FOUR REVOLUTIONS IN ELECTRIC EFFICIENCY

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Demand prospects for electricity are being altered profoundly by four synergistic types of revolutionary change: new technologies for improved end-use efficiency, new ways to finance and deliver those technologies to customers, cultural change within utilities, and regulatory reforms to reward efficient behavior.

Dramatic energy savings achieved so far have been largely in direct fuels and not in electricity, mainly due to price distortions and unique market failures. Resulting inefficient use of electricity is misallocating some $60 billion a year to unnecessary expansions of U.S. electric supply. Yet the best technologies now on the market could save about 92 percent of U.S. lighting energy, about half of motor energy, and much of the electricity used for other purposes. Complete retrofit could deliver equal or better services with only a fourth of the electricity now used. The levelized cost of that quadrupled end-use efficiency averages about 0.6 cents/kWh—well below short-run marginal cost. Analogous oil-saving potential from the best demonstrated technologies is about 80 Percent of present oil consumption at an average cost below $3/bbl, partly because two of the 9–10 prototype cars already tested at 67–138 miles per gallon are said to cost nothing extra to make.

Many utilities already save large amounts of electricity very quickly and cheaply by financing customers' efficiency improvements through loans, gifts, rebates, or leases. Even more promising is an emerging "negawatt market" making saved electricity a fungible commodity subject to competitive bidding, arbitrage, derivative instruments, secondary markets, etc.

Utilities can make more money selling less electricity and more efficiency. They can earn a spread on the difference in discount rates between themselves and their customers. They can save operating and capital costs while avoiding the associated risks and, under emerging regulatory reforms, can even keep as extra profit part of what they save. They also can generate tradeable emissions rights under the new Clean Air Act. Some utilities now properly ignore sunk costs and seek to minimize marginal variable costs. These utilities, driven by economic—not accounting—principles, find this approach both profitable and operationally advantageous.

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I. OVERVIEW

The "Four Revolutions in Electric Efficiency" to which the title of this paper refers are (i) very dramatic advances in technologies for improving end-use efficiency of electricity, (ii) ways to finance and deliver that hardware to the customers, (iii) cultural change within the utilities, and (iv) reinforcement of those cultural changes with reforms in regulatory philosophy and practice.

Two illustrative graphs (see figures 1 and 2) are from a paper I wrote in 1976 for *Foreign Affairs* on how the U.S. energy system could evolve over the next half-century or so. We now are a quarter of the way through that period and are doing even better than projected. Since 1979, the United States has obtained more than seven times as much new energy from savings as it has from all net increases in energy supply. Of that new supply, more has come from renewables—now about 11–12 percent of total primary supply—than from non-renewables. This obviously is a big improvement. However, nearly all of that saving has been in oil and gas, and very little improvement has occurred in electrical efficiency.

There are 11 reasons why we are saving electricity more slowly than we are saving direct fuels: (i) electricity is about 11 times as heavily subsidized as direct fuels (as of 1984); (ii) most electricity is sold at rolled-in prices, while most fuel prices are based on marginal cost; (iii) long lead times further delay the price response to costly new power plants; (iv) electricity is sold at declining-block tariffs, far more often than are fuels, (v) most U.S. electric utilities are vigorously promoting new sales by all possible means; (vi) traditional electric rate making inadvertently increases profits whenever electric sales increase; (vii) most of the best ways to save electricity are much newer and less familiar than are fuel-saving methods; (viii) most electricity-using devices are marketed to or bought by people who want only to minimize first cost, so that far fewer electricity-using devices than fuel-using devices are chosen in ways that can reflect customers' efforts to minimize life-cycle costs; (ix) some major uses of electricity—e.g., space heating—look very cheap to their installers since their huge capital costs to society are socialized; (x) most research and development on electric use—in both the government and the private sectors—seeks and promotes new uses of electricity; and (xi) most U.S. utilities have no incentive—and have little compulsion or inclination—for least-cost investments. Given all these reasons, the lag in electric savings behind fuel savings is not surprising.

Also, some very strong differences exist among international aggregate electric intensity trends. The United States spends 11–12 percent of its GNP on energy, compared with 5 percent for Japan. This difference gives typical Japanese exports an automatic cost advantage on the order of 5 percent. Japan not only is more energy efficient than the United States; it is becoming even more efficient

FIGURE 1

Energy Strategy: The Road Not Taken?

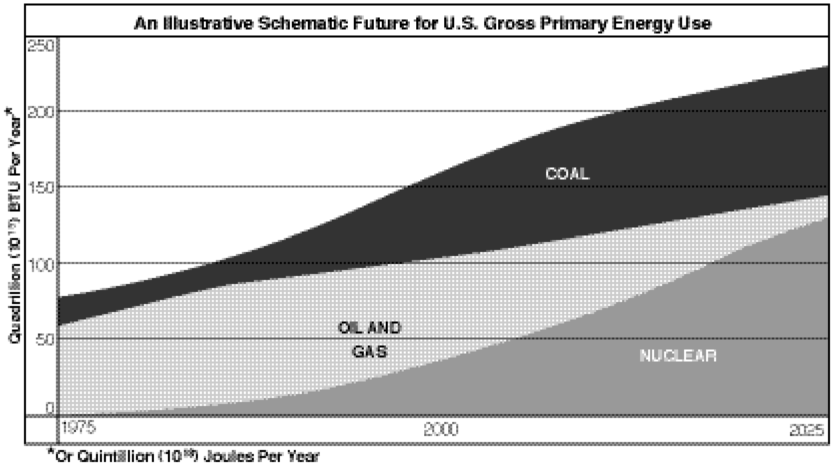
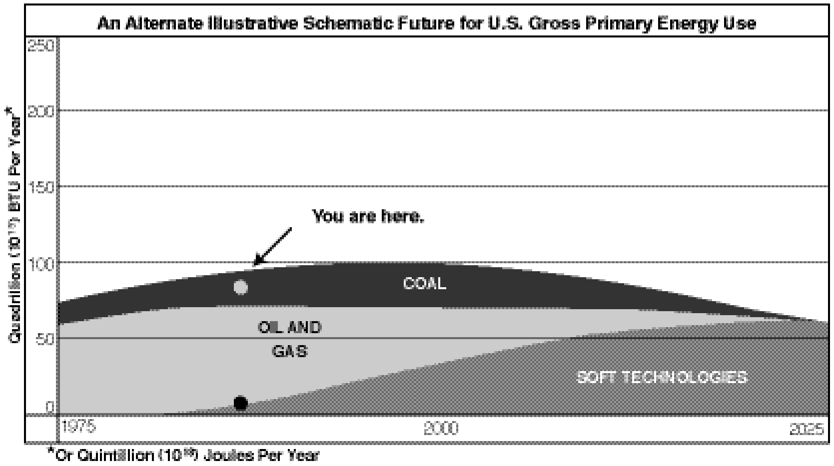


FIGURE 2

Energy Strategy: The Road Not Taken?



much faster. In several major industries, electric intensity per ton is falling in Japan but rising in the United States. In 1986, a dollar of Japanese gross national product (GNP) used 36 percent less electricity than did a dollar of U.S. GNP. Figure 3 depicts some recent International Energy Agency (IEA) data with official projections that show this gap widening to 45 percent by the year 2000.

