of radon from soil into buildings, Joan helped lead some of the first studies to examine soil-gas transport as a pathway for gas-phase organic contaminants in buildings (6). She also developed an interest in understanding environmental tobacco smoke as a major source of indoor airborne contaminants. Joan and her colleagues developed methods to extract and analyze some of the products of sidestream tobacco smoke, resulting in several key papers (7).

Understanding and quantifying exposures to and risks from indoor air contaminants was another focal point for Joan's research efforts. Again, she found colleagues to work with on problems requiring multidisciplinary efforts. In some cases these studies helped launch the early scientific careers of graduate students and postdocs. As with her other research interests, these covered a wide range of topics, from occupational and public health issues (8) to understanding “sick building syndrome” (9) and, finally, back to outdoor air pollution (10). Overall, her work at Berkeley Lab resulted in more than 30 published journal articles and an equal number of conference contributions and reports.

Joan was a significant role model for many of her colleagues—showing by example how to manage a research enterprise yet remain a strong contributor to many of the scientific projects under her direct guidance. However, an under-recognized contribution was the model she established as a woman in science. She was an early member of—and one of the first women to join—the American Association for Aerosol Research, at a time when few women were even in the field of aerosol research. She was a member of the Board of Directors for five years and served the organization in several capacities. She guided the research of several graduate students, postdocs and young staff members—first at NYU and then at UC Berkeley via Berkeley Lab. While all her associates benefited from her guidance, ready availability, and wonderful scientific insights, her women colleagues were particular beneficiaries of her mentoring.

Science Advisory Board Chair

Finally, no tribute to Joan Daisey's career would be complete without mentioning her service to the Science Advisory Board (SAB) of the U.S. Environmental Protection Agency. First appointed to the SAB in 1986, she was appointed co-chair of the Integrated Human Exposure Committee in 1993 and then chair a year later. Joan served as chair of the SAB's executive committee beginning in 1997 and was reappointed to that position by EPA Administrator Browner to another two-year term in the fall of 1999. During her tenure, the SAB was very active—directly through the Executive Committee and via the various standing committees—resulting in 101 full reports, consultations, commentaries, and letter reports sent to the Agency with Joan's signature. In some cases, these reports and the advice to the Agency contained within them were the products of long and sometimes contentious debates among the scientists providing the advice. Joan led several SAB projects where advice was vigorously offered, including steering the efforts of the SAB's complex Integrated Risk Project.

The words of Don Barnes, staff director of the SAB, perhaps best capture the impact Joan had outside the many printed pages in scientific journals and reports she helped author: “The historical record will have a more difficult time capturing her personality and her impact on people. With clear, sparkling eyes and a quick, ready smile, she possessed a wit sharp enough to prick an overinflated ego, a wisdom kind enough to encourage an overworked colleague, and sense enough to know when to use which.”

—Rich Sextro

(1) Lioy and Daisey, *Toxic Air Pollution, A Comprehensive Study of Non-Criteria Air Pollutants.* Chelsea, MI:Lewis Publishers, 1987.

(2) Malek, Daisey and Cohen, “The effect of aerosol on estimates of inhalation exposure to airborne styrene,” *American Industrial Hygiene Association Journal* 47:524-529, 1986.

(3) Hodgson and Daisey, “Sources and source strengths of volatile organic compounds in a new office building,” *Journal of Air and Waste Management Association,* 41:1461-1468, 1991

(4) Gundel, Lee, Mahanama, Stevens and Daisey, “Direct determination of the phase distributions of semi-volatile polycyclic aromatic hydrocarbons using annular denuders,” *Atmospheric Environment* 29:1719-1733, 1995.

(5) Daisey and Hopke, “Potential for ion-induced nucleation of volatile organic compounds by radon decay in indoor environments,” *Aerosol Science and Technology* 19:80-93, 1993.

(6) Hodgson, Garbesi, Sextro and Daisey, “Soil-gas contamination and entry of volatile organic compounds into a house near a landfill,” *Journal of Air and Waste Management Association* 42:277-283, 1992.

