Energy Efficiency: Less Means More

Fueling a sustainable future

By JANET RALOFF

How the world fuels its growth is central to many of earth's most critical problems, especially its environmental health. Increasing evidence links fossil fuel emissions to acidifying lakes, dying forests, reduced crop yields and human respiratory disease. "Our energy systems are irrevocably altering the climate by adding 5.4 billion tons of carbon to the atmosphere each year, more than a ton for each person on the planet," notes Christopher Flavin, an energy analyst with the Washington, D.C.-based Worldwatch Institute. "Simply put, an environmentally sound energy strategy is a prerequisite to a sustainable society." And a prerequisite to any environmentally sound energy strategy, he and others argue, must be more efficient use of energy.

Since the Arab oil embargo nearly 15 years ago, a quiet but dramatic revolution in energy conservation has swept the industrialized world, reducing the projected increase in atmospheric pollutants and in large part producing the world oil glut. "The world has saved far more energy [since 1973] through improved efficiency than it has gained from all new sources," Flavin and Alan B. Durning write in a new Worldwatch Institute report, "Building on Success – the Age of Energy Efficiency."

Yet as experts survey prospects for the 21st century, they see an even more dramatic need for saving energy. Energy waste threatens the economic health of societies large and small, industrial and agrarian, socially planned and market driven. Although new energy-conservation technologies loom on the horizon, institutional resistance, inadequate consumer education and old ways of doing business threaten to slow their adoption.

The United States currently spends about 11.2 percent of its gross national product on energy, while Japan spends only about 5 percent. This relative inefficiency in fueling its energy needs costs the United States $220 billion a year, according to Arthur H. Rosenfeld, director of the Center for Building Science at Lawrence Berkeley Laboratory (LBL) in Berkeley, Calif. Moreover, Rosenfeld points out, this cost differential gives the Japanese "about a 5 percent economic edge on everything they sell" – both in the United States and in foreign competition with U.S.-made products.

This is not to downplay recent progress made in the United States in reducing energy use, says Rosenfeld, whose center is renowned for pioneering energy-conserving technologies. It just illustrates that there is room for much improvement.

How much? Energy analyst John O. Blackburn, Duke University's Distinguished Service Professor Emeritus of Economics, says he believes inefficiencies may still account for 50 percent of the energy used in the United States and most Western European countries, somewhat less than 50 percent in Japan, and considerably more than 50 percent in the Soviet Union.

Flavin and Durning offer incentives and guidelines for tackling these inefficiencies in their report. They point out that the energy saved by Western industrialized countries and Japan exceeds the energy used by Africa, Latin America and South Asia combined, and represents the single largest step toward reducing their dependence on oil imports. In fact, Durning says, "we feel it's now possible in most industrialized countries to keep energy consumption level for the foreseeable future" – without sacrificing economic growth.

Just a decade ago, many energy analysts predicted that efficiency improvements of 20 or 30 percent could be achieved only at the expense of wrenching societal change – such as shivering through winters in the dark or abandoning the family automobile. Now, Flavin and Durning report, these improvements have occurred, but largely without notice. Between 1973 and 1985, most Western European nations reduced energy consumption – as measured per dollar of gross national product – by 18 to 20 percent. The United States and Japan saved even more, 23 and 31 percent respectively.

STRATEGIES

One way to discourage waste is to raise energy prices with user taxes – a policy many nations apply to gasoline. Taxes on U.S. gasoline average about 29 cents per gallon – very low by Western European standards. However, U.S. gasoline is taxed only to generate revenues for road construction and maintenance. Durning points out that Denmark directs its $2.93 tax on each gallon at discouraging gas use. And he notes that because Sweden's gasoline tax is inversely related to the price of oil, it provides a steady conservation incentive. As the price of oil declines, the Swedish tax goes up.

Efficiency standards are an alternative where a tax can't be applied, would not motivate effectively, or would hit certain segments of society unfairly. U.S. major-appliance rules, due to go into effect next year, set minimum efficiency limits for new refrigerators, freezers, air conditioners, heat pumps, water heaters, gas ranges, dish washers, clothes washers, furnaces and boilers.

