ACROSS THE BOARD

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THE NEGAWATT REVOLUTION

By Amory B. Lovins

Using existing technology, says this expert, we can save three fourths of all electricity used today.

Ron Perkins's colleagues at Compaq Computer Corporation were incredulous. Perkins, manager of facilities resource development, believed Compaq's next Houston office building could be designed to use a fourth less electricity per square foot than the previous one. "Why make it so hard on yourself?" they asked. "Our designs are already excellent. Savings of 5 or 10 percent would be pushing your luck." But a year later, when construction was completed, the building's use of electricity proved a third less than previous designs, thanks to the new electricity-saving technology that Perkins had harnessed. The payback period on the energy saving equipment was only a few years. Perkins has since designed another building in which he expects to slash electric use by still another fifth.

The innovative equipment that Perkins uses in his buildings–chiefly advanced lighting fixtures, electronic ballasts, high-efficiency lamps, and lighting controls–are part of a flood of astonishingly cheap and powerful electricity-saving techniques. They have the potential to add many tens of billions of dollars a year to business's bottom line.

Some companies are already enjoying the rewards that come from saving electricity. For example, Southwire, the largest independent rod, wire, and cable business in the United States, found itself facing hard times in the early 1980s as the energy-intensive heavy industry was squeezed between market prices and manufacturing costs. The company responded by cutting its total energy use per pound of product by half in eight years. The energy reductions–about a 60 percent savings in gas and 40 percent in electricity–yielded virtually all of the company's profits during the tough years of 1980 to 1986, and may have saved 4,000 jobs at 10 plants in six states. Southwire continues to make further improvements, which still generally pay back investment in fewer than two years.

Even in less energy-intensive industries, savings from energy efficiency can be dramatic. A couple of years ago, a large company had an energy manager at one of its plants who was achieving annual energy savings of $3.50 per square foot. "That's nice–a few million extra on our bottom line," said one of the company's executives. He then added, in the same breath. "But I can't really get excited about energy. It's only a few percent of our cost of doing business." Such thinking is stalling energy improvements throughout the corporate world. Installing energy-efficient equipment may not be sexy, but the savings are real. If this executive's company had achieved similar savings at all its facilities worldwide, its total net would have gone up by 56 percent.

Industry has already seen major savings from its fuel-conserving programs initiated during the Arab oil embargo of the early 70s. Yet companies spend more than twice as much on electricity as on oil. Unbeknownst to many in industry, in the past few years there have been tremendous advances in electric efficiency. Electricity-saving technology is evolving so quickly that most of the best options now on the market didn't exist last year. Today, you can save twice as much electricity as you could five years ago, at only a third the real cost. Practically every building, however modern, can be made much more efficient.

American companies have a $93 billion annual electric bill, with 25 to 45 percent of the total going toward lighting–about three fourths of it directly and a quarter to counteract the heat generated by the lights. In most commercial buildings, lighting consumes more than a third of the electricity used–upward of half when the cooling load is considered. Yet according to studies by Lawrence Berkeley Laboratory (the leading national lab on saving energy in buildings) and Rocky Mountain Institute, 80 to

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90-plus percent of this lighting energy could be saved by fully converting to today's most efficient lighting equipment.

The vast range of efficient lighting hardware now available fits almost any need, providing unchanged lighting levels with less glare, more pleasant and accurate color, no flicker, and no hum. Upgrading a typical office fluorescent lighting system can be accomplished by installing computer-designed reflectors, which deliver virtually the same light from half as many lamps; new lamps that give off more light per watt and nicer color; sophisticated high-frequency electronic ballasts, which start and regulate the current of the lamp and can now power four lamps instead of two; and several kinds of controls. As a result, a company will need only half as many lamps and a quarter as many ballasts, which should save it 70 cents per square foot on maintenance costs–nearly half the total cost of the upgrade. Typical direct energy savings are about 70 to 90 percent, and including the 35 to 40 percent "bonus" for saved space-cooling, most paybacks are well under two years.

Even juicier savings come from converting incandescent lamps, such as the ubiquitous flood lamps in can fixtures, to compact fluorescent lamps. These lamps can cut lighting bills by 75 to 85 percent, and they last 4 to 13 times as long, thereby more than paying for themselves just by reducing maintenance costs on replacement bulbs and the labor needed to install them.