(7) Mahanama and Daisey, “Volatile N-nitrosamines in environmental tobacco smoke: Sampling, analysis, source emission factors and exposure assessment,” *Environmental Science and Technology* 30:1477-1484, 1996.

(8) Watanabe, Bois, Daisey, Auslander and Spear, “Benzene toxicokinetics in humans: Bone marrow exposure to metabolites,” *Journal of Occupational and Environmental Medicine* 51:414-420, 1994)

(9) Ten Brinke, Selvin, Hodgson, Fisk, Mendell, Koshland, and Daisey, “Development of new VOC exposure metrics and their relationship to ‘sick building syndrome’ symptoms,” *Indoor Air* 8:140-152, 1998.

(10) Tsai, Apte and Daisey, “An exploratory analysis of the relationship between mortality and the chemical composition of airborne particulate matter,” *Inhalation Toxicology,* 12:1210-15, 2000).

For more information about EETD's Indoor Environment Department, see: http://eetd.lbl.gov/ied.ied.html Information on the Environmental Protection Agency's Science Advisory Board is available at: www.epa.gov/science1.index.html.

Joan was a significant role model for many of her colleagues—showing by example how to manage a research enterprise yet remain a strong contributor to many of the scientific projects under her direct guidance.

The Fine XAD Sorbent Coating—2000 R&D 100 Award Winner

A new technology developed by EETD's Lara Gundel, fine XAD sorbent coating used in air-sampling devices called diffusion denuders (such as EETD's Integrated Organic Gas and Particle Sampler), has improved the accuracy of sampling of airborne particles and won an R&D 100 award.

Establishing air-quality standards requires accurate measurement of pollutants in the air. But accurate measurement is difficult because of the varying sizes and kinds of particulates—for example, metals from incinerators, toxic compounds from gasoline and diesel fuels, and soot from unburned fuel. Many pollutants also exist in both particle and gas phases, including pesticides and polycyclic aromatic hydrocarbons, which are widely present in the environment from all combustion sources.

Historically, investigators have searched for ways to measure for the partitioning (distribution) of these chemicals between the gas phase and airborne particulate phase. Because of the U.S. Environmental Protection Agency's recent efforts to characterize airborne particles, gas/particle partitioning is receiving an enormous amount of attention in the research and monitoring communities. This is also a public health issue, since gas and particles are deposited differently in the lungs and have different physiological effects.

Accurate, direct methods of measurement have not been possible until recently, when Lara Gundel developed the fine XAD sorbent coating. This coating, applied to the inside surfaces of diffusion denuders (gas strippers), enables such measurement by trapping gas while allowing particles to be collected separately, using sticky resin beads whose pores are small enough to trap molecules of organic gases.

Most phase measurements have been made by trapping solid particles on a filter and then collecting gases from underlying adsorbent beds. However, vaporization and condensation effects from the particles still present on the filter can lead to errors. In diffusion denuders with the fine XAD sorbent coating, the relatively massive solid particles travel straight through. Gas molecules move around inside the tube, but eventually they hit the inner surface and stick. The tube is short enough so the particles stay airborne but long enough for the gas to get trapped. After an air sample is sucked through the denuder, the particle filter is removed. The gas trapped on the resin beads is analyzed, without including any extra vaporization or condensation effects. The particles are also analyzed so that accurate gas/particle distributions result.

Lara Gundel displays a diffusion denuder coated with a fine XAD sorbent that allows accurate gas/particle-phase measurements.

The coating has two essential characteristics that significantly improve on the performance of existing technology. First, because of its submicrometer size distribution, the coating has 1,000 times the available surface (surface-area-to-volume ratio) of conventional macroreticular (highly porous) sorbent polymers. This imparts the advantage of superior mass-transfer speed in trapping (sorbing) organic species from air or water. Second, the tiny particles of the coating are small enough to adhere by themselves to materials such as glass, plastic, metal, and fabric. This ability to adhere results from the molecular attractive (van der Waals) forces between the particles and the molecules at the surfaces of the materials. At this microscopic scale, van der Waals forces are greater than gravity. Absolutely no adhesive substance other than the coating itself is necessary. Even the force of air or liquid flow cannot dislodge the coating. It can therefore be applied to many shapes and varieties of surfaces to trap and concentrate semivolatile organic gases for measuring and/or controlling air pollution.

