CLIMATE:

Making Sense *and* Making Money

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OLD SNOWMASS, COLORADO
13 NOVEMBER 1997

ABSTRACT

Arguments that protecting the earth's climate will cost a lot rest on theoretical economic assumptions flatly contradicted by business experience. Most climate/economics models assume that almost all energy-efficiency investments cost-effective at present prices have already been made. Actually, huge opportunities to save money by saving energy exist, but are being blocked by dozens of specific obstacles at the level of the firm, locality, or society. Even if climate change were not a concern, it would be worth clearing these barriers in order to capture energy-efficiency investments with rates of return that often approach and can even exceed 100% per year. Focusing private and public policy on barrier-busting can permit businesses to buy energy savings that are large enough to protect the climate, intelligent enough to improve living standards, and profitable enough to strengthen economic vitality, employment, and competitiveness.

Eight classes of regulatory, organizational, and informational failures, perverse incentives, distorted prices and investment patterns, and similar barriers are costing the American economy about $300 billion every year. This waste pervades even well-known and well-managed companies that have been saving energy for decades. Some alert corporate leaders, however, are now starting to break through these barriers to enrich their shareholders by combining careful attention with powerful innovations in design and technology. Many examples illustrate how each of the obstacles to such energy-saving practices can be turned into a lucrative business opportunity, making climate protection a boon for enterprise, innovation, and competitive advantage.

Energy price does matter, but ability to respond to price matters even more. The last time the United States saved energy very quickly—expanding GDP 19% while shrinking energy use 6% during 1979–86—the main motivator was costly energy. Yet similar success can now be achieved by substituting high skill and attention for high prices. In the 1990s, Seattle, with the lowest electricity prices of any major U.S. city, has been saving electricity far faster than Chicago, where rates are twice as high. The key difference: Seattle is starting to create an efficient, effective, and informed market in energy productivity.

Saving fuel typically costs less than burning fuel, and the gap is widening as efficiency costs continue to fall faster than fuel prices. Engineering economics has made climatic protection not costly but profitable. Therefore, debates about climate science, who should save energy first, and how to share the alleged pain of the savings are all misconceived and irrelevant. Just as the American economy has succeeded in displacing leaded gasoline, chlorofluorocarbons, sulfur emissions, and many toxic chemicals—all at costs far lower than initially expected—so modern technologies and market understanding can profitably displace carbon fuels too, yielding both a stable climate *and* a vibrant economy.

PREFACE

Ten successive drafts of this study have been widely circulated for peer review since July 1997. Now as we move to print the final (19 October) version for mid-November release, many encouraging statements by business leaders are starting to emerge. For example:

- The Chairman of General Motors announced on the eve of the Tokyo Motor Show that climate change is indeed "cause for concern" and requires a response, emphasizing strengthened technological innovation in fuel-efficient vehicles.

- The Chairman of Ford Motor Company's Board committees on finance and environmental policy, William Clay Ford Jr., described climate change as a definite threat, declared that firms which denied its reality risked being "marginalized in the court of public opinion," and criticized his industry's overdependence on fuel-inefficient sport-utility vehicles.

- Senior executives of a dozen firms, including construction giant Bechtel and automaker Mitsubishi Motors, joined a public call for strong climate-protection policies.

Most encouragingly, as the review drafts and numerous briefings of senior officials began to seep into the process of policy formation, President Clinton made a pathfinding 22 October speech at The National Geographic Society, defining a national climate policy strongly consistent with our analysis. The crux of this speech read:

The lesson here [from leaded gasoline, CFCs, SO_x, toxics, etc.] is simple: Environmental initiatives, if sensibly designed and flexibly implemented, cost less than expected and provide unforeseen economic opportunities. So while we recognize that the challenge we take on today is larger than any environmental mission we have accepted in the past, climate change can bring us together around what America does best—we innovate, we compete, we find solutions to problems, and we do it in a way that promotes entrepreneurship and strengthens the American economy.

If we do it right, protecting the climate will yield not costs, but profits; not burdens, but benefits; not sacrifice, but a higher standard of living. There is a huge body of business evidence now showing that energy savings give better service at lower cost with higher profit. We have to tear down barriers to successful markets and we have to create incentives to enter them. I call on American business to lead the way, but I call upon government at every level—federal, state, and local—to give business the tools they need to get the job done, and also to set an example in all our operations.

The President's welcome emphasis—on markets, profits, and enterprise, on technological innovation, and on specific barrier-busting policies that turn implementation obstacles into business opportunities—represents exactly the fresh start on reframing the climate debate that this paper calls for. President Clinton echoed that thesis, stating that if climate protection is done properly, "we will not jeopardize our prosperity—we will increase it." This study presents part of the "huge body of business evidence" he mentioned as the basis for a new, profit-oriented climate policy.

We hope that both those who share the President's view and those skeptical of its effectiveness will carefully consider the detailed arguments documented here. For if we are correct, then:

- addressing the climate challenge can create not a handicap but an unprecedented boon for American business;

- leadership by the rich countries will help rather than hurt them in global competition;

- the debate about the many uncertainties of climate science will become irrelevant;

- environmentalists who hoped for stronger carbon-reduction goals will have good reason to hope that just as with sulfur reductions, the initial goals set will in fact be considerably outpaced; and

- those in the business community who have opposed vigorous climate policies will find in this one an opportunity to do even better what they do best—make money.

—ABL & LHL

CONTENTS

INTRODUCTION

On 19 May 1997, the chief executive of British Petroleum said: "[T]here is now an effective consensus among the world's leading scientists and serious and well informed people outside the scientific community that there is a discernible human influence on the climate, and a link between the concentration of carbon dioxide and the increase in temperature." He continued: "[W]e must now focus on what can and what should be done, not because we can be certain climate change is happening, but because the possibility can't be ignored.[1]" Obviously what should be done is to stop raising and start lowering the rate of burning fossil fuels—the source of 84% of America's and most of the world's energy.

The prospect of having to reduce carbon emissions has aroused dismay, foreboding, and resistance among many in the business community who fear it would hurt profits and growth. Robert J. Samuelson asserted in *Newsweek*: "It would be political suicide to do anything serious about [climate]….So shrewd politicians are learning to dance around the dilemma.[2]"

The dilemma arises because almost everyone *presumes* that protecting the climate will be costly. In Samuelson's widely held view, saving a ton of carbon emissions would happen only under a roughly $100 tax, and, he warns, even such a burdensome tax might only cut 2010 emissions back to 1990 levels. Thus "Without a breakthrough in alternative energy—nuclear, solar, something—no one knows how to lower emissions adequately without crushing the world economy." Congress "won't impose pain on voters for no obvious gain to solve a hypothetical problem. And if the United States won't, neither will anyone else."

The earth's climate can be protected *not at a cost but at a profit*—just as many industries are already turning the costs of environmental compliance into the profits from pollution prevention.

Samuelson, like so many business people, believes climate protection is costly because the best-known economic computer models say it is. Few people realize, however, that those models find carbon abatement to be costly *because that is what they assume*. This assumption masquerading as a fact has been so widely repeated as the input and hence the output of supposedly authoritative models that it's often deemed infallible.

It's not. Not only do *other* economic models derive the opposite answer from different assumptions, but an enormous body of overlooked empiricism, including government-sponsored studies[3] and worldwide business practice, shows that the technological breakthroughs Samuelson seeks have already happened. The earth's climate can be protected *not at a cost but at a profit*[4]—just as many industries are already turning the costs of environmental compliance into the profits from pollution prevention.[5] To prove that thesis, this paper will:

- show how firms are starting to capture these profit opportunities;
- explain how most climate/economic models ignore such profitable energy-efficiency opportunities;
- illustrate how businesses can greatly broaden and intensify profitable climate mitigation on even a national and global scale;
- examine how eight kinds of practical obstacles that are retarding even wider implementation can be turned into lucrative business opportunities;
- show that high energy prices are not the only way to ensure rapid adoption of energy-efficient practices;
- clarify how least-cost climate solutions can foster vibrant competitiveness and employment; and
- demonstrate that the climate issue represents a largely unexploited and underrecognized business opportunity.

Consider a few examples. Southwire is the top independent U.S. maker of rod, wire, and cable, a very energy-intensive business, and has nearly 50 acres of industrial facilities under roof. During 1981–87, the firm cut its electricity use per pound of product by 40%, gas by 60%—then kept on saving even more energy and money, still within two-year paybacks. The resulting savings created nearly all the company's profits in a tough period when competitors were going under. The two engineers responsible may have saved four thousand jobs at ten plants in six (now nine) states. The lead engineer, Jim Clarkson,[6] says the technologies were all simple and available; their effective use took only "an act of management will and design mentality, consistently applied." Indeed, Southwire found that such dramatic energy savings both require and facilitate better management and production systems that are vital anyhow for competitiveness. America's energy-saving potential—sufficient "to cut industrial energy use in half," as Southwire did—tags along almost for free.

In 1981, Dow Chemical's 2,400-worker Louisiana division started prospecting for overlooked savings. Engineer Ken Nelson[7] set up a shop-floor-level contest for energy-saving ideas. Proposals had to offer at least 50% annual return on investment. The first year's 27 projects averaged 173% ROI. Startled at this unexpected bounty, though expecting it to peter out quickly, Nelson persevered. The next year, 32 projects averaged 340% ROI. Twelve years and almost 900 implemented projects later, the workers had averaged (in the 575 projects subjected to *ex post* audit) 202% predicted and 204% audited ROI. In the later years, the returns and the savings were both getting *bigger*, because the engineers were learning faster than they were exhausting the "negawatt" resource. In only one year did returns dip into double digits (97% annual ROI). By 1993, the whole suite of projects was paying Dow's shareholders $110 million every year.