These standards should trim electricity consumption 30.4 terawatt-hours

An improvement of 0.1 mile per gallon in the U.S. automobile fleet would save the equivalent of 20,000 barrels of oil per day — roughly the estimated production rate from drilling proposed in the enviro-mentally sensitive Georges Bank fishing grounds off the eastern United States. The retail cost to achieve the improvement, according to energy analyst Arthur H. Rosenfeld, is estimated to be about $4 per new car.

(trillion watt-hours) by 1995 and reduce peak demand by 12,800 megawatts, according to calculations by Howard Geller, associate director of the Washington, D.C.-based American Council for an Energy Efficient Economy (ACEEE). Electric water heaters, gas water heaters and refrigerator/freezers are expected to account for the biggest savings — about 20 percent each by the year 2000.

Most electric utilities are adopting time-of-day and peak-load pricing as conservation incentives. Large, "base load" coal and nuclear plants tend to produce the cheapest electricity. Because producing small increments above that base load costs more per kilowatt, users who contribute to demand peaks—consuming power around midday or throughout the hottest days in air conditioning season — are often charged more.

Newer to utility markets is least-cost planning. Traditionally, when projections indicated that demand for electricity would outstrip a utility's capacity to supply it, the utility ordered new generating equipment. Today, many states require utilities first to prove that new equipment will cost less than other options — such as investing in efficiency, initiating time-of-day pricing, buying power from independent generators (including wind-power-plant owners) and cogenerating heat and electricity.

Since January 1986, 37 states have taken 61 different actions to explore or promote least-cost electrical planning, according to Nancy Hirsh of the Washington, D.C.-based Energy Conservation Coalition (ECC). A December ECC study found that at least 14 states and the District of Columbia directly encourage utility investments in energy-efficiency programs through least-cost measures.

TECHNOLOGIES HIGH AND LOW

Among other innovative concepts for increasing energy efficiency are:

• *Planting trees:* Stately trees not only shade underlying buildings, but also provide regional evaporative cooling as they transpire. The cooling effect is especially useful in limiting the development of urban "heat islands" — inner-city regions whose asphalt and dark-roofed surfaces serve as unintended heat stores. Heat islands can dramatically increase air-conditioning use. But research by Hashem Akbari, Rosenfeld and colleagues at LBL indicates that planting just three trees near a light-colored home can, when done throughout a community, reduce residential cooling demand on a hot summer day — by 18 percent in Phoenix, Ariz., by 34 percent in Sacramento, Calif., and by 44 percent in Los Angeles.

Shade accounts directly for about a third of the cooling. Evapotranspiration and changing home reflectivity with light-colored roofs and paints play a much greater role. "If you plant three trees about every house in [California's] San Fernando Valley, and whitewash those houses, you can save 2,000 megawatts — or two standard power plants' worth of air conditioning," Rosenfeld told Science News. By providing some thermal shelter in winter, these plantings can offer smaller, but still significant, reductions in heating needs.

A less obvious benefit from cooling with trees (instead of with combustion-generated electricity) is reduced production of carbon dioxide — a "greenhouse" gas that contributes to global warming. In a new draft paper, Rosenfeld, Philip Martien and Leo Rainer of LBL conclude that nationwide residential and commercial tree plantings could save 0.9 quads (10^{14} btu) of utility-generated energy and thereby reduce atmospheric carbon emissions by up to 18 million tons annually. While others have suggested using forests to trap carbon emissions (SN: 4/30/88, p.285), Rosenfeld says that because of the fossil-fuel use they save, "our urban trees are about 10 times as effective as forest trees" in limiting atmospheric carbon dioxide buildup.

• *Superinsulating buildings:* Doubling the normal insulation recommended for buildings and including an airtight liner within the wall increases initial building costs by only 5 percent and pays back those added costs in energy savings within five years, Flavin and Durning report. "Energy for a Sustainable World," a September 1987 report by the Washington, D.C.-based World Resources Institute, describes one commercial version. Built near New York City with 120 square meters of floor space, this home could be heated for about 1,400 kilowatt-hours (kwh) of electricity, according to that report — the annual energy consumption of most U.S. refrigerators.