Other improvements can boost lighting savings by another third or more, including better maintenance, lighter-colored finishes and furnishings to distribute light better, top-silvered blinds and glass-topped partitions to bounce sunlight three times as far into buildings, polarizing lenses that make reading easier by almost eliminating glare, half-watt electroluminescent panels to replace 30- to 50 watt EXIT signs, and miniature tungsten-halogen spotlights for displays.

Together, these commercially available lighting innovations have the potential to save about a fourth of all the electricity in the country, at a net cost somewhat less than zero. In fact, Rocky Mountain Institute estimates that because the amount saved on maintenance costs would be more than the cost of the electricity-saving devices, the average cost of replacement will be about *minus* 1.4 cents per kilowatt-hour. In the United States this would displace 120 Chernobyl-size power plants costing about $200 billion and eliminate more than $30 billion a year in utility operating costs. This may be the biggest gold-mine in the whole economy.

Opportunities nearly as dramatic abound in every other electricity-consuming device. Together, they can cut U.S. electricity consumption by another half.

After lights, motors are probably the next fattest opportunity. Motors use at least two thirds of industrial electricity and some 53 to 60 percent of all the electricity in the country–more than $90 billion a year worth, or about 2 percent of our gross national product. In fact, making the electricity to run U.S. motors now uses more fuel than is consumed by all U.S. highway vehicles.

A typical big industrial motor consumes electricity costing some 10 to 20 times its own total capital cost per year. Over a motor's life, a 1 percentage point gain in efficiency typically adds at least $10 per horsepower to the bottom line. Direct efficiency gains averaging about three and-a-half percentage points are currently possible, which for a motor-intensive company, such as a paper mill, can create enough savings to turn around a foundering firm.

Two measures that have gained wide acceptance are buying only high-efficiency new motors, which can now save twice the electricity that they could a decade ago, and using electronic speed controls. Immediately replacing a standard induction motor with a high-efficiency model has many advantages. In addition to cutting electricity costs, the replacement will last twice as long because it runs cooler and has better bearings, will need fewer capacitors to boost the motor's "power factor" (the fraction of electricity fed into the motor that actually turns it rather than heating it), and will work better with adjustable-speed drives.

Electronic speed controls have become popular because many machines, especially pumps and fans, need to vary their speed to match production needs. Before electronic adjustable-speed drives became widespread and affordable, output was usually varied by running the pump or fan at full speed while "throttling" its output with a partly closed valve or damper–like driving with one foot on the accelerator and the other on the brake. Today, electronic speed controls can eliminate this waste. When you need only half the flow from a pump, you can save almost seven eighths of the power because its energy needs vary as roughly the cube of its flow. In all, electronic adjustable-speed drives can save 14 to 27 percent of total U.S. motor energy, with paybacks of a year or two. Only a few percent of this opportunity has yet been grasped.

Currently, most engineers consider just these two measures, ignoring the other half of the total electricity-saving potential in motor systems. At Rocky Mountain Institute we have identified 33 kinds of further improvements that could be made to motor systems, comprising the choice, maintenance, sizing, and controls of motors and the systems that supply electricity and transmit torque from the motor to the driven machine. Implementing all 35 of the improvements can cut the motor systems' use of electricity in half, for a potential national savings equivalent to 80 to 190 giant power plants. (This figure doesn't even take into account the potential for another 50 percent savings on the remaining electricity bill from improving the machinery that the motors are driving.) Because you pay for only seven of the 35 improvements–the rest are cost-free by-products–the average payback on the doubled efficiency is only about 15 months.

Capturing the savings depends on simultaneously doing many things right. For example, to double a motor's lifetime, the motor's shaft must be kept precisely aligned with the shaft it's driving or the bearings will fail prematurely, and the bearings themselves must be lubricated by someone with clean hands to prevent dirt from getting into the grease and eating the bearings–both simple steps that frequently aren't taken in American industry.