If the United States were as efficient (in rough aggregate) as Japan, then we would save an additional sum on the order of $300 billion a year. This is twice the U.S. budget deficit and is more than the military budget. Worse, when we use energy inefficiently, we are leveraging enormous investment into unnecessary energy supply and thereby are removing capital from more productive uses elsewhere. Huge investments in needless energy supply, rather than in modernizing industry, are an even bigger handicap. Expanding the U.S. electric system costs about $60 billion a year in a combination of private investment and federal subsidies. This is about the same as the total annual investment in all durable-goods manufacturing industries. If we were to save electricity only fast enough to keep up with the growth in service demand, then we would have nearly twice as much capital available for investment in those industries.

II. THE FIRST REVOLUTION: TECHNOLOGICALADVANCES

The first revolution that can let us correct a lot of these problems with electric efficiency is a technological one.

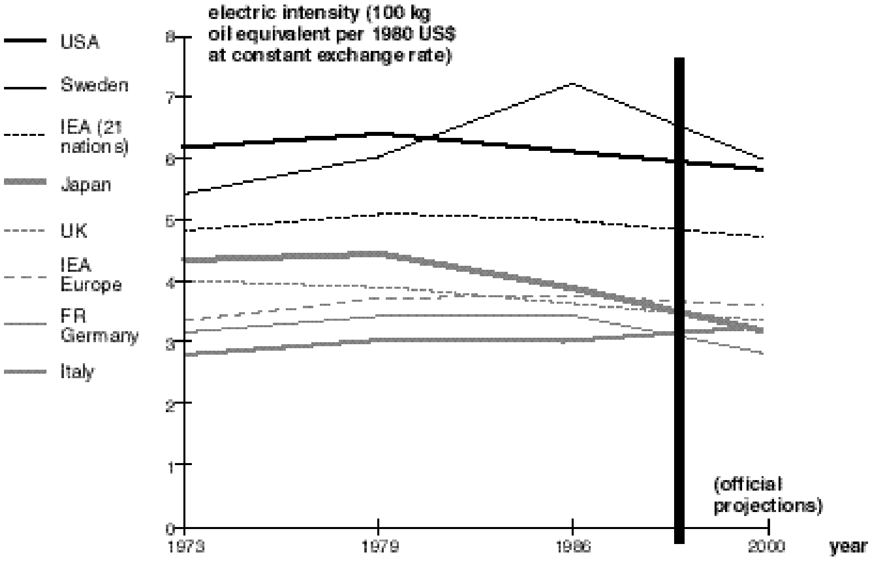
Figure 4 shows electricity use in the United States. A quarter is used for lighting. A little more than half of our electricity is used one way or another for drive power—some of it for space heating and cooling, most for industrial use in machines, and some for air handling and appliances. Heating—both low- and high-temperature—uses nearly another quarter. Electrolysis and electronics use the remainder.

Very dramatic technological progress has occurred in each of these areas. In fact, the half-life of the best electricity-saving technologies is about a year. That is, most of the best such devices on the market today were not on the market a year ago, and the same was true a year ago. We now can save approximately twice as much electricity as we could five years ago, but at only a third of the real cost. That is about a six-fold gain in cost-effective potential in five years, and nearly a 30-fold gain during the past 10 years. I see no signs of this slowing down, though of course the incremental benefits will tend to taper off.

A. *Lighting*

More than 90 percent of the electricity used in the United States for lighting currently could be saved by implementing a full retrofit of the U.S. lighting system with commercially available products that deliver the same amount of light

FIGURE 3
International Trends in Electric Intensity of GNP

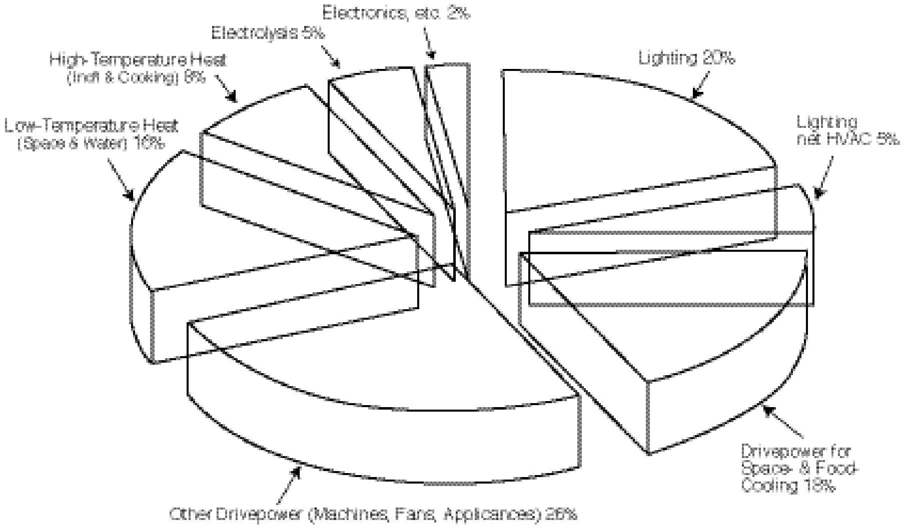


Source: International Energy Agency/OECD

but look better and allow us to see better. This could be accomplished using about 8 percent as much lighting electricity as we now use. That is the biggest fractional savings found anywhere—a factor of 14 improvement—and, based on measured cost and savings data, comes at an average cost of about -1.4 cents/kWh (Lovins and Sardinsky, 1988). Further savings at lower costs are on the way, but the present-value cost of deferring the benefit is so great that we ought to go for it now. We certainly have enough technologies available.