So if the "cost" of protecting the climate ranges from strongly negative to roughly zero or irrelevant, what are we waiting for?

DuPont expects to save the equivalent of 18 million tons of CO_2 by 2000 through simple measures that will also save $31 million each year. Roche Vitamins (Belvedere, NJ) has profitably cut its steam use per unit of production by more than half in five years. A new chiller and related improvements at a Kraft ice-cream plant saved 33% of its electricity and 2,500 tons of CO_2 a year; productivity rose 10% and the plant turned from a money-loser into one of the most competitive. A process innovation at Blandin Paper Company (Grand Rapids, MN) saved each year 37,000 tons of CO_2 and more than $1.8 million.[8] The first two years of billion-dollar carpetmaker Interface Corporation's efficiency efforts, *The Wall Street Journal* reports,[9] have saved "a stunning $25 million…, with another $50 million expected the next two years." Greenville Tube Corporation's demonstration of new drivesystems under DOE's Motor Challenge program boosted productivity 15% and energy efficiency 30%, reduced scrap 15%, and saved $77,000 a year with a five-month payback.[10] And Southern Company's 1984–94 improvements in the thermal efficiency of its fossil-fueled power plants saved 400,000 cumulative tons of SO_2 and 35 million tons of CO_2, plus an annual $108 million.[11]

Because such examples are not yet the widespread practice, America is confronted, as Pogo said, by insurmountable opportunities. By creating enough practical ways to mitigate climatic concerns *and* save more money than they cost, without ascribing any value to the abatement itself, those opportunities can turn climate change into an unnecessary artifact of the uneconomically wasteful use of resources. Specifically[12]:

- Over half[13] of the threat to climate disappears if energy is used in a way that saves money. In general, *it's far cheaper to save fuel than to burn it*.

- Another one-fourth or so of the threat can be abated by adopting farming and forestry practices that take carbon out of the air and put it back in the soil and plants. Soil-conserving and -building practices are generally at least as profitable as soil-depleting, chemical-dependent methods,[14] making the climate protection they provide at least an economic breakeven.

- The rest of the threat vanishes if CFCs are replaced with the new substitutes that are required by global treaty in order to protect the stratospheric ozone layer on which all life depends. Thanks to industrial innovation, these substitutes now work the same or better and typically cost about the same or less.

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ASSUMING THE CONCLUSION

Climate policy has been held hostage to a tacit presumption that if saving a lot more energy were possible at an affordable price, it would already have been implemented. That's like not picking up a $100 bill from the sidewalk because if it were real, someone would previously have picked it up; or like an entrepreneur who abandons a good business idea because if it were sound, it would have been done earlier.

All economists know that real markets are far from theoretical perfection. But most climate/economy models assume that almost all profitable energy savings must already have been bought—as if a perfect market did exist. On this basis, the modelers suppose, buying significantly bigger savings will be worthwhile only at higher energy prices. They then use big computer models to calculate how high an energy tax is needed (based on historic elasticities), how much that will depress the economy, and hence what the "cost" of protecting the climate must be.

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Those models have driven policy for the past two decades. Ever more elaborate models continue to be built on the same old assumption—that saving energy isn't profitable at present prices and hence will require higher prices that will burden firms and the national economy. They're like a model, popular in the Reagan-Bush years, that trumpeted the notion that meeting the Toronto carbon-reduction goals would *cost* the U.S. about $200 billion a year. Yet the empirical evidence of what energy efficiency actually costs showed that reducing fossil fuel use that much would *save* the U.S. about $200 billion a year compared with buying and burning that fuel.

Critics of climate protection often cast doubt on the elaborate computer models that simulate the physical processes of the earth's climate. Ironically, those physical models, which now closely fit the historic climate data, are far more detailed and realistic than the climate-*economics* models used to claim that climate protection is too costly. Pervasive barriers to buying energy efficiency, described below, make those economic models' perfect-market theory as otherworldly as if the physical climate models omitted atmosphere, clouds, and oceans, and relied instead on a theoretical assumption based on a simple historical regression linking CO_2 levels to global average temperatures.

Ignoring real-world conditions leaves most of the climate-economics models riddled with flaws. For example,

- Most economic models are very sensitive to how fast, if at all, energy efficiency is assumed to improve by itself at present prices: one model, for instance, found that as this rate was increased from 0.5 to 1.5% per year (it actually averaged *1.54%* per year during 1973–95),[15] the calculated cost of cutting carbon emissions to 20% below 1990 levels fell from $1 trillion nearly to zero.[16]

- Very few of the models take any explicit account of efficiency technologies, and those that do (like the government studies that show ways to save 20–25% of the carbon at negative cost, with much further potential at low cost[17]) are very conservative for many reasons,[18] including their use of outmoded, costly, incremental, component-based technologies rather than reflecting the modern whole-system approach that can often tunnel through the cost barrier and achieve bigger savings at lower costs, as we shall describe below.[19]

- The economic models don't let technologies improve as price incentives increase, even though rising prices are well known to spur innovation.[20]

- The economic models all forget that renewable sources get cheaper when produced in higher volumes, as they've been doing for decades—leading Royal Dutch/Shell Group Planning to consider it plausible that over the next half-century, renewables could grow to supply more than half the world's energy.[21]

- Most models quietly assume that carbon-tax or -permit-auction revenues are simply rebated (which lowers GDP) instead of being used to displace the distorting taxes that discourage savings, work, or investment (which would raise GDP).[22]

- The relatively few models that allow international trading of emissions and reductions assume that *all* countries have essentially perfect market economies—even those, like the former USSR and China, that don't have economies at all, but only giant machines for eating resources, and hence enjoy the biggest opportunities for improvement.

A lucid guide to 162 predictions by the 16 top climate/economy models[23] found that seven underlying assumptions explained 80% of the differences in their results. Does a model assume there's any "backstop" energy source, such as renewables or nuclear, that can be widely adopted if fossil-fuel prices get high enough? Does it assume the economy responds efficiently to

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price signals and can make significant substitutions between fuels and between products? Can different countries trade their savings opportunities? Are revenues recycled efficiently? Does the model count the value of avoiding climate change (perhaps a relatively minor term, but enough, with efficient revenue recycling, to improve economic welfare)?[24] Does it count the benefit of abating associated forms of conventional air pollution[25] as a free byproduct of burning less fossil fuel—benefits large enough to offset 30–100%[26] or more[27] of the assumed cost of carbon abatement? For (say) a 60% carbon reduction in 2020*, these seven assumptions can predetermine whether the model shows by then a 7% decrease or a 5% increase in GDP.*[28] That noted economists should find such wildly divergent results underscores not only their lack of unanimity on whether climate protection is disastrous or beneficial for the economy, but also that the difference is due to divergent model structures and assumptions.

In sum, most economic models—especially the extreme ones publicized by fossil-fuel companies' intensive ad campaign—calculate large costs because they assume rigid, constrained, and unintelligent responses to economic signals. The few models that show economic benefit from protecting climate, even if they assume outmoded energy-efficiency techniques and impute no value to reducing carbon or other pollution, merely assume that people and firms behave with the ordinary sagacity and flexibility that market mechanisms offer—and can therefore adopt new techniques that can save far more energy, at far lower cost, at far greater speed, than most theorists can imagine.

Energy savings: big, cheap, and getting more so

If the builders of climate-economic models had ever run an energy-saving business, they'd know that the potential for energy savings, cost-effective at present prices, is both real and vast. GE Chairman Jack Welch said of American industry,[29] "Our productivity is at the beginning stages. There's so much waste. There's so much more to get, it's unbelievable. And somehow or other people think all these things are finite." Practitioners often find that the more that the industry-pervading waste is corrected, the more new opportunities emerge to save even *more* resources, even faster and cheaper—especially electricity, which is the costliest and most climate-affecting form of energy.[30]

Pumping is the biggest use of electric motors. Leading American carpetmaker Interface was recently building a factory in Shanghai. One of its processes required 14 pumps. The top Western specialist firm sized them to total 95 horsepower. But a fresh look by Interface/Holland's engineer Jan Schilham, applying methods learned from Singapore efficiency expert Eng Lock Lee,[31] cut the design's pumping power to only 7 hp—a 92% or 12-fold energy saving. It also *reduced* the system's capital cost, and made it more compact, easier to build and maintain, and more reliable and controllable.

These astonishing results required two changes in design. First, Schilham chose big pipes and small pumps instead of small pipes and big pumps: friction falls as nearly the fifth power of pipe diameter. Second, he laid out the pipes first, then installed the equipment, not the reverse: the pipes are therefore short and straight, with far less friction, requiring still smaller and cheaper pumps, motors, inverters, and electricals. The straighter pipes also allowed him to add more insulation, saving 70 kilowatts of heat loss with a two-month payback.

Schilham marveled at how he and his colleagues could have overlooked such simple opportunities for decades. His redesign required, as inventor Edwin Land used to say, not so much having a new idea as stopping having an old idea. Engineering economics commonly uses a rule-of-thumb that balances the extra capital cost of fatter pipe only against the saved *operating* cost of reduced pumping energy. Schilham's new design instead optimized for lifecycle savings in pumping energy *plus* capital cost—of not just the pipes but the *whole system*. The extra cost of the slightly bigger pipes was smaller than the cost reduction for the dramatically smaller pumps and drivesystems. Such whole-system lifecycle costing is widely used in principle, but in practice, energy-using components are usually optimized (if at all) over the short term, singly, and in isolation. This tends to pessimize the whole system and hence the bottom line.