• *Replacing aging major appliances with more efficient ones:* U.S. refrigerators consume about 7 percent of the nation's electricity, the energy equivalent of about 25 large power plants. New units use considerably less. According to ACEEE's John H. Morrill, a 1972 refrigerator with a top-mounted freezer and automatic defrost typically used, when new, about 2,000 kwh of electricity per year. A similar model sold in 1985 runs on about 1,100 kwh a year. And 27 similar models marketed under nine brand names last year exceeded the best efficiency available only a year earlier. Says Morrill, "If all the households in the U.S. had the most efficient refrigerators currently available, the electricity savings would eliminate the need for about 12 large nuclear power plants." Similar savings are possible with other appliances.

• *Using more efficient lighting:* Currently, 20 to 25 percent of U.S. electricity — about 100 power plants' worth — provides illumination. Fluorescent fixtures using the most efficient ballasts (spark discharge devices) consume 25 to 30 percent less electricity than standard fluorescents, and roughly 75 percent less energy than typical incandescents with the same light output.

Testifying in March before the House Subcommittee on Energy and Power, ACEEE's Geller estimated that enacting pending legislation for U.S. ballast-efficiency standards would save 500 billion kwh of electricity between 1990 and 2010 — about half of which would have been generated from oil and gas. The oil and gas savings alone would be equivalent to 560 million barrels of oil, meaning "the ballast standards can be viewed as a very large oilfield," says Geller.

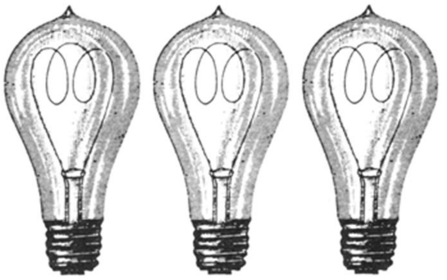
And fluorescent-efficiency increases of another 40 percent or more are on the horizon, says Rudy Verderber at LBL's National Lighting Laboratory. For example, when the mercury plasma discharges in a fluorescent light, it generates invisible ultraviolet radiation. Each ultraviolet photon reaching the tube's phosphor-coated inner surface will cause that coating to emit a photon of visible light. However, using a different phosphor, "it's [theoretically] possible to provide two photons of visible light from each photon of ultraviolet," Verderber says – doubling the lamp's efficiency. Efforts to find such a phosphor should begin soon at his lab.

Already underway are several other programs. One seeks to equalize the ratio of mercury isotopes typically pumped into fluorescent tubes. This will limit photon "entrapment" (absorption) by the overrepresented isotopes, Verderber says, for a 3 to 5 percent increase in efficiency. Far more impressive are the potential gains possible with LBL's new "surface wave" fluorescent lamp. Its higher-frequency ballast – cycling at about 100 million hertz, not the 20,000 hertz typical of today's high-frequency ballasts or 60 hertz of conventional fluorescents – eliminates the need for electrodes. Since these are the primary limit to a fluorescent lamp's life, the new models might last five or more times longer, Verderber says. And because this lamp produces ultraviolet emissions closer to the phosphor coating, far fewer ultraviolet photons are lost to entrapment. The result is a 40 to 50 percent increase in efficiency. Finally, because this design eliminates current limitations on a fluorescent's shape, future models might resemble regular incandescents.

• *Coating windows with infrared reflectors:* Today, a third of the heat in U.S. homes escapes through closed windows. That is because the standard insulated wall has an insulating "R value" of 11, but the typical single pane of glass is a mere R-1. Double-glazed windows, with an R-2 insulating value, can be upgraded to R-4 by coating the inner surface of one pane with an infrared-radiation (heat) reflector, such as tin oxide, and filling the space between the panes with argon gas. Developed at LBL, such windows are commercially available.

But LBL now has experimental "triple-glazed" windows with an insulating value of R-6 to R-10. Its latest models cover the inner surface of each exterior pane with an infrared-reflecting coating and fill the insulating space between each pane with krypton – a gas about 60 percent less conducting than air and twice as insulating as argon. According to LBL's Dariush Arasteh, commercially prepared experimental versions of this window should debut in demonstration homes later this year.