The availability of this technology has revolutionized monitoring strategies for characterizing ambient particulate matter. Research groups at Environment Canada, including one led by Douglas Lane, and others throughout the United States have employed this sampling technology in studies of semi-volatile organic compounds. Among these are investigations of the atmospheric behavior of dioxins and the contribution of diesel, other vehicle exhausts, and wood smoke to smog formation—all under various weather conditions, in various parts of the country, and at different times of the day or night.

Diffusion denuders with the fine XAD sorbent coating are currently being tested by the U.S. Environmental Protection Agency as part of the effort to characterize pollution particles throughout the country. In addition, this coating will be instrumental in creating new, "active" surfaces with potential applications not only in pollution monitoring, but also in indoor climate control, ventilation, auto-control of buildings, and real-time instruments and sensors. Lane's Environment Canada group collaborated with Berkeley Lab to incorporate the FXADS into air-sampling tests scaled for ambient air sampling.

—Dan Hawks

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More information on the Integrated Organic Gas and Particle Sampler is available at: http://www.lbl.gov/Science-Articles/Archive/gas-particulates.html.
For more information on the R&D 100 Awards, go to http://www.rdmag.com.

This research was supported by the National Heart Lung and Blood Institute, the Department of Energy's ER-LTR Program, the U.S. Environmental Protection Agency, and Environment Canada.

Polymers Take Charge

Most people think of polymers in terms of plastic boxes, moldings, grocery bags, and a host of other common structural uses where the mechanical properties of plastics are tuned for the purpose of support. Think of your lunch box, for example. Polymers are also everywhere in the form of thin films. The paper in this newsletter is coated with polymers designed to enhance the optical quality of what is probably poor quality paper. Another very common use of polymers is in insulation of electrical wire, to prevent the passage of electrical current. Paradoxically, one of the most exciting new uses of polymers is now to conduct electricity.

You might think this is a new development, but the means by which you sense and even understand the words on this page involve an electrical charge moving along or through polymer membranes. All life depends on membranes that interact with charged species, generally called ions, to produce concentration gradients that give rise to the generation of voltages and thus to the action of nerve cells. Many similar membrane processes occur throughout living things that provide for separation of chemicals and generation or supply of energy, in addition to generating electrical signals. In a case of technology imitating life, emerging energy technologies are making use of membranes that conduct current through the passage of either ions or electrons. The most familiar technology today would be fuel cells for electric vehicles, which use remarkable polymer membrane materials that conduct high currents but also stand up to rigorous chemical conditions. Lest you think these are laboratory curiosities, ion exchange membranes are used in the production of caustic soda and chlorine, an activity that pushes several percent of the nation's electricity supply through the membranes. Electrically conducting polymer membranes are therefore a major factor in energy technologies.

Two other technologies that depend on organic membranes are lithium batteries for electric vehicles and electrochromic windows for buildings. As a result of the Division's Advanced Energy Technologies Department (AETD) battery group's participation in the U.S. Advanced Battery Consortium program to develop batteries for electric vehicles, a polymer synthesis and characterization program has been developed. This activity, sponsored in large part by support from 3M and DOE, has helped the Laboratory provide membranes for batteries and fuel cells that use geometries familiar to anyone who visits the produce section. Figure 1 shows a typical jelly-roll configuration for a lithium battery. If this looks a bit like a roll of scotch tape, it's not surprising. The intent is to use technologies developed for other uses to package the batteries. 3M and polymer companies that make rolls of "poly" bags are adept at this. Although electrochromic windows have not yet made a big impact on the market, electrochromic mirrors are now quite common. These devices automatically darken the mirror to avoid glare and are available in vehicles made by Lexus, BMW, and Daimler-Chrysler. The operation of these devices again depends on driving ions through a polymer separator by means of an electric field. Figure 2 shows the principle of these devices. Ions, electrons, and electron holes, the charges, are driven through the membrane by applying an electric field. This results in the production or storage of energy, separation of chemicals, or production of light.