Such opportunities exist in more than just pumps and pipes. Major energy savings are available in valves, ducts, dampers, fans, motors, wires, heat exchangers, insulation, and most of the other design elements, in most of the technical systems that use energy, in most applications, in all sectors. Virtually all energy uses are designed using rules-of-thumb that are wrong by about three- to tenfold. Substituting economically rational design would therefore save much of the energy used by industry, while reducing capital costs. Many of those savings can also be profitably retrofitted into existing plants, either immediately or as part of routine renovations and expansions.

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Among hundreds of examples, similar rethinking of building design has lately yielded:

- houses that are comfortable with no heating or cooling equipment in climates ranging from –47°F in the Colorado Rockies[32] to +115°F in central California,[33] yet cost less to build than houses with normal equipment;
- air-conditioning savings ranging from 90% in a new Bangkok house, at no extra cost,[34] to 97% in a cost-effective California office retrofit design[35];
- total energy savings from over 50% to nearly 90% in cost-effective U.S. house and small-office retrofits[36]; and

- a retrofit design to save 75% of the energy in a typical 20-year-old Chicago curtainwall office tower,[37] providing far greater comfort and a simple payback of –5 to +9 *months*.[38]

A particularly effective retrofit strategy, illustrated by the last example, is to coordinate the installation of energy efficiency measures with renovations that are needed anyhow, such as replacing aging glazings and mechanical systems. New superwindows can insulate fourfold better and let in six times as much daylight but a tenth less unwanted heat. That can trigger further savings, notably in lighting, that can cut air-conditioning needs fourfold. Then the mechanical system can be replaced with a redesigned version four times as efficient, yet four times smaller, hence cheaper than renovating the old one. That saves about enough money to pay for the extra costs of the superwindows and other improvements. The retrofit saving three-fourths of the energy then costs essentially the same as the routine renovation that saves nothing; the money is simply spent in a different way that also reduces operating costs by $1.10 per square foot per year. Every city in America has such buildings ripe for similar treatment—100,000 of them nationwide.

Since big motors use their own capital cost's worth of electricity every few *weeks*, switching to more efficient motors can pay back quickly.

Careful scrutiny of actual market prices for equipment ("In God we trust; all others bring data") reveals that even at the component level, many technical devices—motors, valves, pumps, rooftop chillers, etc.—show no correlation whatever between efficiency and price. A 100-hp American motor, for example, can be cheaper at 95.8% efficiency than an otherwise identical 91.7%-efficient model.[39] But if you don't know that—if you assume, as economic theory predicts, that more efficient models always cost more—then you probably won't shop for it. That can be costly. If the motor runs continuously, each one-percentage-point gain adds about $50 per horsepower to the bottom line, so not choosing the most efficient 100-hp motor can reduce present-valued profits by $20,000. Many factories have hundreds of such motors, which are less efficient than even mediocre new models.

Again, the key is not so much adopting new technologies, though they're important, as using proper recipes for combining the best available technologies in the optimal manner, sequence, and proportions. Some of the recipes are embarrassingly obvious. Light-colored roofs and pavement, plus shade trees and revegetation to help bounce solar heat away, could cool Los Angeles by about 6 F° and cut the city's cooling loads by about 20% and its population-weighted smog by about 12%, saving $0.5 billion per year.[40] An urban tree keeps about nine times as much carbon out of the air as the same tree planted in a forest where it won't also save air-conditioning energy by keeping people and buildings cooled and shaded.[41] Such effects multiply: traditional passive cooling methods formerly provided summer comfort even in steamy Bangkok, and can do so again if superefficient cars and buildings are gradually introduced so the waste heat from cars' engines and air conditioners stops making the city so hot.[42] Bangkok will still be hot, but comfort can be achieved more cheaply using much less energy.

Proven examples abound in every kind of business:

- Properly choosing office equipment and commercial and household appliances has saved over two-thirds of their energy use with the same or better service and comparable or lower cost.[43]

- Skilled retrofits have saved 70–90% of office and retail lighting energy, yet the light quality is more attractive and the occupants can see better. In many cases, the better lighting equipment more than pays for itself by costing less to maintain.[44]

- Motors use three-fourths of industrial electricity, three-fifths of all electricity, and more primary energy than highway vehicles. This use is highly concentrated: about half of all motor electricity is used in the million largest motors, three-fourths in the three million largest. Since big motors use their own capital cost's worth of electricity every few *weeks*, switching to more efficient motors can pay back quickly. A comprehensive retrofit of the whole motor system typically saves about half its energy and pays back in around 16 months.[45] This requires integrating up to 35 kinds of improvements to the motors, controls, electrical supply, and drivetrains. However, the first seven of those improvements yield 28 more kinds of savings at no additional cost,[46] making the resulting energy saving twice as big as conventional retrofits', yet one-fifth as costly per kW-h saved.

- The chemical industry saved nearly half its energy per unit of product during 1973–90 by plugging steam leaks, installing insulation, and recovering lost heat.[47] Now it's discovered that better catalysts and matching heat to the required temperature can often save 70% or so of what's left, yet pay back within two years.[48] Next-generation industrial plant design, now moving from the chemical industry into semiconductors, is uncovering 50–75% savings with lower capital cost, faster construction, and better performance. Early adopters will prosper.

Many of these examples illustrate a new design concept: whole-system engineering can often make it cheaper to save a large than a small fraction of energy use.[49] Integrating the design of an entire package of measures so they do multiple duty (such as saving on both energy *and* equipment costs), or piggybacking on renovations being done anyway for other reasons, or both, can enable designers to "tunnel through the cost barrier." Good engineers think this is fun. Most economic theorists assume it's impossible.

Moreover, the cornucopia of efficiency opportunities keeps expanding far into the future:

- America's power stations turn fuel into one-third electricity and two-thirds waste heat, thereby throwing away heat equivalent to the total energy use of Japan. But the American firm Trigen instead uses the waste heat from small, off-the-shelf gas turbines to run industrial processes. Such "cogeneration," common in Europe, increases system efficiency by about 2.8-fold, harnessing 90–91% of the fuel's energy content, and hence provides very cheap electricity (0.5–2¢/kWh). Fully adopting this one innovation would profitably reduce America's total CO_2 emissions by about 23%.[50]

- Selling waste heat from industrial processes, in turn, to other users within affordable distances could cost-effectively save up to about 30% of U.S. and 45% of Japanese industrial energy[51]—or 11% of America's total energy.

- Still largely unexploited are new kinds of heat exchangers and motors, membrane separators and smart materials, sensors and controls, rapid prototyping and ultraprecision fabrication, and radically more frugal processes using enzymes, bacteria, and biological design principles.[52]

- Saving materials also saves the energy needed to produce, process, transport, and dispose of them. Product longevity, minimum-materials design and manufacturing, recovery of any scrap not designed out, repair, reuse, remanufacturing, and recycling together present a menu of business opportunities that also save energy, pollution, mining, and landfilling. Japan cut its materials intensity by 40% just during 1973–84; but far more is yet to come. Americans throw away enough aluminum to rebuild the country's commercial aircraft fleet every three months, even though recycling aluminum takes 95% less energy than making it from scratch. Smart manufacturers take their products back for profitable remanufacturing, as IBM does with computers in Japan and Xerox does with photocopiers worldwide. Interface, the world's top carpet-tile maker, reckons to cut its materials flow by about tenfold, ultimately by a hundredfold, by leasing floor-covering services instead of selling carpet, and by remanufacturing old carpet.

- Innovative new approaches also seem poised to solve the most intractable part of the climate problem—road vehicles.[53] Ultralight, ultralow-drag, hybrid-electric "hypercars"[54] with 70–90% fuel savings, superior safety, comfort, and performance,[55] and competitive costs have attracted about $2.5 billion of private investment by 25-plus firms worldwide, half of them new market entrants. Signs of related efforts are already starting to emerge. GM has announced it's developing cars with half the weight, half the drag, and hybrid drive (hypercars in all but name). Ford just began road-testing 40%-lighter 6-passenger cars (including two kinds with hybrid drive), meeting essentially the goals of the government's tripled-efficiency car program but 3–6 years early. Toyota will mass-market in Japan this December a hybrid-electric Corolla-class car with doubled efficiency, tenfold lower emissions, and a reported $17,700 pricetag. Daimler-Benz has pledged to be making 100,000 fuel-cell cars a year by 2005. Chrysler just unveiled an experimental molded-polymer-composite[56] "China car" with half the weight of a Neon but more room, 15% lower cost, 80% lower investment, 86% lower factory space, and 60 mpg. With such instances of progress being *announced*, imagine what's going on behind closed doors. Ultimately hypercars will save, probably at a substantial profit, as much oil worldwide as OPEC now sells.

Americans throw away enough aluminum to rebuild the country's commercial aircraft fleet every three months, even though recycling aluminum takes 95% less energy than making it from scratch.