Lighting offers perhaps the most dramatic historic drop in service cost, a nearly *600-fold* drop going from candle to carbon incandescent to tungsten incandescent. Yet even today, during an era when obvious technological gains supposedly have been made, a further factor of 14 improvement could be realized with the best technology now on the market. This includes not only improvements in hardware to produce light and control its delivery, but also better use of that hardware. One improved use is supplying light that is easier to see with so that less light is needed to achieve the same visual performance—e.g., radial polarizers that reduce the glare on a reader's paper or screen to provide better contrast so that one can see as well with half as much light.

FIGURE 4
Approximate End Uses of U.S. Electricity: 1985



A second improved use is substituting natural light for artificial light. One option not counted is that we now can use natural light in the middle of big buildings with a little Fresnel-grooved light-pipe material. It is rolled up in a pipe. Sunlight goes in one end and photocell-dimmed, high-efficiency supplementary artificial light is put in the other end. The pipe is run along the ceiling. Wherever light is wanted, an extractor film is placed—and the light squirts out. The Japanese do the same with fiber optics. So, if we want to go even further to save electricity for lighting, we actually could do a lot of daylight retrofitting in the middle of big buildings.

Providing the right amount of light—at the right time and place—for the task is crucial. If light is on in an empty room, then that does no good—it just uses energy. So there is a gadget that turns off the lights after you have left the room.

One can illustrate what the potential savings are in practice. Approximately 42 percent of lighting energy in the United States—and a larger fraction in most other countries—is incandescent. Such lighting now can be replaced with compact fluorescents that come in about every size and shape imaginable. Electronically ballasted versions with no flicker, no hum, and excellent color rendering are available. Adapters that can take six different sizes are available, and the outer threads take accessories such as reflectors and globes. Lamps using only 8 1/2 watts can replace lamps using 75 watts, and lamps using 10 watts can replace lamps using roughly 75 watts or maybe a bit more. Floodlamps or about 20 types of decoratives with cut-glass globes and the like are among the many styles available. These versatile systems can save at least three-quarters of the electricity conventional systems use. With the floodlamp configuration, the saving typically is more like a factor of six or so. Compact fluorescents also last about 13 times as long as do regular light bulbs, and so each of these saves a dozen lamps and a dozen trips up a ladder to install them. That saving, in present value, exceeds the marginal cost of the lamp in the first place. Therefore, the electric saving is better than free. For integral compact fluorescents, the cost typically is -2 to -3 cents/kWh. For modular systems, it typically is -10 to -25 cents/kWh. This is not a free lunch. This a lunch one is paid to eat.

These replacement lamps have a U.S. potential, including the net space-conditioning effects, to save about 50 gigawatts, and the average cost works out to roughly -6 cents/kWh.

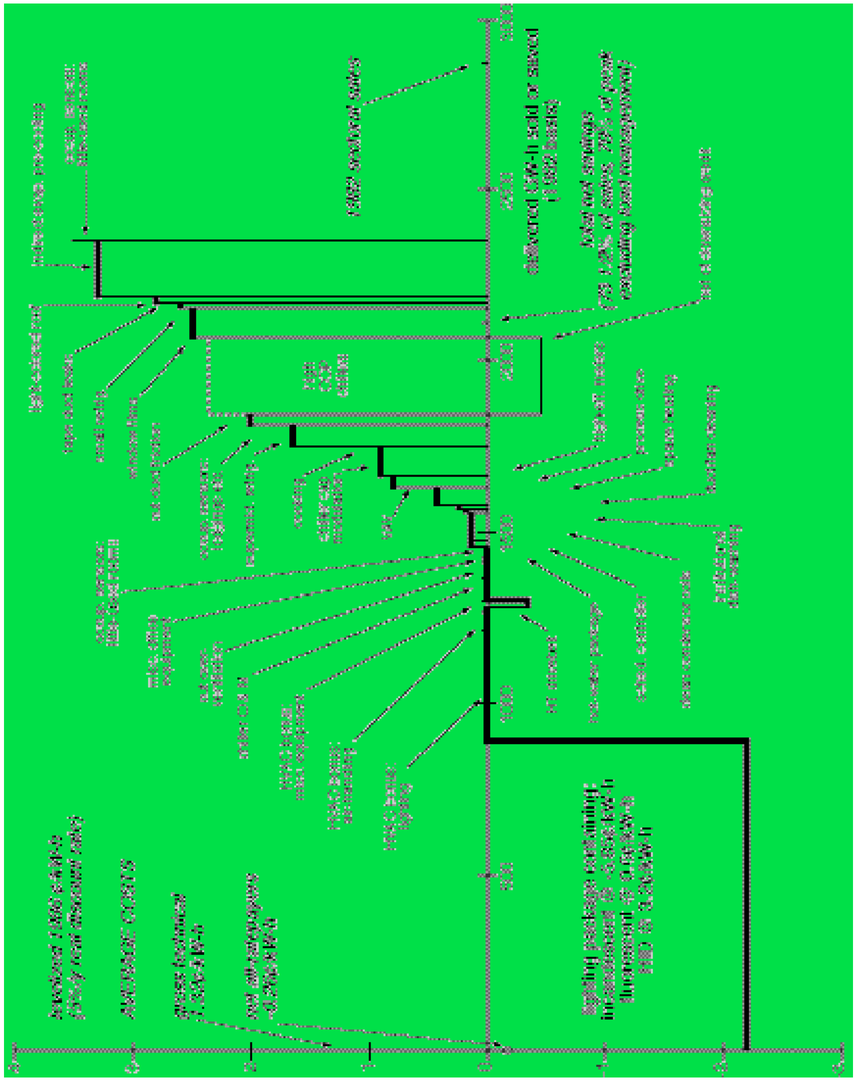
For fluorescent fixtures, start by putting a shiny piece of metal—bent into a special computer-designed shape—up above the lamps as an imaging specular reflector. This makes possible removing of half the lamps, relocating the rest, and still getting nearly the same amount of light underneath as before. When lamps are changed, they can be replaced with those using the more efficient phosphors. These now are about 17 percent more efficient and give much nicer color than do standard lamps. And when the ballast is moved around, it can be replaced with a high-frequency electronic ballast. This is electronic "Wonder Bread"—it helps save electricity nine ways. Measured savings range from roughly 50 to 90 percent depending on the daylight and other control conditions. There go another 60 gigawatts at 0.6 cents/kWh.

In an office building, many exit signs do with 30–50 watts what now can be done with half a watt. There go a few more gigawatts. The new lighting equipment comes in enough sizes and shapes to fit nearly any application.