Figure 1. Jelly-roll design for lithium/polymer batteries.

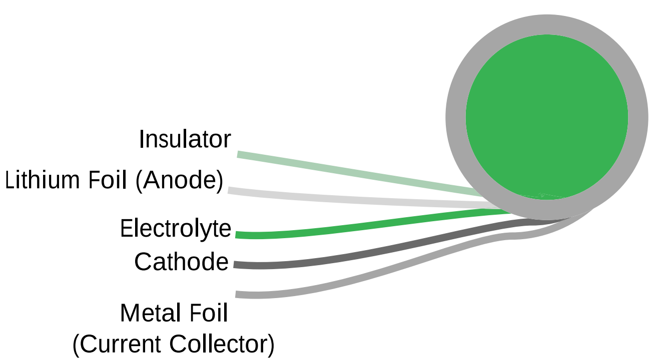
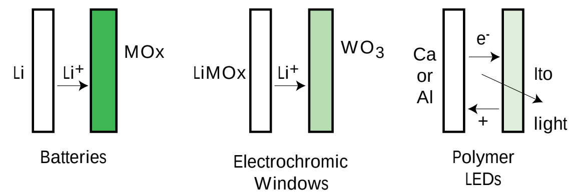


Figure 2. Energy devices that depend on polymer membranes.



This last device is a very exciting development that has occurred only in the last decade and has the potential to revolutionize computer screens, for example. At EETD, Steve Johnson, Head of the Lighting Group, has identified the potential of these devices for area lighting. Soon, polymer membranes will be lighting up rooms in Berkeley Lab's Building 62 as well as helping to store or convert the energy needed to run them.

Other polymer developments in EETD involve research in which polymer membranes are used for biological processes. Working with Dick Fish of the AETD, we are developing membranes that support selective enzymatic chemical reactions that mimic in many ways the biological processes. However, by applying the principles developed in batteries and fuel cells and the chlor-alkali industry, we are moving toward accelerating bioprocesses to rates that make the use of biomass feasible as feedstock for chemicals and fuels. The polymer story has only just begun in EETD, so watch for further articles on these exciting fields.

—John Kerr

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This work is supported by the U.S. Department of Energy, the Advanced Battery Consortium and 3M.

Hotel Survey Illuminates Energy Savings

Lighting fixtures in hotel rooms can contribute greatly to overall building energy use. The average number of fixtures per room is often five or six, and as many as half of the 15 million hotel rooms in the U.S. are still using incandescent lamps. With this in mind, researchers Erik Page and Michael Siminovitch of EETD's Building Technologies Department set out to measure how much energy could be saved with simple changes to hotel-room fixtures.

With cooperation from the Crowne Plaza in Redondo Beach, California, EETD researchers retrofitted 10 guestrooms with novel prototypical fixtures and lighting controls developed by EETD and its industry partners. The prototypes included dedicated compact fluorescent lamp table lamps and torchieres and specially designed lighting controls in the bathrooms (see Figure 2). In its standard mode, the bathroom controller operates as a simple occupancy sensor, turning off the fixture when it senses no movement. The occupancy sensor was set to an extra-long one-hour timeout so it wouldn't turn the light off if a guest was in the shower or bath for an extended period. In its "nightlight" mode, the controller allows the bathroom light to operate at 10% light output for 10 hours, or until the switch is pressed. This feature was designed as an energy-efficient option for people who want a low-level night light in their bathroom.

Lighting-use profile data from all rooms were collected for three months. Loggers recorded the times at which fixtures were turned on and off, and timers detected movement in the room with motion sensors. An analysis of the data shows that of all the fixtures, bathroom lights were operated the most at nearly eight hours a day. Since bathroom fixtures in the Redondo Beach Crown Plaza use four 60W incandescent bulbs, usage for each guestroom averages more than 600 kilowatt-hours per year, for a cost of almost $60 for each room. The next most-used fixture, bedside table lamp, burned an average of almost 5 hours per day and represent nearly 180 kilowatt-hours per year of energy consumed, at an operation cost of more than $12 per table lamp per year.