- Many energy savings reduce climatic threats from more gases than just CO_2, thus yielding even more climatic protection per dollar.[57] Advanced refrigerators can save over 90% of standard refrigerators' energy, and thus avoid burning enough coal to fill the refrigerator every year, but their vacuum insulation and helium-engine coolers also eliminate climate- and ozone-disrupting CFCs from insulation and refrigerant.[58] Landfill and coal-mine gas recovery turns heat-trapping and hazardous methane emissions into a valuable fuel while making electricity that displaces coal-burning. Recycling paper (the average person in a rich country uses as much wood for paper, mostly wasted, as the average person in a poor country uses for fuel) saves it from turning cellulose's carbon into landfill methane, and also saves fossil-fueled manufacturing and transportation. Superefficient cars simultaneously reduce at least eight classes of heat-trapping gases. These and scores more examples represent business opportunities with multiple profit streams.

WHAT DO YOU DO WHEN EFFICIENCY RUNS OUT?

Critics of climate-change mitigation point to a growing world population, many of its members desperately poor, who are projected to need far more energy to attain a decent life. Yet economically and pragmatically, the best energy option for developing nations too is greatly increased energy efficiency. This offers even greater relative scope, and meets an even more urgent developmental need, in the South than in the North, because the South, on average, is three times less energy-efficient to start with. But global development will also require energy production. Where will it come from if not fossil fuels?

Such firms as British Petroleum, Shell, and Enron are investing heavily in renewables—for good reason.[59] London's Delphi Group has advised its institutional-investor clients that alternative energy industries not only help "offset the risks of climate change," but also offer "greater growth prospects than the carbon fuel industry.[60]" In 1990, five U.S. National Laboratories reported that either fair competition plus restored research priority,[61] or proper counting of environmental benefits, could cost-effectively expand renewable energy output to three-fifths of today's current total U.S. energy use; renewable electricity supply could be one-fifth *more* than present usage.[62] In 1997, a heavily peer-reviewed five-Labs study[63] found that efficiency, renewables, and other low-carbon options could hold 2010 U.S. carbon emissions at about the 1990 level, reducing the carbon intensity of the economy at a 1997–2010 average rate of 2.3–2.5% per year, at "net economic costs—under a range of assumptions and alternative methods of cost analysis—[that] will be near or below zero.[64]" Just in the buildings sector, reducing the 1990–2010 carbon increase from 26% to 4% would save about $20 billion a year more than it would cost.[65]

Best of all, sunlight is most abundant where most of the world's poorest people live. In every part of the world between the polar circles, freely distributed and efficiently used renewable energy is adequate to support a good life continuously, indefinitely, and economically using present technologies.[66] And this potential, once considered visionary, is starting to be validated in the marketplace. The world's fastest-growing energy source, outpacing even energy savings, is now…windpower, up 26% in a single year (1995–96), and led by Germany (which just overtook American installed capacity), India, Denmark, and Spain.[67] Double-digit annual growth in solar cell shipments is bringing costs steadily down, and counting some of the dozens of kinds of "distributed benefits" can make those cells cost-effective right now in many uses.[68] (The Sacramento utility even found it's cheaper to hook alley lights to solar cells than to the existing wires.) Adding other advanced renewables can cut utilities' carbon emissions by as much as 97% with unchanged reliability and essentially the same cost.[69]

Meanwhile, doubled-efficiency combined-cycle gas turbines, with only one-fourth the carbon intensity of coal-fired power plants, have quietly grabbed more than half the utility market for new stations. But they may not hold that lead for long. The new dark horse is low-temperature polymer fuel cells: equally efficient but silent, clean, reliable, scaleable from large to computer-battery-sized, and likely to transform global power markets.[70] Indeed, converting wellhead natural gas to hydrogen for fuel cells could offer a new option. That separation of hydrogen from carbon is already cost-justified by the fuel cell's high efficiency, so its free byproduct—CO_2—can be reinjected into a depleted gasfield. This cheaply sequesters all the carbon—up to about twice as much as the field's natural gas originally contained—and is nearly paid for by the extra gas recovered by repressurizing the field.[71]

In contrast, the products of socialized costs and central planning have not fared well. The world's slowest-growing energy source is nuclear power—under 1% in 1996, with no prospect of improvement.[72] Despite strenuous effort, its global capacity in 2000 will be a tenth, and its ordering rate is now only a hundredth, of the lowest official forecasts made a quarter-century ago. In America, civilian nuclear technology ate $1 trillion, yet delivers less energy than wood. It died of an incurable attack of market forces. The only question is whether, as many analysts believe, a third or more of U.S. nuclear plants will retire early because their operating and repair bills make them uncompetitive to run. The writing is on the wall: worldwide, around 90 nuclear plants have already retired after serving fewer than 17 years. Even in France, nuclear expansion was outpaced two-to-one by its poor cousin—unheralded, unnoticed, unsupported, but more cost-effective energy efficiency.

The collapse of nuclear power—once the great hope for displacing coal-burning—might at first appear to be bad for climate. But since nuclear power is the costliest way to displace fossil fuels, every dollar spent on it displaces less climatic risk than would have been avoided by spending that same dollar on the best buys first.[73] This opportunity cost is why nuclear power actually makes climatic threats worse rather than better.

From the Firm to the Nation

Whole countries, especially heavily industrialized ones, can achieve big energy savings, and alternative supplies, just by adding up individual ones. During 1979–86, in the wake of the second oil shock, America got nearly five times as much new energy from savings as from all net expansions of supply, and 14% more energy from sun, wind, water, and wood but 10% less from oil, gas, coal, and uranium. By 1986, CO_2 emissions were one-third lower than they would have been at 1973 efficiency levels. The average new car burned half the fuel of 1973 models (4% of that gain came from making cars smaller, 96% from designing them smarter[74]) and emitted almost a ton less carbon per year. Annual energy bills fell by ~$150 billion. Annual oil-and-gas savings grew to become three-fifths as large as OPEC's capacity.[75] In those seven years, GDP rose 19% but energy use shrank 6%. No problem.

All that effort in the '80s only scratched the surface. In 1989, the Swedish State Power Board (Vattenfall) published—without, by order of its CEO, the usual disclaimer saying it didn't represent official policy—a thorough and conservative technical study of Sweden's further potential to save electricity and heat (which Sweden often cogenerates).[76] The team found that fully using mid-1980s technologies could save half of Sweden's electricity, at an average cost 78% lower than making more. That plus switching to less carbon-intensive fuels and relying most on the least carbon-intensive power stations could enable Sweden simultaneously to

- achieve the forecast 54% GDP growth during 1987–2010,
- complete the voter-mandated phaseout of the nuclear half of the nation's power supply,
- reduce the utilities' carbon releases by one-third, and
- reduce the private internal cost of electrical services by nearly $1 billion per year.

If this is possible in a country that's full of energy-intensive heavy industry, cold, cloudy, very far north, and among the most energy-efficient in the world to start with, then countries not so handicapped must have important opportunities too. Sure enough, a year later, a study for the Indian state of Karnataka found that even a limited menu—several simple efficiency improvements, small hydro, cogeneration from sugarcane waste, biogas, a small amount of natural gas, and solar water heaters—would achieve far greater and earlier development progress than the fossil-fueled plan of the state utility, with two-fifths less electricity, two-thirds lower cost, and 95% less fossil-fuel CO_2.[77] These two analyses spanned essentially the full global range of energy intensity and efficiency, technology, climate, wealth, income distribution disparities, and social conditions. Yet they both found that efficiency plus renewables yielded a highly profitable carbon-reducing investment package.

The Karnataka study exposes the twin canards that climate is the North's problem and that reducing the South's carbon emissions would inequitably cripple development. Precisely because energy waste hobbles economic progress, some governments in the South and East have lately been quietly cutting subsidies to energy-intensive industries and even to fossil fuels themselves—the latter more than twice as fast in the South as in the North. Reformers are also opening up the energy sector to greater competition, innovation, and efficiency. Such policies have achieved better overall economic efficiency *and*, as a free byproduct, much lower carbon emissions. Such countries are saving carbon about twice as fast as OECD countries have committed to do, and they're probably saving more carbon in absolute terms than OECD countries actually will do, while boosting their own economic growth.[78] In short, they're saving energy for *economic* reasons and reaping the incidental environmental benefits. Among the strongest economic advantages is that building, for example, superwindow and efficient-lamp factories instead of power stations and transmission lines requires a thousandfold less capital.[79] Such demand-side investments also pay back their cost about ten times as fast for reinvestment, thus liberating for other development needs the one-fourth of global development capital now consumed by the power sector.[80]

> **By 1986, CO_2 emissions were one-third lower than they would have been at 1973 efficiency levels. The average new car burned half the fuel of 1973 models and emitted almost a ton less carbon per year.**

China has three times the energy intensity of Japan, which itself has surprisingly big efficiency opportunities still untapped.

But China is improving rapidly. Spurred by energy shortages that idle an estimated 25–30% of its manufacturing capacity, China now gets a quarter of its total primary energy from renewables and over an eighth of its electricity from cogeneration. It's converting all large industrial boilers to cogeneration. It's cut its coal subsidies from 37% to 29% (1984–95) and its oil subsidies from 55% to 2% (1990–95). These and other policy initiatives reduced the 1980–90 growth in China's carbon emissions by 40%, nearly all through better technologies.[81] Now, encouraged by internal rates of return on recent manufacturing energy efficiency projects all exceeding 12% and usually exceeding 20%, China is tackling a further savings potential which the World Bank last year estimated would reach in 2020 a level greater than China's entire 1990 energy consumption.[82] In steelmaking alone, best practice could reduce China's typical 1990 energy per ton by 64% promptly and 82% ultimately.[83] And there is a huge potential for profitable Chinese supply-side substitutions, ultimately including the displacement of coal by an East Asian natural-gas grid comparable to today's pan-European one.[84] Combined-cycle gas-fired power stations emit only about one-fourth as much CO_2 per kWh as do coal-fired stations, are faster and cheaper to build, and free up coal-hauling rail capacity. They can also be easily sited at industrial complexes so their waste heat can be reused as described above, boosting their efficiency from nearly 60% to about 90%.