B. *Commercial Retrofit Potential*

Figure 5 is a supply curve of savings. (I hope this will not be offensive to economists. Showing potential savings as a supply curve instead of as a shift in a demand curve is now conventional.) The vertical axis is the levelized cost of saving electricity. It is the installed cost of the device minus any present-valued credit for saved maintenance costs, all divided by the discounted stream of electric savings over the life of the device using a 5 percent per year real discount rate. The horizontal axis is how much electricity is saved out of this total amount

FIGURE 5
AP & L Commercial-Sector Retrofit Potential



used in all the commercial-sector buildings in the territory of Arkansas Power and Light Co. Implementing all of the energy-efficiency measures yields a saving of about three-quarters of the electricity at an average cost of about -0.25 cent/kWh. Why negative? Because the types of lighting measures described here are heavily (about 45 percent) weighted for going from incandescent to compact fluorescent lights—and other similar conversions—with a strongly negative cost. Therefore, all the lighting conversions in the commercial sector cost about -1.4 cents/kWh. The area below the horizontal axis exceeds the area above it, especially after a correction for downsizing the replacement chillers. Making the chillers smaller saves more money than the cost of making them nearly twice as efficient. All the cost and performance data shown are measured (Lovins, 1988).

A utility would not take credit for the maintenance costs that the customers saved. That is, if a utility wanted to give commercial-sector retrofits away and wanted to know the cost, then it would add back again the maintenance costs that the customers saved and would get a gross technical cost of about +1.3 cents/kWh. That still is pretty attractive: It is less than most systems' short-run marginal cost. And, of course, a utility seldom gives away commercial-sector efficiency. It normally would just give a rebate for perhaps a fifth of the cost, and the customers would come up with the rest. In sum, the supply curve is very flat if one takes lighting seriously. Notice that lighting plus space conditioning accounts for half of the total savings potential and more than pays for *all* of the savings in the commercial sector.

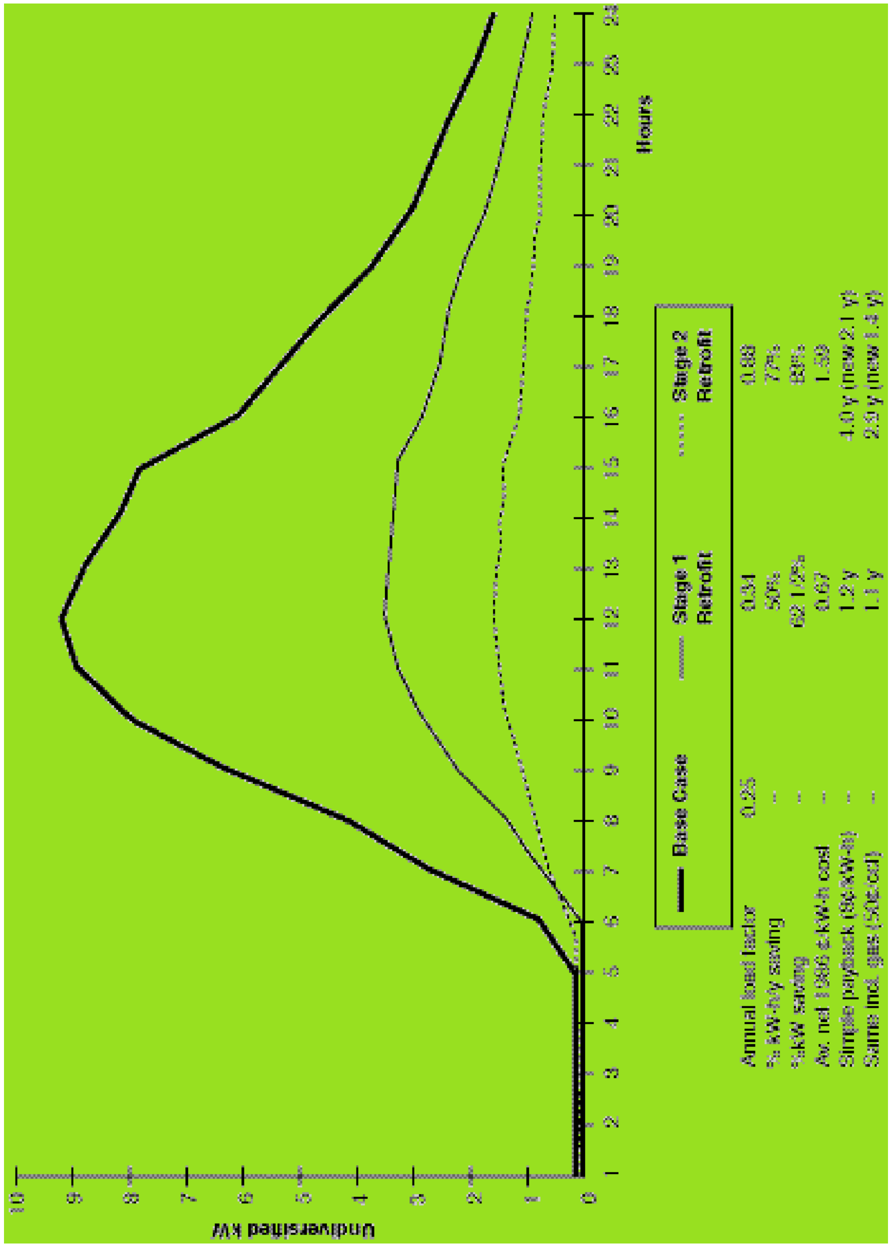
C. *Residential Retrofit Potential*

Retrofitting in the residential sector is more expensive and more complicated. We have done a parametric simulation on the typical single-family house in Little Rock with a central air conditioner on a typical hot July day (figure 6). Instead of getting a daily loadshape such as the highest curve, one can get a loadshape such as the lower two curves with two packages of about a dozen retrofit measures. The improvements are to the shell of the building, to the air conditioner itself, and to other appliances, while maintaining the same comfort or improving comfort. The Stage One Retrofit (figure 6) saves half the annual energy and two-thirds of the peak load at a levelized cost of 0.7 cents/kWh, with a one-year payback. The Stage Two Retrofit saves three-quarters of the annual energy and four-fifths of the peak load at 1.6 cents/kWh, with a three-year payback. The annual load factors are 25, 34, and 88 percent, respectively.