Data from the loggers, which recorded times of use, showed some surprising results. The periods of high use (mornings between 6 and 10 A.M.) and evenings (after 5:30 P.M.) were not unusual. However no significant dips in use were recorded during typical unoccupied daytime periods (11 A.M. to 5 P.M.), leading researchers to conclude that hotel staff were not instructed to turn off fixtures when leaving the rooms. Here lies another opportunity for considerable energy savings. For example, the long burning hours of the bathroom luminaire and the usage pattern found there make a strong case for occupancy sensors. While the bathroom fixtures were rarely left on for long periods, when they were, it added up to significant energy usage. The bathroom lights were left on longer than two hours only 10% of the time, but these longer burning periods account for over 75% of this fixture's energy consumption. These data point to an obvious need for an occupancy sensor. Because bathrooms are separated from the general room, the occupancy sensors are unlikely to be triggered falsely.

Further study of the energy-saving potential of occupancy sensors, including a more focused study on bathroom controls, is necessary. User acceptance must be factored into the study as well. It's important to configure energy-saving technologies such as occupancy sensors to be as transparent and unnoticeable to the users as possible. Otherwise, a possible barrier is the perception that the technologies will somehow deter from the quality of the guestroom in spite of the energy savings.

—Ted Gartner with Erik Page

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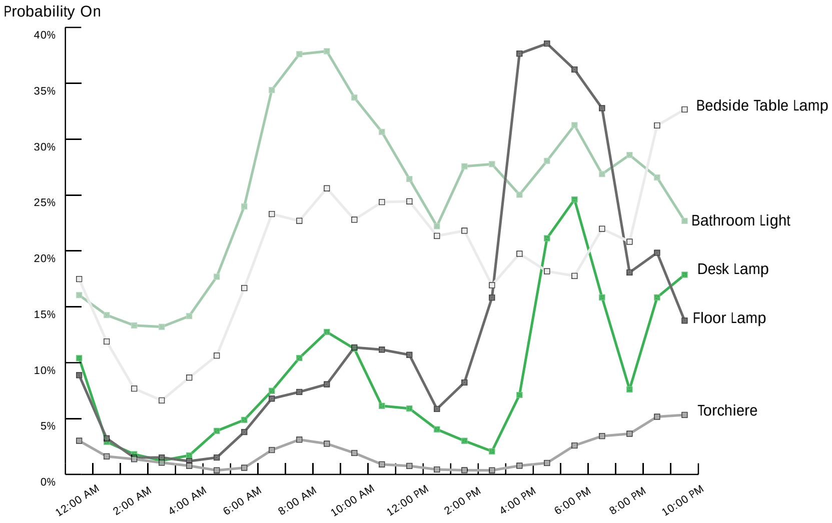
Figure 2. These bathroom controls, co-designed by Berkeley Lab and Wattstopper, feature an occupancy sensor and a low-level "nightlight" feature.

Figure 1. The percentage of lamps on at any given hour for each lamp type. For example, at 10 A.M., 38% of all bathroom lamps are on.



The report is available at: http://eetd.lbl.gov/btp/lsr/projects/hotel/Hotel.htm.

This work was prepared for the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs, Office of Building Equipment of the U.S. Department of Energy.

Research Highlights

Energy-Efficient Fume Hood To Begin Field-Testing Phase

After passing industry standards for safety and containment earlier this year, the energy-efficient high-performance fume hood will begin field testing this summer. Current research has reduced air flow to 30 percent of a typical hood installation. Because less air is flowing through the hood, a building's environmental conditioning system can be downsized, saving both energy and initial costs of construction.

The revolutionary low-flow fume hood technology began development under supervision by Helmut Feustel in 1995. The U.S. Patent and Trademark Office has issued a patent for the technology. The Applications Team's Geoffrey Bell and Dale Sartor are currently leading the research team.