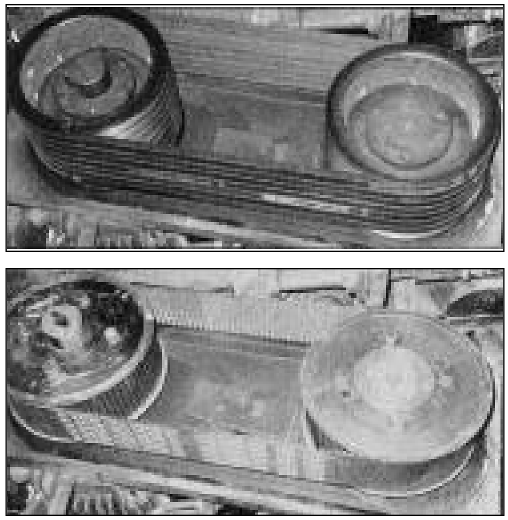
Companies should switch from V-belts, which stretch, slip, and require so much tension to stay in place that they harm the bearings, to "synchronous" belts, which have teeth that engage sprocket lugs so the belt doesn't slip, and fiberglass or Kevlar bands inside so it doesn't stretch. Not only would such a conversion save about 5 to 15 percent of the transmitted energy, but it would cost about *minus* a dollar per kilowatt-hour because of immense maintenance savings.

Maintenance itself must also be improved. Poor maintenance ruins costly motors, wastes energy, and needlessly incurs downtime costs that can exceed $10,000 per hour. Measurements by General Electric Company suggest that in the United States between $1 billion and $2 billion worth of electricity is wasted each year by the damage done to the iron cores of motors as a result of poor repair practices used to remove old windings. An alternative technique using only gentle warmth to loosen old windings for removal causes no damage and is faster and cheaper, but is known to relatively few motor repairmen. Another step to improve the state of motor maintenance would be to make lubrication and other motor upkeep a white-lab-coat profession, with a "motor doctor" who makes house calls and administers precisely metered dosages of special medicine to motors.

When it comes to energy efficiency, details matter. Jim Clarkson, the mastermind behind Southwire's dramatic savings, found that before executives toured plants, motors were often given a coat of shiny new paint. Over the years, so many coats built up that the heat couldn't get out. Today, you can't repaint a Southwire motor without first stripping off the old paint. Clarkson also discovered that of the typical 6 percent power loss between the meter and the machinery, three fourths could be saved, with a payback of around two years, just by installing wire twice as fat. The wire in most big buildings, it seems, is chosen by low-bid electricians told to meet the local building code, which is meant only to prevent fires, not to save money.

Many energy-saving techniques require no investment. Clarkson found he could save Southwire 10 percent of its motor electricity bill by turning off idling motors. At some machines he installed a red light that went on when high peak-period utility charges approached, and told the operators that if they would take a coffee break when the light went on, the company's overall profits would be more than if they kept working.

Almost every other electricity-consuming device holds potential savings as well. Replacing a desktop computer with an equally sophisticated laptop model can save up to 95 percent in electricity–enough to pay for the difference in cost for the laptop–while improving safety, portability, ergonomics, and space use, and eliminating the need for a costly uninterruptible power supply. Simple improvements to such common office devices as laser printers and photocopiers can save most of their energy and help avoid multimillion-dollar investments to expand air-conditioning capacity to handle machine heat in older buildings. For both these devices, for example, "cold fusing"–setting the toner onto the paper with a cold compression roller rather than a hot drum–saves 90 percent of the electricity, eliminates fumes and warm-up time, and gives twice the life with half the maintenance. Further savings can be gained by installing controls that turn such machines off or into a standby mode when not in use.



Belt-tightening: Electric drives can be made 5 to 15 percent more efficient by switching from V-belts (top) to synchronous belts, such as the Poly Chain GT (bottom) made by the Gates Corporation.

Making windows more efficient also saves money. Most buildings use plain glass, so you're hot in summer and cold in winter. But new "superwindows" provide year-round comfort. Some let in 60 percent of the visible light, thereby displacing electric light and the heat it produces, while admitting only two percent of the sun's heat. Other windows, designed for cold climates, can insulate up to six times as well as double glazing, and can even gain more heat than they lose in the winter while facing in any direction, including north. At Rocky Mountain Institute's research center, we have no furnace in a climate that goes down to -47°F. Our cold-climate windows not only permit us to do without a furnace, cutting winter heating bills by $1,000 a month, but also have reduced our building's net capital cost. The reason: We saved more by eliminating the furnace and ductwork than it cost us to install the superwindows and superinsulation. Fully used, superwindows could save the United States four million barrels worth of oil and gas per day, at costs of a few dollars per barrel–far cheaper than drilling for more.