Energy savings since 1973 have cut America's energy bill by $150–200 billion a year *and* carbon emissions by one-fourth.

Similarly encouraging conclusions have been found at scales ranging from California[85] and New England[86] to western Europe[87] and the world.[88] Studies for the governments of Canada[89] and Australia[90] confirmed that ~20% CO_2 cuts would be highly profitable. In Australia, for example, a 36% energy and 19% CO_2 reduction from projected 2005 levels would save $6.5 billion (Australian) of private costs per year by 2005, because each $5 invested in efficiency would save $15 worth of fuel purchases *and* 1 ton of CO_2.[91] A new U.S. study similarly found that saving 26% of carbon emissions and 15% of primary energy by 2010 would also save 13% of national energy costs—$85 billion a year, or $205 per ton of avoided carbon emissions, or $530 per household per year—and create nearly 800,000 net jobs. Investments in more efficient energy-using devices to 2010 would average $29 billion a year, but direct monetary savings would average $48 billion a year, excluding any value of stabler climate and cleaner air.[92]

Such profitably efficient energy futures are simply a logical extension of past achievements. Energy savings since 1973 have cut America's energy bill by $150–200 billion a year[93] *and* carbon emissions by one-fourth. We did all that quietly, easily, and profitably—but now we know how to do far better: America, and the world, have barely begun to capture the energy efficiency that's available and worth buying. Modern cars, after a century of devoted engineering refinement, use only 1% of their fuel energy to move the driver.[94] An ordinary light-bulb converts only 3% of the power-plant fuel into light. The entire U.S. economy is only about 2% energy-efficient compared with what the laws of physics permit. National materials efficiency is even worse: only about 1% of all mobilized materials are actually put into and remain in the average product six weeks after its sale. Thus despite impressive achievements so far, America still wastes upwards of $300 billion a year worth of energy: more than the entire military budget, far more than the federal budget deficit, and enough to increase personal wealth by more than $1,000 per American per year. That waste begs to be turned into profits.

MARKETPLACE ENERGY SAVINGS: TURNING OBSTACLES INTO OPPORTUNITIES

So if such big savings are both feasible and profitable, why haven't they all been done? Because the free market, effective though it is, is burdened by subtle imperfections that inhibit the efficient allocation and use of resources. It is necessary at the outset, writes Professor Stephen DeCanio,[95] Senior Staff Economist for President Reagan's Council of Economic Advisers,

> …to discard the baggage carried by most economists (the author confesses membership of that much-maligned group) that immersion in a market environment guarantees efficient behavior by the market participants. Much of modern economic theory practically *defines* efficiency as the outcome of competitive market exchanges. But the bloodless "competition" of mathematical general equilibrium models bears only a partial relationship to the actual experience of real firms.

This is tacitly conceded whenever market economists, as a senior government official recently wrote, "are unpersuaded that just because an act seems to make good economic sense it will happen." Many economically rational things *don't* happen—precisely because of real-world obstacles and complexities that aren't reflected in the perfect-market economic models relied upon for the conventional conclusion that saving much energy will require much higher energy prices.[96] In fact, those barriers block economically optimal investment in efficient use of energy in at least eight main ways. The good news is that *each of these obstacles represents a business opportunity*.[97] Consider some examples of how they match up:

Obstacles	***Opportunities***
Capital misallocation Energy is only 1–2% of most industries' costs, and most managers pay little attention to seemingly small line-items, even though small savings can look big when added to the bottom line. Surprisingly many executives focus on the top line and forget where saved overheads go; and without managerial attention, nothing happens. In addition, manufacturing firms tend to be biased toward investments that increase output or market share and away from those that cut operating costs.[98]	A few years ago, the CEO of a Fortune 100 company heard that one of his sites had an outstanding energy manager who was saving $3.50 per square foot per year. He said, "That's nice—it's a million-square-foot facility, isn't it? So that guy must be adding $3.5 million a year to our bottom line." Then in the next breath, he added: "I can't really get excited about energy, though—it's only a few percent of my cost of doing business." He had to be shown the arithmetic to realize that similar results, if achieved in his 90-odd million square feet of facilities worldwide, would boost his corporation's net earnings that year by 56%. The energy manager was quickly promoted so he could spread his practices across the company.
About four-fifths of firms don't assess potential energy savings using discounted-cashflow criteria, as sound busi-	Top finance firms have joined the U.S. Department of Energy to create the International Performance Measurement and

Obstacles

ness practice dictates; instead, they require a simple payback whose median is 1.9 years.[99] At (say) a 36% total marginal tax rate, a 1.9-year payback means a *71%* real aftertax rate of return, or around six times the marginal cost of capital. (For example, before state and then federal standards prohibited worse options, high-efficiency magnetic ballasts, with a 60% real internal rate of return, won only a 9% market share.[100]) Many capital-constrained industries use even more absurd hurdle rates: in some, the energy managers can't buy anything beyond a six-month payback.

Many supposedly sophisticated firms count lifecycle cost only for big items and make routine "small" purchases based on first cost alone. Thus 90% of the 1.5 million electric distribution transformers bought every year, including the ones on utility poles, are bought for lowest first cost—passing up an aftertax ROI of at least 14% a year and many operational advantages, and misallocating $1 billion a year.[102]

Opportunities

Verification Protocol[101] now adopted in more than 20 countries, including Brazil, China, India, Mexico, Russia, and Ukraine. This voluntary industry-consensus approach, like FHA mortgage rules, standardizes streams of energy-cost savings in buildings so they can be aggregated and securitized. Only a year old, the Protocol is creating a booming market in which loans to finance energy (and water) savings can be originated as fast as they can be sold into the new secondary market. Achieving the savings therefore no longer requires one's own capital, can be affordably financed, and needn't compete with other internal investment needs.

A new generation of buildings is overcoming the psychological barrier of supposedly higher capital cost. A hundred case-studies[103] demonstrate that large energy savings, often of 75% or more, can come with superior comfort, amenity, and real-estate market and financial performance—yet *identical or lower* capital cost, because integrated design creates synergies that help displace equipment and infrastructure.

Southern California Edison Company gave away more than a million compact fluorescent lamps because doing that saved energy more cheaply than running power stations could produce it.

Obstacles

If you invest to save energy in your business or home, you probably want your money back within a couple of years, whereas utilities are content to recover their power-plant investments in 20–30 years—about ten times as long. Thus householders (and many corporate managers) typically require tenfold higher returns for saving energy than for producing it,[104] equivalent to a tenfold price distortion. This practice makes us buy far too much energy and too little efficiency. Not fairly comparing ways to save with ways to supply energy means not choosing the best buys first, hence misallocating capital. Until the late '80s, the U.S. wasted on uneconomic power plants and their subsidies (each roughly $30 billion a year) about as much as it invested in all durable-goods manufacturing industries, badly crimping the nation's competitiveness.

High consumer discount rates are especially tough: people used to paying 50¢ for an incandescent light-bulb are often unwilling or unable to pay $15–20 for a compact fluorescent lamp which, over its 13-fold-longer life, keeps nearly a ton of CO_2 out of the air and saves tens of dollars more in power-plant fuel, replacement lamps, and installation labor than it

Opportunities

Arbitrageurs make fortunes from spreads of a tenth of a percentage point. The spread between the discount rates used in buying energy savings and supply are often hundreds of times bigger than that—surely big enough to overcome the transaction costs of marketing and delivering lots of small savings.[105] (Scores of utilities proved this in well-designed '80s and early '90s programs that delivered efficiency improvements at total costs far cheaper than just *operating* existing thermal power stations.[106]) This is the basis of the Energy Service Company concept, where entrepreneurs offer to help cut your energy bills for nothing up front—just a share of the savings. Skilled firms of this type are flourishing worldwide, although the American ESCO industry is still in its shakeout phase, and many Federal agencies don't yet hire ESCOs because of rigid procurement habits.

Southern California Edison Company gave away more than a million compact fluorescent lamps because doing that saved energy more cheaply than running power stations could produce it. SCE then cut the lamps' retail price by about 70% via a temporary subsidy paid not to buyers but to lamp manufacturers, thus leveraging all the markups.[107] Some other utilities costs. It's a good deal, but sounds like too much up-front money out of pocket.

lease the lamps for, say, 20¢ per lamp per month, with free replacements; customers can thus pay over time, just as they now pay for power stations, but the lamps are cheaper.

Most international vehicles for investing in national or utility-level electric power systems consider only supply-side, not demand-side, options and have no way to compare them.[108] The resulting misallocation is like the recipe for Elephant and Rabbit Stew—one elephant, one rabbit.

Rapidly growing new investment funds, partly funded by the climate-risk-averse insurance industry, are bypassing utilities altogether and investing directly in developingcountries' house-level "leapfrog" efficiency-plus-solar power systems. Those often cost less than villagers are now paying for lighting kerosene and radio batteries,[109] and represent a new market of two billion people.

Organizational failures

Old habits die hard. A famous company that hasn't needed steam for years still runs a big boiler plant, with round-the-clock licensed operators, simply to heat distribution pipes (many uninsulated and leaking) lest they fail from thermal cycling; nobody has gotten around to shutting the system down. Why rock the boat to make someone else look good? Why stick your neck out when the status quo seems to work and nobody's squawking?