Field testing will take place at Montana State University (MSU) in Bozeman and at the University of California, San Francisco this fall. Both testing phases will run for several months. MSU is working with a national team including Berkeley Lab to design a 21st century academic laboratory that will function as a showcase for environmental stewardship.

The Berkeley Lab high-performance design uses a "push-pull" approach to contain fumes and move air through a hood. Small supply fans, located at the top and bottom of the hood's face, gently push air into the hood and into the user's breathing zone, setting up a "divider" of air. The air divider helps prevent fumes from reaching a user standing in front of the hood and pushes air toward the hood's exhaust outlet. Consequently, the fume hood's exhaust fan can operate at a much lower flow.

To measure the effectiveness of the hood, the research team is testing air flow through the hood by various means. For example, the team has used a schlieren system to help visualize air flow inside the fume hood. The schlieren system enhances natural light diffraction caused by air at different densities, so the diffraction can be seen on camera with temperature differences of as little as 3°F.

The Applications Team is partnering with several industry leaders to disseminate information on the fume-hood technology. The research team is working with Labconco, a prominent fume-hood manufacturer, to enhance the current fume-hood design. The team is also partnering with ATMI, a semiconductor distributor, to apply the containment technology to applications in the microelectronics industry, such as for wet benches.

The low-flow fume hood was showcased at this year's Laboratories for the 21st Century conference, which was held from September 6-8, 2000 in San Francisco, CA. Berkeley Lab was one of the organizers of the conference. Visit the Lab 21 Web site at: http://www.epa.gov/labs21century.

—Annie Tsai

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Beth Shearer (right), director of DOE's Federal Energy Management Program, and Tatiana Muessel, the Project Financing Team Leader, get a demonstration of the energy-efficient fume hood from A-Team's Geoffrey Bell.

Unusual Approaches to Investigating Energy Efficiency

Berkeley Lab researchers sometimes resort to unusual approaches to understand how energy is used and the opportunities to conserve. EETD's Alan Meier has been studying standby power use in appliances—i.e., the energy consumed when appliances are switched off or not performing their primary function. Almost all devices with remote controls (such as TVs, VCRs, and garage-door openers), soft keypads (microwave ovens), or rechargeable batteries (cordless phones) have standby power consumption. Meier estimates that almost 10 percent of the electricity used in California homes is now devoted to standby.

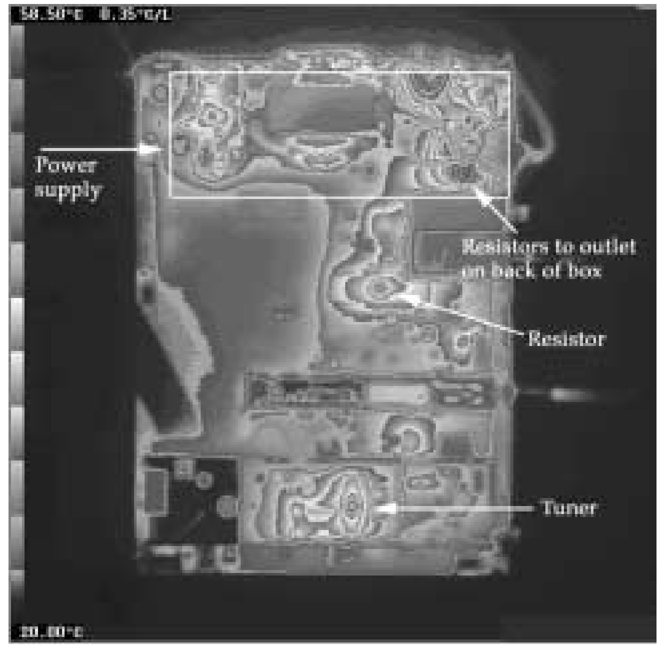
Meier expects that set-top boxes for TVs will be the next important appliance with standby power. These devices receive signals from a cable or satellite and feed them into the TVs. Because some include Internet access, digital hard disks, and other features, they are becoming increasingly complex. One of the curious aspects of set-top boxes is that they use nearly as much power when switched off as when switched on. To learn where the power is going, Meier used infrared photos to determine which components were energized in its various modes. The initial goal was to identify energized components that were not required or where more efficient ones could be substituted. Meier, along with graduate student Stefan Zandelin, photographed the units with an infrared camera. Energized components appeared as bright red objects. The researchers could then determine those component's functions (see figures on following page.)