Retrofits with superwindows are one of the more important measures that make this Stage Two package cost 1.6 cents instead of 2.5 cents. Windows that insulate twice as well as triple glazing are available. (Think of this as one Alaska of oil and gas savings, or as one North Sea, in U.S. potential at about $2 or $3 a barrel. The retrofit has

FIGURE 6

July Load Reduction from Retrofitting an Archetypical AP & L Single-Family House



a couple of years' payback.) In between the two layers of glass is suspended an invisible plastic film with high-tech coatings that transmit visible light but reflect infrared light. The film comes in seven flavors for different climates. The assembly often is filled with insulating gas such as argon or krypton. Windows twice this good now are available, at about R-12, at no greater cost per unit of saved energy.

D. *Example: Rocky Mountain Institute*

That, by the way, is how we manage in our research center—in temperatures down to -44ºC (-47ºF)—to have upwards of 99 percent passive space heating (figure 7). In fact, we saved more money getting rid of the furnace and duct work than we paid extra for passive heating. The marginal cost of eliminating essentially all of our heating is negative. The household electric bill, too, is about $5 a month. The payback on that 90 percent saving, plus more than 99 percent saving on space and water heating, plus 50 percent saving on water, was 10 months with five-year-old technology. And the structure need not look like this to work like this (figure 7). One could do the same thing with a tract house in essentially any climate.

E. *Industrial Retrofit Potential*

For the industrial sector, Rocky Mountain Institute (RMI) has just completed an encyclopedia on drivepower—not just in industry but in other areas as well (Lovins et al., 1989). Normally, utilities promoting drivepower efficiency look at two primary efficiency improvements: high-efficiency asynchronous motors and adjustable-speed drives. However, 35 possible measures are available, including choice of motors, maintenance practices, motor size, four kinds of electronic motor controls (including some for load management), mechanical tune-ups, and electrical good-housekeeping measures that every manager knows but that few bother to do well. A small example is a model of a 42:1 speed reducer. Normally speed reduction would be done with a worm gear that is 40 or 50 percent efficient on paper and often half that in practice. This one is 96 percent efficient and requires no maintenance. So even in a Victorian area such as gears, quite impressive technical improvements have occurred.

RMI studies calculate the total U.S. retrofit drivepower savings potential at 44 ±16 percent at an average cost of less than 0.5± 0.15 cents/kWh. The saving is substantial. By comparison, motors use more primary energy than highway fuel and represent upwards of half of electricity end use. The cost of retrofit is modest. In the United States, that is about an 80- to 190-gigawatt net potential. The average payback at 5 cents/kWh is less than 15 months.

Excellent business opportunities are available here. An example would be what one might call a "Torque Team." If I run a widget factory, then I care about widgets. I do not care about 35 things I can do to my drive systems since I do not

FIGURE 7
Rocky Mountain Institute

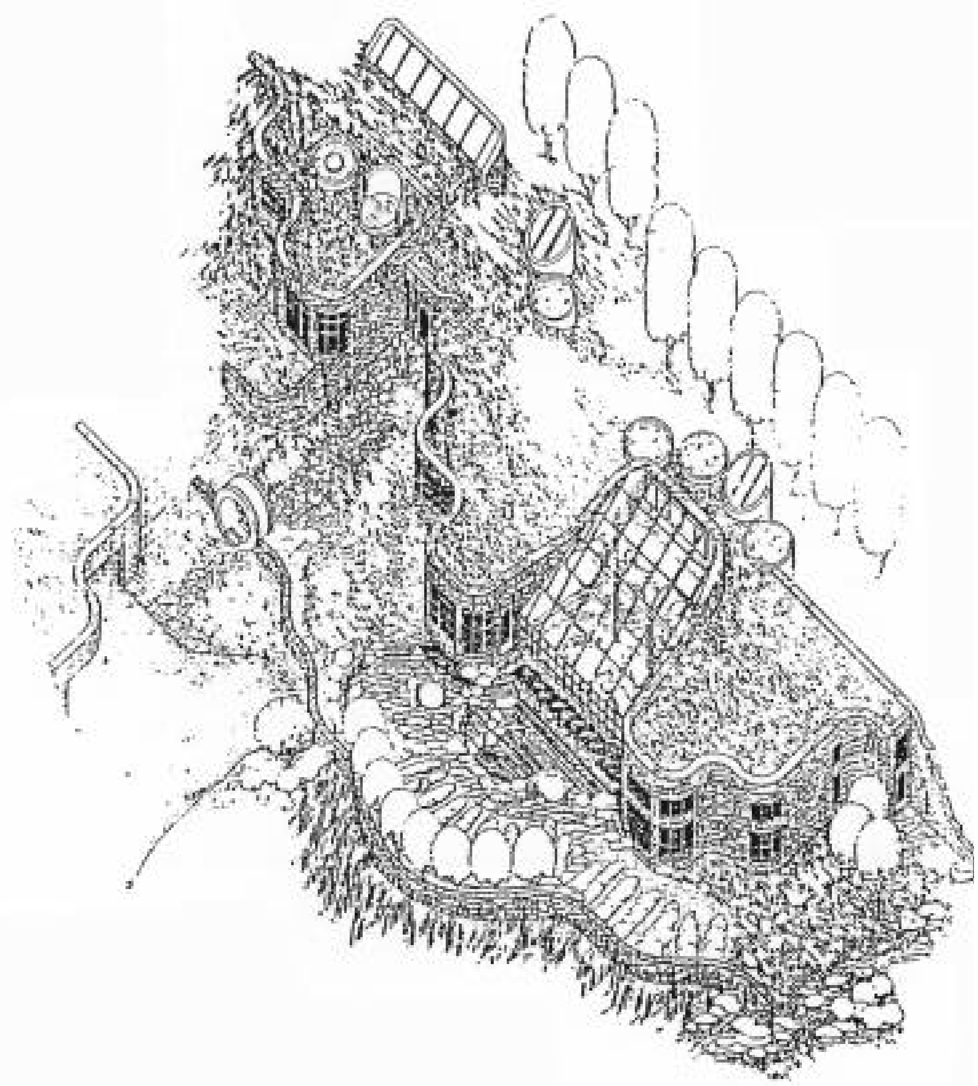


FIGURE 8

Preliminary Estimate of the Full Practical Potential for Retrofit Savings of U.S. Electricity at Average Cost 0.6¢/kWh