Columbia University had entrenched practices too. A tough new energy manager, Lindsay Audin, was told to cut 10% off its $10-million-a-year energy bill, with uncompromised service and no upfront capital. Authorizations were painfully slow—until Audin showed the delays were costing $3,000 a day in lost savings, more than the delayers' monthly paychecks. Five years later he was saving $2.8 million a year, 60% of it just in lighting; had won 9 awards and $3 million in grants and rebates; and had brought 16 new efficiency products to market.[110]

Schedules conquer sensible design. One of us called the chief engineer of a huge firm to introduce opportunities like a cleanroom that uses a small fraction of the energy he was used to, performs better, costs less, and builds faster. His reply: "Sounds great, but I pay a $100,000-an-hour penalty if I don't have the drawings for our next plant done by Wednesday noon, so I can't talk to you. Sorry. Bye." The result is "infectious repetitis"—like the semiconductor plant where a pipe took an inexplicable jog in mid-air as if it were going around some invisible obstacle. The piping design had been copied from another plant that had a structural pillar in that location. In short, intense schedule pressures combine with design professionals' poor compensation and prestige, over-specialized training, and utterly dis-integrated processes to yield commoditized, lowest-common-denominator technical design.

Both such designers and their clients can get away with poor design, and probably won't notice it, so long as their competitors use the same methods, consultants, and vendors. But once such striking improvements are introduced to a given market segment, the laggards must adopt them or lose market share. Thus competitive forces can do automatically much of the marketing and outreach normally required. Rocky Mountain Institute, having successfully promoted superefficient buildings and cars by this method, is now helping with a new initiative to overhaul the semiconductor industry, which has $100 billion worth of fabrication plants on the drawing boards worldwide, all very inefficient. The opportunity for clean-sheet redesign is intriguing industry leaders who now understand that they can't compete internationally without leapfrogging over old methods. For example, energy cost per East Asian-made hard-disk drive now differs by as much as 54-fold[111]—many times the margin critical to market share.

Few firms carefully measure how their buildings and processes actually work. Their design assumptions are therefore untested and often incorrect. Their design process is linear—require, design, build, repeat—rather than cyclic—require, design, build, measure, analyze, improve, repeat. No measurement, no

The late economist Kenneth Boulding said hierarchies are "an ordered arrangement of wastebaskets, designed to prevent information from reaching the executive." But letting viscous information flow freely to those who need it stimulates intelligence, curiosity, and profits. At a large hard-disk-improvement. And no discoveries—like the plant that for decades had been unwittingly running a 40-kilowatt electric heater year-round under its parking lot to melt snow. Nobody remembered or noticed until measurement found the books didn't balance, and the wiring was traced to track down the discrepancy.

drive factory, the cleanroom operator started saving lots of money once the gauge that showed when to change dirty filters was marked not just in green and red zones but in "cents per drive" and "thousand dollars' profit per year." In another plant, just labeling the light-switches, so everyone could see which switches controlled which lights, saved $30,000 in the first year.

In another plant, just labeling the light-switches, so everyone could see which switches controlled which lights, saved $30,000 in the first year.

Departments often don't or can't cooperate. A noted firm calculated that its proposed new office building should get all-new, superefficient office equipment, because the extra cost of buying it early (rather than waiting for normal turnover) would be less than the up-front savings from smaller cooling equipment. No deal: the chiller was in one budget, office equipment in another. Similarly, Federal buildings are bought from one budget, then operated from another; they may even be forbidden to share investments so as to reduce taxpayers' total costs.

Electric utilities traditionally dis-integrate their operations too. But Canada's giant Ontario Hydro inverted its culture to make end-use efficiency and distribution planning its primary focus and generation an afterthought. Its first three experiments in meeting customers' needs by the cheapest means—typically demand-side investments plus better wires management—rather than reflexively building transmission and generating capacity cut its investment needs by up to 90%, saving US$600 million.[112] Such achievements can motivate deep structural and cultural reforms.

If you save, the beancounters simply cut your budget some more. Institutional or personal rewards for cutting energy costs are rare, even in the private sector. It's equally hard to prime the investment pump so savings from one project can help pay for the next.

Washington State routinely shares the savings between their achievers, the General Fund, and an account reserved for reinvestment in more savings. The 1997 Federal Energy Bank Bill, modeled on Texas's LoanSTAR, would set up a revolving fund for such savings.

Corporate turmoil spoils continuity. Many firms, assuming they'd already done all the worthwhile energy savings, have downsized their energy managers right out of a job, stuffed the task onto other overloaded agendas, and watched it slip to an invisible priority. How many economists does it take to screw in a compact fluorescent lamp? None, goes the joke—the free market will do it. But we all know that somebody actually has to get the lamp from shelf to socket; otherwise the wealth isn't created. In many firms, that somebody doesn't exist.

After Ken Nelson, the sparkplug of the remarkable Dow/Louisiana savings, retired in 1993, a reorganization disbanded his organizing committee, tracking ceased, and it became impossible to evaluate how much progress, if any, continued without him. (Lacking a champion, the neighboring Texas division reportedly never undertook a comparable effort in the first place.) But now Mr. Nelson, like Southwire's Mr. Clarkson and some of their ablest peers, is an independent consultant, sharing his skills with more firms.

Companies full of smart, competent, rational, and profit-oriented people often fail to optimize because of even deeper kinds of inherent organizational failures well described in the economic literature.[113]

Proper measurement and incentives help: a utility that started paying its efficiency marketing staff a dollar for every measured kilowatt they saved quickly found that verified savings got bigger and cheaper—both by an order of magnitude.

Regulatory failures

All but a handful of states and nations reward regulated utilities for selling more energy[114] and penalize them for cutting your bill, so shareholders and customers have opposite goals—with predictable results. Many proposed restructuring efforts would enshrine the same perverse incentive in new commodity-based market rules—rewarding the sale of as many kilowatt-hours as possible at the lowest possible price, rather than rewarding better service at lower cost.[115] Similarly, New York State just cut ConEd's efficiency investments by 95% and is bringing back declining-block rates that make savings unprofitable.[116]

In some (though increasingly rare) cases, obsolete codes, standards (as for cement composition[117]), specifications (including those for corporate and military procurement), and laws actually prohibit sound and efficient practices. Far more often, standards meant to set a floor—like "meets code" (euphemism for "the worst building you can put up without being sent to jail"), or the British expression "CATNAP" (Cheapest Available Technology Narrowly Avoiding Prosecution)—are misinterpreted as a ceiling or as an economic optimum. For example, almost all U.S. buildings use wire sizes equal to National Electrical Code minimum requirements, because the wire size is selected and its cost passed through by the low-bid electrician. But in a typical lighting circuit, the next larger wire size yields about a 169%/y aftertax return.[118] Few electricians know this; even fewer care, since their reward for lower-loss wires is typically a lost bid.

Simple accounting innovations in a few states decouple utilities' profits from their sales volumes, and let utilities keep as extra profit part of whatever they save off their customers' bills. The nation's largest investor-owned utility, PG&E, thus added over $40 million of riskless return to its 1992 bottom line while saving customers nine times that much. In California alone, Governor Wilson's PUC found that efficiency investments rewarded and motivated by this incentive system's emulation of efficient market outcomes, just during 1990–93, had saved customers a net present value of nearly $2 billion. Thoughtful utility restructuring can do the same.

To encourage developers to exceed the minimal energy-saving requirements of building codes, Santa Barbara County entitled overcompliers (by 15–45+%) to jump the queue for approvals—a valuable reward at no cost. Elsewhere, some builders of superinsulated homes that leapfrogged far beyond code requirements have won credibility, and dominant market share, by offering to pay any heating bills over, say, $100 a year, or all utility bills for the first five years' ownership.

The private sector is also starting to highlight profit opportunities from exceeding code minima. The Copper Development Association,[119] for example, publishes wire-size tables optimized to save money, not just to prevent fires. However, these will do little good unless winning bidders are chosen for minimizing lifecycle cost, not just first cost.

In a typical lighting circuit, the next larger wire size yields about a 169%-per-year aftertax return. But an electrician who uses that money-saving wire may lose the bid, which is judged on first cost.

The transportation sector is the fastest-growing and seemingly most intractable source of carbon emissions precisely because it is the most socialized, subsidized,[120] and centrally planned sector of the U.S. economy—at least for favored modes like road transport and aviation. It has the least true competition among modes, and the most untruthful prices, with hidden costs of hundreds of billions of dollars per year for U.S. road vehicles alone.[121] These distortions leverage more billions into otherwise uneconomic infrastructural and locational decisions. In particular, the dispersion of uses that causes so much excessive driving is mandated by obsolete

Strong evidence is emerging that co-locating where people live, play, shop, and work creates such desirable, friendly, low-crime, walking-and-biking-dominated neighborhoods that they yield exceptional market performance.[123] Such co-location, and land-use policies that integrate housing and jobs with transit, can be further encouraged by "locationally efficient mortgages"—the subject of a $1-billion Fannie Mae experiment—that effectively let homebuyers capitalize the avoided costs of the car they no longer need in order to get to work.

single-use zoning rules meant to segregate noxious industries that scarcely exist today. Congestion is specifically caused by non-pricing or underpricing of the road resource: most roads are supported by taxes, not users, so they look free to drivers who behave much as Soviet customers did in demanding a great deal of energy when it looked free. Congestion is not only unpriced, but is further exacerbated by building more subsidized roads that elicit even more traffic, and by requiring developers to provide as much parking as people use when they pay nothing for it.[122] Future generations will marvel that the incredible social costs of these policies—costs intertwined with many inner-city ills—went so long uncorrected: all ways to get around, or not to need to, were never made to compete fairly against each other, and drivers neither got what they paid for nor paid for what they got.