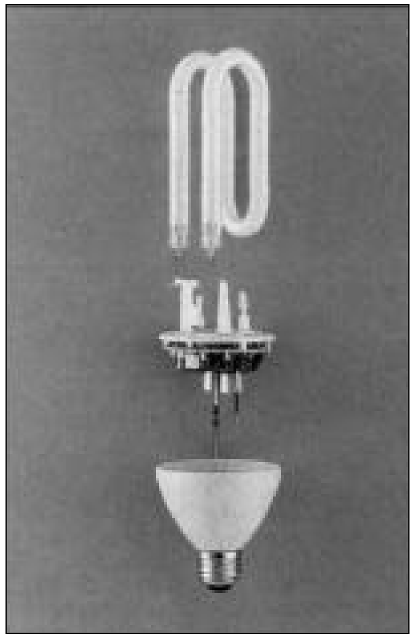
Increasingly popular superefficient appliances are another fountainhead of savings: There are refrigerators and freezers on the market that consume 10 to 20 percent of the usual amount of energy, commercial refrigeration systems that save more than 50 percent, and televisions and high-performance showerheads that save 75 percent. The collective results can be astounding. My 4,000-square-foot home's lights and appliances cost only $5 a month to run–a 90 percent savings over normal bills. Installing new technology has also resulted in a more than 99 percent savings in space and water heating and a 50 percent reduction in water usage. Best of all, the payback period for my home's improvements was only 10 months, and that was with 1983 technology.

What do all these opportunities add up to nationwide? A comprehensive study by Rocky Mountain Institute suggests that if the thousand or so best electricity-saving innovations now on the market were fully installed in U.S. buildings and equipment, they'd save about three fourths of all electricity now used, at an average payback of slightly more than one year, while providing unchanged or improved services.

Some of these innovations are now becoming popular. Sales of many kinds of electricity-saving devices are more than doubling every year. Advanced windows, for instance, have gone from 1 percent to more than 60 percent of the insulated-glass market in just a few years. More than 20 million compact fluorescent lamps are expected to be sold this year.

Yet progress in converting to electricity-saving technologies has so far been much slower than it should be. A major obstacle to efficiency is the indifference or outright opposition of about a third of the utility industry. Some utilities have exemplary (and highly profitable) programs to help their customers use electricity more efficiently, but others are still trying to sell more electricity, not less. This reflects a basic misunderstanding of their business. Customers don't want kilowatt-hours; they want services such as hot showers, cold beer, lit rooms, and spinning shafts, which can come more cheaply from using less electricity more efficiently. Good programs to save commercial and industrial electricity cost only about a half cent per kilowatt-hour, which is several-fold cheaper than just operating a coal or nuclear plant, and 10 to 20 times cheaper than building a new one.

Many utilities, conditioned by a century of rising sales and revenues, still forget that, like any other business, they can make money on margin instead of volume. This is true even for utilities with overcapacity: If it's cheaper to save electricity than to make it, then a utility should save it regardless of how much capacity it has, because capacity is a sunk cost, whereas marginal variable costs can still be saved. New regulations in California, New York, and Massachusetts are encouraging such choices by decoupling utilities' profits from their sales and letting them keep part of the savings as extra profit, thereby directly rewarding efficient behavior. A dozen more states are developing similar incentives for their utilities.



Bright Idea: Replacing a 75-watt incandescent bulb with an SL fluorescent bulb from Philips (above) cuts electricity use by 76 percent.

A second obstacle to efficiency is that many electricity-using devices are purchased by people who won't be paying their running costs and thus have little incentive to consider efficiency when comparing prices. Furthermore, most customers don't know what the best efficiency buys are, where to get them, or how to shop for them. Business customers have trouble conveniently buying integrated packages of efficient equipment; only a handful of companies can do everything to your lighting systems and do it right, and nobody as yet offers such a service for completely overhauling your motor systems.

Perhaps the most critical obstacle to overcome is the "payback gap" between consumers and utilities. If you invest your own money to save energy in your business or home, you'll probably want it back within a couple of years, implying a real discount rate upward of 60 percent a year. In contrast, if a utility has to build or expand a power plant to meet increased demand, it'll probably use a 20-year payback horizon, or about a 5 or 6 percent real annual discount rate. The utility's great technical and financial strengths, low information costs, diversified risk portfolio, and steady cash flow allow it to take a more relaxed view of investments than consumers can.