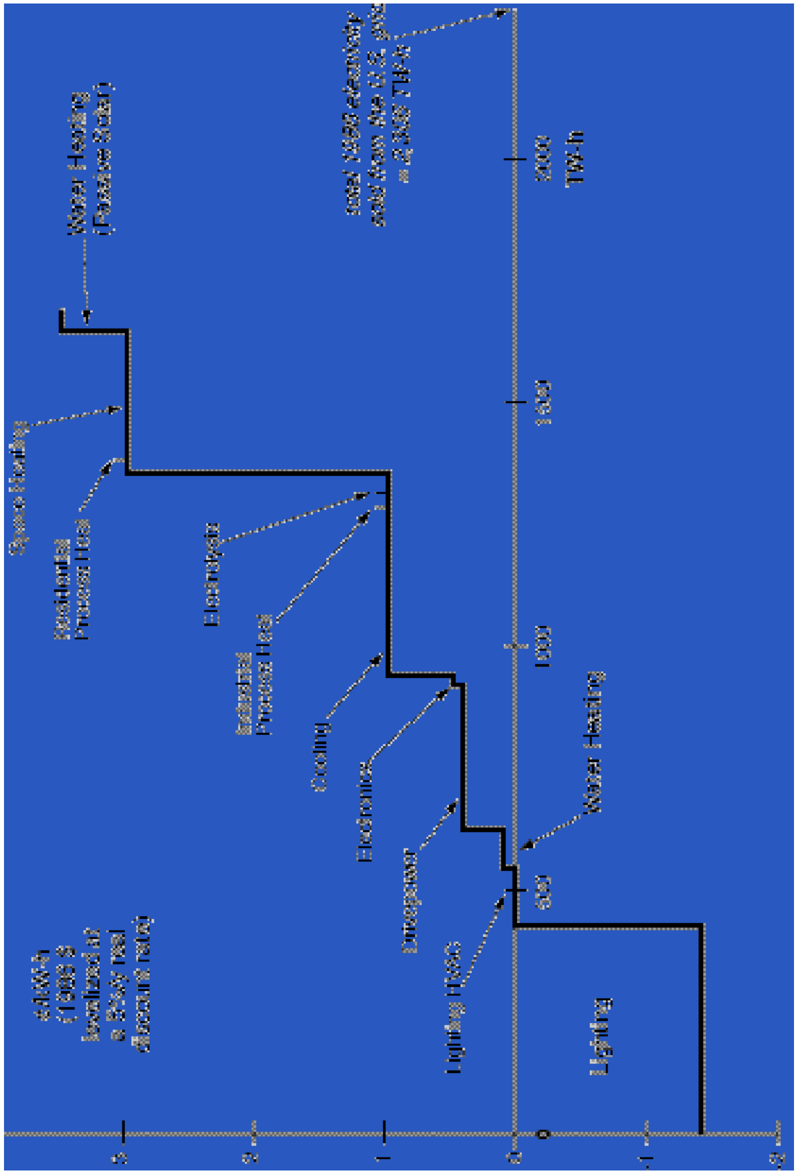
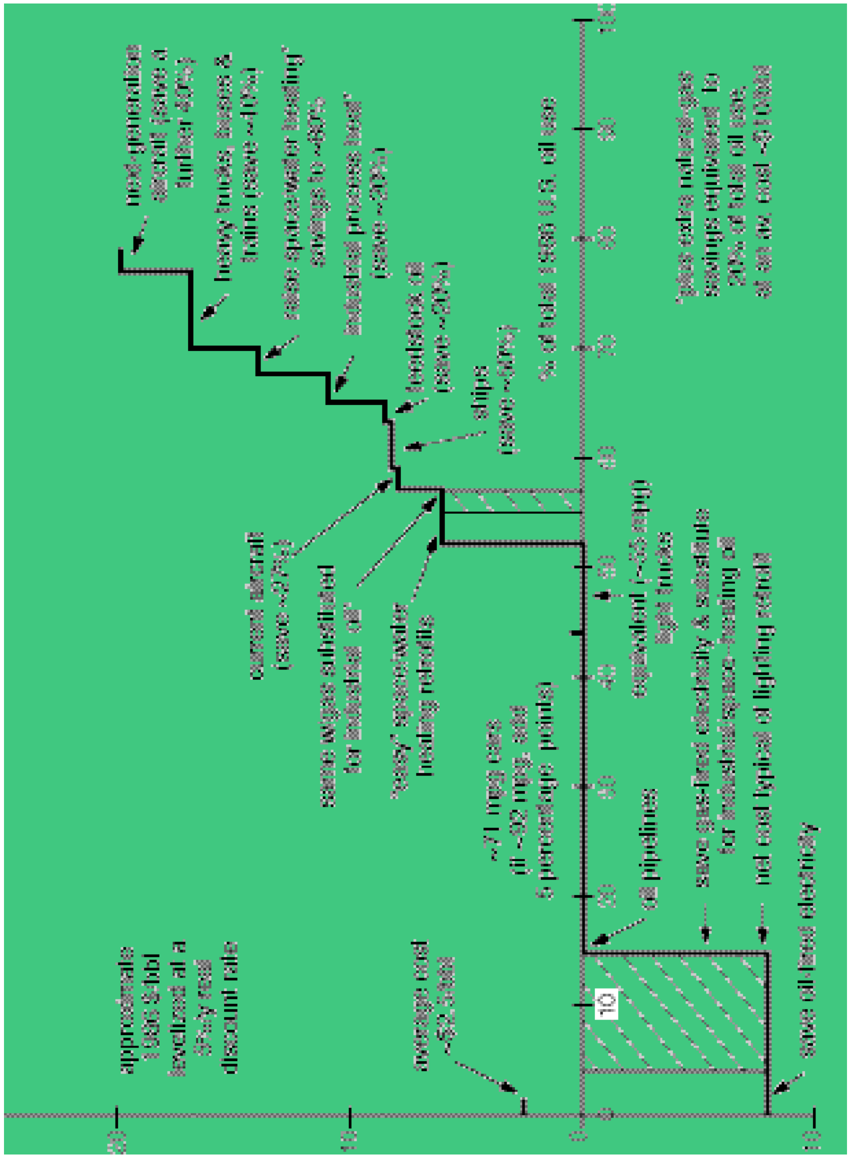


FIGURE 9

Preliminary Estimate of the Full Technical Potential to Save U.S. Oil Consumption



want to have to deal with them. I ought to be able to call in the Torque Team to make the drive system improvements and to finance them. No such number is available for me to call. If I want to call the Light Brigade to charge in and improve my lights in a couple of dozen ways, then perhaps only three people in the country are reliable enough to do them all well. So a lot of institution-building must be done.