Under a 1997 legal innovation, employers can profit from "cashing out" employee parking spaces—charging fair market value for each space, and paying each employee a "commuting allowance" of equal aftertax value. By monetizing competition between all means of getting to work (or, through sensible land-use or telecommuting, of not needing to), this will typically reduce demand for parking spaces—which often cost $10,000–30,000 apiece[124]—by enough to make employees, employers, and the Treasury all better off.

Real-estate developers can profit from annuitizing perpetual transit passes rather than providing a $25,000 parking place with each housing unit (which yields less but costlier housing). Allowing residents to rent out their daytime parking spaces can yield enough income to pay their home property tax.[125]

Thailand loses a sixth of its GDP to Bangkok traffic jams, so it's building Los Angeles-style freeways that will create more traffic.

Singapore is almost congestion-free because it charges drivers their true social cost and invests the proceeds in effective public transit and coordinated land-use.

Informational failures

The extremely high returns implicitly demanded for buying efficiency often reflect a paucity of accurate and up-to-date information. Do you know where to get everything you would need to optimize your own energy use, how to shop for it, how to get it properly installed, who would stand behind it? If any of the preceding examples of big, cheap savings surprised you, you've just observed a market barrier: if you don't know something is possible, you can't choose to do it.

Misinformation is also a problem. The United States, for example, uses about 1,000 megawatts continuously (the output of one Chernobyl-sized power station) to run television sets that are turned off. Adding VCRs' and other household devices' standby loads roughly quintuples this waste. It's typically described as a convenience feature (no warm-up delay, TV turns on at previously selected channel, etc.). But few customers or manufacturers realize that exactly the same convenience is available with 80–95% less standby power. Similarly, few customers, vendors, or plumbers know that the best high-performance showerheads can deliver just as wet, strong, and satisfying a shower as poorly designed models that use 2–6 times as much hot water.

Labeling tells buyers how competing models compare. Some voluntary labeling systems (as of a quarter-million San Francisco houses in 1978–80) have swept the market because buyers quickly became suspicious of any house that *wasn't* labeled. EPA's voluntary Energy Star standard for office equipment did the same, now embracing over 2,000 products by more than 400 manufacturers, because the efficient machines worked better, cost the same or less, and were therefore mandated for federal purchasing. They're saving a half-billion dollars a year, could nearly double that by 2000, and promise a profitable ten-million-ton-a-year carbon saving by 2005. Other voluntary programs that provide informational, technical, and trade-ally support, like EPA's Green Lights,[127] are succeeding because they create competitive advantage. Involving more than 2,300 organizations, Green Lights' retrofits save over half the lighting energy with 30% ROI and unchanged or improved lighting quality. The national potential for this effort alone is a $16-billion annual saving, plus a 12% reduction in utilities' carbon and other emissions.[128] Just the new EPA voluntary standard to reduce unnecessary standby energy in TVs, VCRs, etc. can save, at zero cost, about eight million tons of carbon per year—as much as eight million cars now emit.[129]

"Hassle factor" and transaction costs prevent efficient microdecisions in day-to-day life. For example, how much do you pay at home for a kilowatt-hour of electricity, and how many kilowatt-hours does your refrigerator—typically the biggest single user in the household unless you have electric

It's precisely to make such decisions hassle-free—and because most appliances are bought not by billpayers but by landlords, homebuilders, and public housing authorities—that Congress almost unanimously approved mandatory efficiency standards for household appliances. They merit extension to space or water heating—use each year? If you don't know, because you're too busy living to delve into such minutiae, then you're part of another market barrier. And if you do know, then there's probably another barrier, because for the same price, you could have bought a seemingly identical refrigerator 2–3-fold more efficient, or nearer 20-fold with advanced techniques not yet brought to the mass market.

some commercial and industrial devices too. Such standards knock the worst equipment off the market and reward manufacturers for continuous improvement. That's largely why careless shopping for a same-priced refrigerator can sacrifice only 2–3-fold efficiency gains in America, *vs*. 6-fold in Europe. Smart utilities also reinforce standards by rewarding customers for beating them.

Risks to manufacturers and distributors

Industry lacks information too—about what customers really want and whether they'll put their money where their mouths are. Manufacturers often hesitate to take the risk of developing and making new energy-saving products, because of limited confidence that customers will buy them in the face of all the obstacles listed here. For example, the Idaho National Engineering Laboratory has developed a very promising and affordable ultralight elevated train called CyberTran,[130] but it's so different from conventional trains that manufacturers aren't sure it will sell, so nobody is yet making it, so nobody can buy it—even though it appears able to relieve many communities' road congestion at far lower cost than building more roads, and without needing land.

Swedish official Hans Nilsson pioneered contests for bringing efficient devices into the mass market. A major public-sector purchasing office issues a Request for Proposal guaranteeing to buy a large number of devices, bid from certain prices, if they meet certain technical specifications, including energy savings highly cost-effective to the user. This explicit expression of market demand has already elicited many important innovations giving a strong advantage to Swedish industry in both home and export markets. A "golden carrot" devised by Dr. David Goldstein of the Natural Resources Defense Council followed suit, improving U.S. refrigerators.[131] Pioneer customers could also be encouraged to try such technologies as CyberTran by a system analogous to one EPA formerly used: the first adopters of an innovative wastewater treatment system would get a free replacement with a conventional alternative if the novel one didn't work.

Efficient equipment often isn't available when and where it's needed—as anyone knows who's tried to replace a burned-out water-heater, furnace, refrigerator, etc. on short notice. Yet distributors, aware of the slow uptake of efficient devices, don't want to take the risk of carrying inventory that may sell slowly or not at all. Thus British Columbia Hydro found that the huge motors in that Province's mining and pulp-and-paper mills were virtually all inefficient, simply because that's what local vendors customarily stocked; anything else took too long to order, and the mills couldn't afford to wait.

B.C. Hydro paid a small, temporary subsidy to stock only efficient models, covering vendors' extra carrying cost. In three years, premium-efficiency motors' market share soared from 3% to 60%. The subsidy was then phased out, supported by a modest backup standard. Similarly, PG&E found in the '80s that rather than paying customers a rebate for buying efficient refrigerators, it could improve refrigerator efficiencies faster, at less than a third the cost, by paying retailers a small bonus for each efficient model stocked, but nothing for stocking inefficient ones. The inefficient models quickly vanished from the shops, so when you wanted the next unit the dealer could put on the truck, it'd be efficient, because that's all they'd have.

Corporations may think they won't be liable for their products once sold to someone else—then be unpleasantly surprised by laws and litigation that pursue deep pockets back through the value chain. This uncertainty leads to inefficient defensive behavior and discourages choices that minimize societal cost.

Under the "cycle principle" pioneered in Germany, manufacturers own their products forever. This leads to design for minimum lifecycle (cradle-to-cradle) costs and maximum lifecycle efficiency. Both then become new sources of profit, as illustrated by the remanufacturing and service-leasing ex amples given elsewhere.

Perverse incentives

Compensation to architects and engineers worldwide is based directly or indirectly on a percentage of the *cost* of the building or equipment specified. Designers who work harder to eliminate costly equipment therefore end up with lower fees, or at best with the same fees for more work. Such backwards incentives have led the U.S. to misallocate about $1 trillion to air-conditioning equipment (and utility systems to power them) that wouldn't have been bought if the same buildings had been optimally designed to produce the same or better comfort at least cost.[132]

Pilot projects launched by RMI are now testing how much more efficient buildings become if their designers are rewarded for what they save, not what they spend, by letting them keep several years' measured energy savings as extra profit.[133] Early results are encouraging. The German and Swiss architectural associations are pursuing similar reforms.

The real-estate value chain is full of incentives so perverse that each of the 25 or so parties in a typical large deal is systematically rewarded for inefficiency and penalized for efficiency.[134] The 75% energy saving designed for the Chicago office tower mentioned earlier, with instant payback, wasn't bought: the property was controlled by a local leasing office, incentivized on dealflow, that didn't want to delay its commissions a few months by retrofitting before leasing up the building. The building then proved unmarketably costly and uncomfortable, so it had to be sold off to a bottom-feeder. Yet the owner wasn't unsophisticated: it was one of the world's largest fiduciaries.

Careful case-studies are revealing that in well-designed, highly efficient buildings, the better visual, acoustic, and thermal comfort enables people to do about 6–16% more and better work. In a typical office, where people cost 100 times as much as energy, that boost in labor productivity is about 6–16 times as valuable to the bottom line as eliminating the entire energy bill.[134A] Analogous benefits, big enough to create decisive competitive advantage, are also being found in retail sales and manufacturing. These results may help to explain why firms participating in EPA's voluntary Green Lights lighting-efficiency programs showed stronger earnings growth than nonparticipants.[135] Increasingly educated tenants will not long tolerate buildings that don't contribute to their success.

Pilot projects are now testing how much more efficient buildings become if their designers are rewarded for what they save, not what they spend, by letting them tap some energy savings as extra profit.