Although these respective discount rates are rational for each party, for the American economy their tenfold payback gap makes us invest too little in efficiency and too much in new power plants, misallocating some $60 billion a year.

Many utilities are seeking to equalize the disparity in discount rates between them and their customers by financing efficiency via concessionary loans, rebates, and even gifts. Southern California Edison Company, for instance, has given away more than 800,000 compact fluorescent lamps because it's cheaper than operating the company's existing power plants. Utilities are also beginning to explore leasing electricity-efficient lamps and motor systems to consumers. For example, a 20-cent-per-lamp-per-month charge on a consumer's electric bill lets him pay for the efficiency improvement over time, exactly as he now pays for power plants.

Rocky Mountain Institute has come up with an innovative way to foster such efficiency gains: creating negawatt markets. Negawatt markets would treat saved electricity as a commodity, just like copper, wheat, and pork bellies. Negawatts (saved watts) would be subject to competitive bidding, arbitrage, and secondary markets. Some entrepreneurial utilities even want to become "negawatt brokers" and create spot, future, and options markets in saved electricity. Such markets could be highly profitable: Arbitrageurs make money on spreads of a fraction of a percent, but the spread in discount rate between utilities and their customers is closer to 1,000 percent.

Perhaps the strongest incentive to create negawatt markets is their win-win solution to many environmental problems. Because it's now generally cheaper to save fuel than to burn it, global warming, acid rain, and urban smog can be reduced not at a cost but at a profit. A 1989 Swedish State Power Board study found that by using electricity twice as efficiently, Sweden could fulfill the electorate's mandate to phase out the nuclear half of the nation's power supply while simultaneously supporting 54 percent growth in real gross national product, reducing the utilities' carbon dioxide output by a third, and cutting the total cost of electrical services by nearly $1 billion per year. This finding is all the more encouraging because Sweden has a severe climate, a heavily industrialized economy, and perhaps the world's highest aggregate energy efficiency to start with.

In the United States, a conservative study by the American Council for an Energy-Efficient Economy found that reducing sulfur emissions from Midwestern power plants by 55 percent through scrubbers and fuel-switching would cost about $4 billion to $7 billion. Yet it also found that by using electric savings to pay for the cleanup, that cost would change to a $4 billion to $7 billion profit.

Today, the best energy investments provide the most environmental protection. A study by Rocky Mountain Institute found that a dollar spent on nuclear power will displace less than a seventh as much coal-fired electricity as would spending the same dollar on efficient use of electricity. This means that each dollar spent on nuclear energy will result in the release of at least six units of extra carbon that would not have been released if it had been spent instead to improve electric efficiency. From this perspective, nuclear power makes global warming worse. Most of global warming, Rocky Mountain Institute analysts believe, can be abated by advanced energy-saving techniques; at a net profit of about $200 billion per year.

Given the negawatt markets' profit opportunities, why are a market-oriented Administration and many in the business community opposing aggressive abatement of energy-related pollution such as acid rain and global warming? Probably because they think abatement will cost extra. Eminent economists running computer modeling studies have shown costs running into the trillions of dollars for reducing fossil-fuel combustion by, say, 25 percent by 2005. But these models base costs on economic theory, while ignoring the results of real-life efficiency programs. What those economists presumably have in mind is that because fossil-fuel use declined when energy prices quadrupled after the Arab oil embargo of 1973, a decline today in fossil-fuel use must be accompanied by similar price increases. As a result, their models only ask how high energy prices need go, based on historical elasticities, to reduce fossil-fuel use by a given amount. They forget that major efficiency gains are cost-effective at well below current fuel prices. It is a national tragedy that a few noted economists' ignorance of the empirical costs of energy efficiency has so widely spread the myth of costly environmental protection that it threatens to paralyze energy-efficiency and anti-pollution programs, thereby blocking major profit opportunities for the private sector.

Energy efficiency ultimately represents a trillion-dollar-a-year global market. American companies have at their disposal the technical innovations to lead the way. Not only should they upgrade their plants and office buildings, but they should encourage the formation of negawatt markets. And they should let the United States Government know that the best energy policy for the nation, for business, and for the environment is one that focuses on using electricity efficiently–for it's the only policy that makes economic sense. ■