Meier found many cases where components (such as image-processing chips) were switched on, even when there was no possibility they would be needed. Since some of these chips consume lots of power, there was obvious potential for energy savings. He found that simple redesign of some set-top boxes could cut power consumption by as much as 90 percent without any reduction in services or features.

***Unusual Approaches** (continued)*

Figures. The figure on the left shows electricity consumption (13W) by components of a cable box in the on position. The figure on the right shows the electricity consumption (12W) when the box is "off."

IR photographs by Stefan Zandelin



Investigating Standby Energy Use of New Internet Technology

Dale Sartor of the Applications Team (A-Team) recently upgraded the Internet connection on his home computer from a dial-up to a fast DSL modem. Noticing that the new modem was running hot to the touch, Dale contacted EETD's Alan Meier and Karen Rosen, who have been studying standby power loss in household appliances. They outfitted him with a watt meter and sent him back home.

Sure enough, Dale found that his new equipment had bumped up his "standby" usage by 14 watts, which amounts to a 26% increase in load.

In the mode that many users leave their computer, (i.e., computer on, monitor off), the 67 watts of standby power (seen in Table 1) is about half of the total energy used when both the computer and monitor are on, connected at high speed to the Internet, and in print-ready mode (138 watts on Dale's PC).

The computer monitor remains the largest energy consumer for PC components. When Dale's 17" monitor is on, it consumes up to 60 watts. Many people also use a screen saver. Screen savers don't save energy. In fact, standby energy use of a personal computer with a screen saver almost doubles. On Dale's PC, it increases energy use to 122 watts (from 67 watts).

Fortunately Dale has an ENERGY STAR™ compliant monitor which powers down into a "sleep" mode after a set length of inactivity. His monitor goes to sleep after 15 minutes and the standby losses are reduced to 67 watts (with only 2 watts going to the monitor). Many computers have this feature, but it is often disabled.

The DSL modem and router added 26% to Dale's standby power consumption. Karen Rosen reminds us that even switching "off" the computer may leave the power supply and some internal equipment components "on" (almost 7 watts in Dale's case). Alan Meier's recommendation: If you don't need continuous access, unplug the computer at the power strip to eliminate this waste.

—Karen H. Olson

Table 1. Power consumption of PC in standby mode (watts)

	Plugged in, but "off"	Turned on, but not being used
DSL modem	1.4	7.4
DSL router with firewall	2.7	6.5
Ink jet printer	2.4	7.7
17" monitor	0.7	2 (±1)[1]
Generic PC CPU	0	43 (±3)
Total standby power	7	67

[1]Computer off or in ENERGY STAR™ "sleep" mode

Lab's Energy-Efficiency Research Benefits Shippers of Perishables

An inexpensive advanced insulating material developed by Berkeley Lab researchers has been licensed by San Diego start-up Cargo Technology Inc. for use as a thermal packaging to ship perishable cargo such as seafood, meat, fruit, prepared foods, and pharmaceuticals.

The Cargo Technology product, AirLiner, is an inflatable insulating bag that converts an ordinary corrugated box into a cooler to keep perishables cold and fresh during shipping. AirLiner can be inflated with ordinary air or, to further enhance its thermal performance, with inert gases.

Cargo Technology says the markets for insulated packaging materials for shipping perishable cargo by air are growing and estimated at about $500 million annually. The company says that about 5.5 billion pounds of perishables are shipped by air without refrigeration annually in both the U.S. domestic and import/export markets in nearly 100 million containers.

Currently, most of these shipments are kept cold in expanded polystyrene foam containers. Polystyrene is a 30-year-old technology that is bulky, cumbersome, and prone to cracking and leaking.