E. *Aggregate U.S. Potential Electricity Savings*

From the technical viewpoint, here is my best guess of what the supply curve looks like for total U.S. electrical savings on retrofit (figure 8). For convenience, I have lumped together into one package all the things one could do in each end use—roughly 1,000 technologies in all. If one starts with 120 gigawatts of lighting at -1.4 cents/kWh and adds drivepower and so on (figure 8), then the saving is about three-quarters of the electricity in the country by the time the marginal cost rises to a few cents/kWh. But the *average* cost of doing that is only about 0.6 cents/kWh. (The uncertainty is about ±10 percent for the quantity and give or take a factor of two on the average cost.) Notice also that one can get up to roughly a 50 percent saving for zero average cost—the quantity at which the area under the axis equals the area over the axis. That is good news, especially regarding problems such as the greenhouse effect from $C0_2$, acid rain, and smog.

Electricity savings also have some important implications for the supply curve of oil efficiency, which looks something like figure 9. Again, the vertical axis is levelized dollars per barrel. The horizontal axis shows the percentage of total 1986 U.S. oil use. On the left side, saving(s) start at about 16 percent from oil-fired electricity, gas-fired electricity, and the substitution of the saved gas for oil currently used for industrial heat and space heating. Notice that figure 9 shows these initial savings at a negative cost since this quantity of electricity savings made by oil and gas is less than that saved just by the lighting retrofit shown in figure 8.

One also can move to the right along the curve in figure 9 by using some of the high-efficiency prototype cars that the makers claim have no marginal production cost. Similarly, one can move to light trucks and so on with some more familiar measures. The costs at the far right are less reliable, but one ends up saving about 80 percent of U.S. oil consumption at about $2.50/bbl average cost—cheaper than drilling for more.

III. THE SECOND REVOLUTION: IMPLEMENTING NEGAWATTS

Examining some of the new ways to finance and deliver the technology to the customers is even more exciting. This often is done by electric utilities, partly because they have roughly one-tenth the implicit real discount rate that customers have for energy-saving investments. Therefore, the utilities have a business opportunity of arbitrage on the difference in discount rates. The difference in discount rates is in no sense irrational. It indeed reflects the costs and benefits seen by utilities and consumers, but it results in terrific societal misallocations. We end up buying too little efficiency and too many power plants, misallocating that $60 billion a year, and diluting price signals 10-fold.

The old method by which utilities encouraged efficiency was to market "negawatts." Negawatts are electricity savings: One can think of a 14 watt replacement for a 75-watt lamp, for example, as a 61-negawatt power plant. Utilities would market negawatts by general or specific information, concessionary loans, rebates, equipment leasing, third-party investors (including utility service companies), and gifts. Southern California Edison, for example, gave away a half-million of the Japanese version of compact fluorescent lamps since doing so was slightly cheaper than running existing power plants.

These old methods of implementing negawatts are quite powerful—as the following success story illustrates. Around 1983–1984, before the attention of Southern California Edison’s management wandered, the company had a 14-gigawatt peak load and was reducing its long-term forecast peak by nearly 1,200 megawatts a *year*. Nearly half of the reduction was through its own programs—costing 0.3 cents/kWh, or some $30/peak W—and a little more than half was through state programs that cost the utility nothing but that could have been replaced by utility actions costing from zero to a few mills (tenths of a cent) per kWh. If all Americans saved electricity at the same speed and cost as those 10 million people demonstrated during the mid-1980s, then the national 10-year-out forecast requirements for power supply would go down by about 40 gigawatts a year. The program costs to utilities to achieve these savings would average about 0.1 or 0.2 cents/kWh, or about 1 percent of the long-run marginal cost. However, I think we can do better than that with new implementation methods that do not replace but instead supplement the old techniques for marketing negawatts.

These new methods seek to create a market *in* negawatts—a market in which everybody can play, so that buyers and sellers can get together. A competitive bidding process is a good place to start. For example, follow Central Maine Power's lead and offer cash grants to industry to invest in saving electricity; give the grants to whichever firms offer to save the most electricity per dollar of grant. Then generalize this through all-source bidding. Thus, a utility that wants *x* megawatts next year can put it out to bid and see how many megawatts customers are willing to provide or save and at what price. Take the low bids, which are generally savings since they cost less than building new power plants. This is going on now in at least eight states. This competitive bidding process clearly is better than fixed-price rebates. You might think of rebates as similar to a fullavoided-cost PURPA(Public Utilities Regulatory Act of 1978) buy-back in which the producer captures all the rent and very little competition exists—among the different types of savings or different providers of savings—to drive down the cost. The competitive bidding process is better than rebates since it tends to capture the negawatts at the lowest cost, hence maximizing societal surplus.

To make negawatts look like copper, wheat, or any other commodity, they must be fungible. This can be done on any scale. We already have had the first few contracts signed in which utility A pays utility B to save electricity in its own territory and then sell it back to A at a discount. This also can be done in any utility territory *between customers*. If I have a factory and want cheaper electricity, then I ought to be able to come here and fix up this building's ridiculous lights—which all are little cash cows waiting to be milked. And then Sierra Pacific should sell electricity to me in my factory—the same amount I save here—but they should sell it to me at a bit of a discount so that the saved operating cost is shared between me and the other customers. That way we can declare open season on negawatts, and anyone who wants to benefit would have an incentive to go bounty-hunting.

We have a lovely example of pure arbitrage now being discussed on the spread between the costs of supplying electricity and saving electricity. Hydro-Quebec wants to sell Vermont 450 megawatts of very costly new hydropower at a levelized cost of about 9 cents/kWh. Vermont is not interested since that is too expensive. But Vermont has an interesting counter-offer—namely, to come to Montreal, hire some contractors, fix up the buildings, and save 450 megawatts, which Vermont will then buy back from Hydro-Quebec for, say, 3, cents/kWh. Vermont will pay perhaps a cent to save each kWh, and 3 cents to buy each kWh, for a total of 4 cents—much less than 9 cents! So far, so good. But Hydro-Quebec will make more money this way, since the 3-cent power that Vermont saves and Hydro-Quebec sells is from an old dam amortized 20 years ago. This is a lot more profitable than selling Vermont the output of a very expensive new power plant. Even if Hydro-Quebec sells the power at 9 cents, it still will make less that way. Vermont also will eliminate the environmental cost and financial risk of building the new dam: It offers to build, in effect, a cheaper dam in Montreal with negawatts. Hydro-Quebec is rather intrigued by this notion—at least in some sections of the company—since it is realizing that saving and reselling electricity is a lot more valuable than continuing to waste electricity at home.