• *Installing power electronics:* Today, most electrical equipment is configured to be either fully on or fully off. Yet most demands on them need only some fraction of full capacity. For example, when a commercial process needs to reduce the flow of a liquid through a pipe, most systems use valves to restrict flow while the pump's motor runs on at full speed. Varying pump speed might save 25 to 40 percent of the energy and accomplish the same thing.



Between 50 and 60 percent of U.S. electricity currently drives electric motors, most of which run at fixed speeds and voltages. Power-electronics devices – from light dimmers to variable-speed drives – can better match electrical devices and appliances to their varying needs, and save energy in the process.

Unfortunately, designers of most offices, industrial processes and residential appliances have failed to keep up with recent advances that have dramatically cut their size, cost, weight, inefficiencies and unreliability, says Ralph J. Ferraro, manager of power electronics control systems for the Palo Alto, Calif.-based Electric Power Research Institute (EPRI). To identify where new generations of such devices might play a role, EPRI founded the Power Electronics Applications Center (PEAC) in Knoxville, Tenn. Now an independent applied-research center, PEAC works with EPRI, universities, national laboratories, manufacturers and trade associations to spur greater use of these energy-saving and productivity-enhancing devices. Only about 10 to 15 percent of U.S. electricity now flows through power-electronics systems, but "it's anticipated that by the turn of the century, some 50 to 60 percent of all U.S. electricity will," Ferraro says.

REDUCING OBSTACLES

These and other technologies indicate room for further energy savings. But potentially formidable social obstacles are holding back adoption of many improvements. For example, while high-efficiency water heaters may cost only slightly more than inefficient ones, many consumers won't buy them because they lack the information needed to calculate how quickly energy savings will pay back the extra cost. Similarly, many of the least-energy-efficient industries (like housing) are fragmented. This makes it hard for them to institutionalize change and to conduct the long research programs that pay off in more energy-efficient materials. Finally, many governments lack the economic and environmental data that might serve as incentives for imposing measures to encourage energy conservation.

Several organizations are working to counter these obstacles. ACEEE, for example, publishes an annual brand-name and model-number list of the most efficient major residential appliances in the United States. It also provides instructions for computing how quickly a more efficient unit will pay back its higher cost.

Researchers and policy analysts have attempted to persuade Congress that increasing federally funded energy-conservation research budgets will pay handsome dividends – especially in areas like housing. For example, Rosenfeld testified last year that federal funding for U.S. energy-conservation projects is declining – from $344 million in 1980 to $162 million in 1987 – despite the many examples of projects whose technologies, once widely adopted, "will yield savings of 1,000-to-1." Initial implementation of some new technologies by the building sector is already yielding energy savings of several billion dollars a year, Rosenfeld says. Within a few decades, he predicts, they will save U.S. energy consumers roughly $100 billion annually.

And finally, a spate of new studies have begun quantifying environmental and economic repercussions of measures affecting energy use. For example, "Money to Burn?," an October 1987 World Resources Institute study by Mark Kosmo, analyzed costs associated with energy subsidies. His data, reflecting measures in 30 countries, forcefully support the axiom that where energy costs more, consumers tend to use it more efficiently. Similarly, "Acid Rain and Electricity Conservation," published last year by ACEEE, says that both the environment and the pocketbook would benefit from saving energy. The report's data came from an analysis of East Central states. Geller, one of the study's authors, believes its findings offer an encouraging message: "Use of emission ceilings, along with the least-cost approach to acid-rain control, could cut energy use for electricity production by 10 to 20 percent, and save states and their consumers tens of billions of dollars."

Although improving energy efficiency lacks the glamour of fusion and space-based solar collectors, Flavin and Durning say, "perhaps no other endeavor is as vital to the goal of fostering sustainable societies." Moreover, the Worldwatch analysts argue, because most energy use carries a high environmental cost, "without improved efficiency, it is only a question of which will collapse first: the global economy or its ecological support systems. With greater energy efficiency, we stand at least a fighting chance" of staving off the collapse of both. □