AirLiner is produced from plastic films with internal baffles that inhibit heat transfer. AirLiner can be transported to shippers in flat packages, saving warehouse space and delivery expenses for shippers who use foam boxes. About 50 AirLiner bags fit into the same space now as one similarly sized foam container.

EETD researchers developed the gas-filled panels used in AirLiner back in the 1980s as a spin-off of research on superwindows. Superwindows are double- or triple-paned energy-efficient windows with infrared-reflective coatings and inert gases filling spaces between panes for extra insulation.

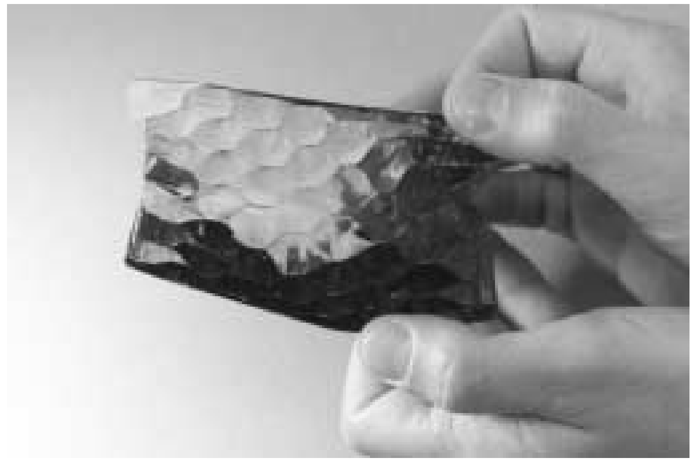
The gas-filled panel technology was developed and patented at Berkeley Lab and was extensively tested at Oak Ridge National Laboratory to confirm its insulating performance. Since then, these panels have been used as thermal insulation in a variety of applications, notably in prototype energy-efficient cars and appliances, and as a potential insulating material in buildings.

Gas-filled panels are made of multiple, honeycombed layers of thin, aluminized plastic filled with a gas, either air or an inert gas: argon, krypton, or xenon. The insulating value of the panel depends on which gas is used as a fill—it ranges from R-5 per inch (air-filled) to R-20 per inch (xenon-filled). By comparison fiberglass insulation for buildings is rated at about R-4 per inch. In 1991, gas-filled panels won the Grand Prize for Home Technology in *Popular Science's* "Best of What's New" awards.

"We are hopeful that this market success will motivate others in the building and appliance field to look again at this promising, high-performance insulation technology," says Stephen Selkowitz, Head of the Lab's Building Technologies Department.

http://gfp.lbl.gov

Figures. The honeycombed layers can be filled with air or gas to produce a superior insulating material.



Clarification

In the Spring 2000 issue of *EETD News*, an article in the Research Highlights section titled "Miscellaneous Electricity Usage Growing" inadvertently omitted EETD's Karen Rosen, primary author of several papers on the subject. The article states that the combined electricity usage of small appliances (TVs, VCRs, audio equipment, etc.) in the "miscellaneous" end-use category often approaches that of the refrigerator, which is typically considered the largest electricity-using appliance in the home. The article further states that most of this energy consumption occurs while these small appliances are not in use.

To put some figures to these assertions, research by EETD's Karen Rosen and Alan Meier has shown that consumer electronics use about one-third of the electricity in the "miscellaneous" end-use category, or about 10 percent of total residential electricity use. Energy used while these systems are not providing the main service for which they were designed adds up to 60 percent of this total, for about six percent of total residential energy use.

For more information, see Rosen, Karen B. and Alan K. Meier. "Energy Use of U.S. Consumer Electronics at the end of the 20th Century," LBNL-46212, in the *Proceedings of the 2nd International Conference on Energy Efficiency in Household Appliances and Lighting.* 27-29 September 2000, Naples, Italy: Association of Italian Energy Economics (Rome).
URL: http://eetd.lbl.gov/EA/Reports/46212/

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Bound paper copies of the entire set of the *Center for Building Science News*, the publication that preceded the *Environmental Energy Technologies Division News,* are now available free to anyone interested while supplies last. Quarterly issues from 1993 through summer 1998 cover energy-efficiency research.
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