Additional new methods to market negawatts could be in spot, futures, and options markets—good ways to hedge planning risks.

Another approach is peak-load covenants traded in secondary markets. For example, if I fix up this building so that it never will use more than *x* megawatts, then I ought to be able to sell the utility a binding covenant to that effect as part of its resource plan. That could be traded in a secondary market. One can draw an exact parallel with brokers' making markets in certificates of decreased air pollution under the EPA (Environmental Protection Agency) "bubble concept."

Another new method of implementing negawatts involves efficiency cross-marketing by gas and electric utilities. About a dozen utilities sell efficiency for fun and profit in the territories of *other* utilities. Since there is no monopoly on negawatts one can sell them to anyone. Puget Power thus sells efficiency in nine states and electricity in one state. Wisconsin Power and Light has been making noises lately about selling efficiency in Commonwealth Edison's territory, where the tariff is nearly twice as high. Even at the lower tariff, Wisconsin P&L earns a 16–17 percent return selling efficiency. Gas utilities could make a lot of money selling electric efficiency, and that also would change the behavior of buildings in ways that help them sell more gas. Gas utilities have all the same abilities as do electric utilities to deliver negawatts, but apparently none have the same ambitions.

Other new methods of implementing negawatts include performance linked hookup fees—or “feebates"—for new buildings (Koomey and Rosenfeld, 1990), and targeted mass retrofits, especially of commercial lighting. A feebate for new houses is in Austin, Tex., would generate on the order of $35,000 net wealth *per house*. The builder makes money up front, since the rebate for a very efficient house, in the form of a negative hookup fee, more than covers the extra cost of building it that way. So the builder has an immediate profit. But the builder also has an expanded universe of qualified buyers since, under existing secondary mortgage rules, Fannie Mae and Freddie Mac relax the qualification ratios if the borrower has lower utility bills. Thus one can get a bigger mortgage on the same income. The builder can market the house by saying: "For the first five years you own this efficient house, I will pay all the utilities—no questions asked." Or, "If the utilities are more than $100 a year, then I will pay the extra." (Homebuilders who superinsulate do that, and they usually have long waiting lists.) The house then can be labeled so that the efficiency will be internalized in market value. When the house is resold,, the seller most likely will get about 15 to 25 years' worth of energy savings back as extra equity. Meanwhile, the utilities typically can save five or 10 times the value of the rebate.

IV. THE THIRD REVOLUTION: CULTURAL CHANGE WITHIN UTILITIES

Why should utilities help save electricity? Basically, because if saving electricity is cheaper than producing it, then one should do so regardless of how much capacity one has. Capacity is a sunk cost, but one still can save marginal variable costs. This is a rather heretical idea, since most utility managers view themselves as being in the kilowatt-hour business—if they have idle capacity, then they want to put it to work. But asset utilization comes from amortization pressure, and that is an accounting concept—not an economic concept. The question, I think, is not: "Can you figure out a clever new way to get people to buy more electricity and spread your fixed costs?" But rather, it is: "Have you exhausted efficiency opportunities that are cheaper than short-run marginal costs?" Clearly not.

The biggest cultural hurdle to get over in getting people to take seriously sunk versus marginal costs is that in the utility business—where sales and revenues have risen pretty steadily for a century—most utility executives have gotten into the terrible habit of looking at the top line instead of the bottom line. Getting them used to the idea that selling less electricity and bringing in less revenue is perfectly all right, *as long as their costs go down more than their revenues go down*, is difficult. Yet this cultural change within the utilities, as they realize the implications of a competitive energy-service marketplace, is going faster than I thought possible. They used to say this process took a new chairman of the board 10 years, but some companies now are doing it much faster. I think part of what is driving them is the realization that the efficiency hardware is out there. Sooner or later, despite all the hassle, consumers will discover it. The question is not so much, "Will people buy efficiency?" as, "Who is going to sell it to them? Do we want to do it as a utility and become more of a technical bank? Or do we simply want to see our sales disappear with no foresight or explanation?" Clearly, if we want to avoid mistakes in our supply-side investments, then we ought to be heavily involved in this process and try to influence it in some way that will help us minimize regret by managing risk and reducing uncertainty. In short, because electricity is costly and efficiency is cheap, customers will want to buy less electricity and more efficiency. Selling customers what they want before someone else does is generally a sound strategy business.

The U.S. utilities currently fall into two broad classes: those that are still commodity vendors trying to sell more electricity, and those that are energy service market competitors trying to provide the best deal for the customer. The latter are the utilities that realize, as Georgia Power puts it, that their mission is merely "the profitable production of customer satisfaction." The latter group of utilities is smaller, but it is growing rapidly as everybody is seeing that those companies are the most profitable, are the most fun to work for, and are attracting the most talented people.

V. THE FOURTH REVOLUTION: REGULATORY PHILOSOPHYAND PRACTICE

This cultural change is being hastened by the fourth revolution, which I cover very briefly. Last July, the Conservation Committee of the National Association of Regulatory Utility Commissioners unanimously endorsed two new principles of utility regulation that I think have far-reaching implications for utility behavior. (Note added in proof: These principles were unanimously adopted on the floor of the full NARUC convention in November 1989.) The first is that utilities' profits should be decoupled from their sales, so that utilities will not be rewarded for selling more than expected or penalized for selling less than expected, as is currently the case in every state except California. Second, if utilities do something smart that cuts the customers' bills, then utilities ought to be allowed to *keep* part of the savings as extra profit. If all of the savings flow through to the customers, then the utility CEO—who has next quarter's earnings per share very much in mind—is unlikely to pay much attention. In Florida, for example, many utilities participate voluntarily in an hourly spot-market brokerage of the cheapest power. They wheel it around to equalize system lambda. At the end of the year, the computer adds up how much money this saves each utility, and each is automatically allowed to keep one-fifth of the savings in addition to its normal return. That is great for the customers, too: Having four-fifths of an actual, prompt saving is better for them than having all of nothing.

There are a lot of ways to generalize such incentives to all kinds of savings, whether they result from end-use efficiency programs, better tariff design, better heat rate, better grid management, or whatever. Several states are just starting this year to experiment with such incentives in a serious way. I believe that such regulatory reforms will greatly speed the already rapid transformation of utility culture by bringing more and better entrepreneurs out of the woodwork.

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