Split incentives—one party selecting the technology, another paying its energy costs—limit ultimate consumers' choices by substituting intermediaries who don't bear the cost of their poor decisions. This issue is ubiquitous. Why should you fix up your rented premises if you don't own them? Why should the landlord do it if you pay the energy bills? Alternatively, if you *don't* pay the bills, why use energy thoughtfully (for example, why maintain or efficiently drive a company car whose costs are paid for you)? In the Shanghai pumping example above, the pipefitters don't mind putting in lots of extra bends, because they're paid by the hour and they won't pay the equipment or electricity bills. Efficiency measures used in owned space often aren't in rented.

Lease riders can fairly share savings between landlords and tenants so both have an incentive to achieve them. Energy utilities could also (as some water/wastewater utilities already do) apply "feebates" to new building hookups: you pay a fee or get a rebate to connect to the system, but which and how big depends on how efficient you are, and each year the fees pay for the rebates. Unlike building codes and appliance standards—which are better than nothing, but become instantly obsolete and offer no incentive to beat the standard—such a revenue-neutral economic instrument drives continuous improvement. It also signals lifecycle costs up front, when the long-term investment decisions are being made.[136]

Obstacles	Opportunities
Similar split incentives apply to the makers and users of all kinds of equipment used in buildings and factories. Such equipment is almost always inefficient and designed for low first cost alone, since those who sell it won't pay the operating costs and most buyers won't shop carefully. (Indeed, for most kinds of equipment, efficient equipment simply isn't available—until a big customer demands better, as Wal-Mart successfully did for daylighting and air-conditioning equipment.)	The world's largest maker of air conditioners, Carrier Corporation, is leasing comfort services—much as elevator-maker Schindler leases vertical transportation services and Dow leases solvent services. This improves not only resource efficiency but also incentives: the *more* efficient, durable, and flexible Carrier's air-conditioning systems become, the *greater* its profits, and the better the service it provides at lower cost to more customers. Service leasing aligns the providers' incentive with their customers' objective.
In one respect the market works all too well: wasteful old equipment often gets salvaged for resale in the secondary market—mainly to poor people who can least afford the high running costs that motivated the scrappage in the first place. Such "negative technology transfer" can cripple development efforts.[137]	Some big California utilities buy up inefficient old motors, refrigerators, and other devices in order to scrap them before they enter the second-hand market: they're worth far more dead than alive. Unocal even bought and scrapped numerous polluting old cars in order to gain pollution credits for its refinery near Los Angeles.

False or absent price signals

Obstacles	Opportunities
Energy prices are often badly distorted by subsidies and by uncounted external (larcenous) costs not internalized by the Clean Air Act's laudable trading system. The U.S. in 1989 still subsidized energy supply by about $21–36 billion per year,[138] mostly for the least competitive options and essentially all for supply. Significant costless (or better) reductions in carbon emissions are therefore available just by removing subsidies,[139] a process already underway. And that doesn't count even bigger subsidies to security of supply that make the true cost over $100 per barrel[140] for Persian Gulf oil.[141] (Yes, more was at stake in the Gulf War than just oil, but we'd hardly have sent a half-million troops there if Kuwait just grew broccoli.)	Subsidies are under increasing pressure by a more skeptical Congress, a better-informed public, and more transparent prices. Utility regulators in about 30 of the United States also take account of some externalities in considering utilities' proposed resource acquisition decisions. Some proposals for industry restructuring would worsen but others would help to correct these longstanding distortions, improving economic efficiency. Global annual energy subsidies are estimated to have fallen from about $350–400 billion in the early 1990s to about $250–300 billion in the mid-1990s.[142] Their further transparency and reduction will reduce the risk of making investments not justified by fundamentals.
Energy price signals are diluted by other costs. For example, U.S. gasoline, cheaper than bottled water, is only an eighth of the total cost of driving, even though the car is cheaper per pound than a Big Mac. Why buy a 50- instead of a 20-mpg car when both cost about the same per mile to own and run?	Feebates (above) can reward turning over big capital stocks like car fleets more quickly, getting the worst ones off the road soonest. This offers a huge new market opportunity—especially if the rebate for your efficient new car depends on the *difference* in efficiency between the new one you buy and the old one you scrap.
Few firms track energy costs as a line-item for which profit centers are accountable. Firms in rented space may have energy bills prorated rather than submetered. Most billing systems give no end-use information that lets customers link costs to specific devices. Many firms, especially chains and franchises, never even see their energy bills, which are sent directly to a remote accounting department for payment. Some large firms still assume that utility bills are a fixed cost not worth examining.	New bill-paying and -minimizing service companies are springing up to met exactly this need. Many provide submetering and two-way communications to pinpoint opportunities for improvement. Such simple efforts as ensuring that each meter generating a bill is actually on the customer's premises often generate big savings.

Obstacles	*Opportunities*
Appraisers rarely credit efficient buildings for their actual energy savings, so efficiency's value isn't capitalized. Most leasing brokers base pro forma financials on average assumed operating costs, not actual ones. Few buildings have efficiency labels. Few renters have access to past energy bills.	Some jurisdictions have right-to-know laws; others get similar results by training renters and buyers to be assertively inquisitive. Smart leasing brokers are distinguishing their services by offering valuable advice on minimizing occupancy costs. Home and commercial-building energy rating systems are rapidly emerging.
Tax asymmetries further distort energy choices. For example, energy purchases are deductible business expenses, but investments to save energy get capitalized.	Some countries do better. When the Japanese government wanted to clean up sulfur emissions from power plants, it allowed scrubbers to be expensed in one year.
Market prices don't include many environmental costs and risks: the Clean Air Act, for example, created a cap-and-trade regime for sulfur but not for carbon emissions.	The Natural Resources Defense Council published an index of relative exposure to carbon-tax risks for all U.S. utilities, and let capital markets adjust ratings accordingly.

Global annual energy subsidies are estimated to have fallen from about $350–400 billion in the early 1990s to about $250–300 billion in the mid-1990s.

Incomplete markets and property rights

Obstacles	*Opportunities*
There is no market in saved energy: "negawatts" aren't yet a fungible commodity subject to competitive bidding, arbitrage, secondary markets, derivatives, and all the other mechanisms that make efficient markets in copper, wheat, and sowbellies. You can't yet go bounty-hunting for wasted energy, trade negawatt futures and options (or bid them in a spot market against megawatts), or even, in general, bid them fairly against expansions of energy supply. You can seldom sell reduced demand or reduced uncertainty of demand; yet both are valuable resources that deserve markets. Property rights in most forms of depletion-and-pollution avoidance are incomplete or absent and hence cannot be traded.	When Morro Bay, California, ran short of water, it simply required any developer wanting a building permit to save, somewhere else in town, twice as much water as the new building would use. Many creative transactions occurred as developers discovered what saved water is worth. Two-fifths of the houses were retrofitted with efficient fixtures in the first four years. A more comprehensive market transformation effort enabled Goleta, California, to cut per-capita residential water use by over 50%, and total water use by over 30%, in one year and with no loss of service quality—thereby deferring indefinitely a multi-million-dollar wastewater-treatment-plant expansion.

Compare the "actually existing market" in the left column above with the requirements of a *theoretical* free market: perfect information about the future, perfectly accurate and complete price signals, perfect competition, no monopoly or monopsony (sole buyer), no unemployment or underemployment of any resource, no unmarketed resources, no transaction costs, no subsidies, no barriers to market entry or exit, and so forth. It's a whole different universe. But under *actual* market conditions, can energy efficiency be implemented rapidly without the high energy prices that many economists and businesspeople fear?

EVEN CHEAP ENERGY CAN BE SAVED QUICKLY

Energy efficiency can be implemented very rapidly, by either or both of two quite different methods. One method, inadvertently demonstrated in the 1970s and '80s, is to have high or rising energy prices and a sense of urgency:

- During roughly 1975–85, most new U.S. energy-using devices—cars, buildings, refrigerators, lighting systems, etc.—*doubled* their efficiency, improving at an annual rate averaging around 7%.

- If all Americans saved electricity as quickly and cheaply as ten million people served by Southern California Edison Company did during 1983–85, then each year they'd decrease the forecast need for power supplies a decade hence by about 7%, at a cost to the utility around one-tenth that of today's cheapest new power stations.[143]

- In the 1980s, skillful utilities captured ~70–90+% of particular efficiency micromarkets, mainly difficult ones like retrofitting house shells, in just one or two years.

- Speed can extend to renewables as well as efficiency. Maine used auctions and other competitive processes to raise its private share of power generation from 2% in 1984 to 20% in 1989 to 36% in 1995—and more than two-thirds of that new production was renewable.

Of course, a lot has changed since the '80s. At first, U.S. primary energy consumption "froze at about 74 quads" (quadrillion BTU per year) during 1973–86 "while the GNP grew by 35%.[144]" Those huge energy savings largely caused the mid-1980s crash in energy prices. This in turn retarded further savings[145]: "Starting in 1986, [real] energy prices began their descent…that has continued to the present. As a result, energy demand grew from 74 quads in 1986 to 91 quads in 1995"—a 22% increase, while GDP grew 23%. With more fuel being burned, "carbon emissions have been increasing at a similar pace.[146]"

This history makes it natural for economists to suppose that since costly energy formerly propelled rapid energy savings, the only way to return to rapid energy savings is to return also to costly energy. But price is not the only tool available, and lower fuel prices needn't bar us from regaining energy efficiency's former momentum. Today's better technologies and smarter delivery methods can far outweigh the lower energy prices and the used-up initial opportunities, achieving quick savings even *without* re-creating the spur of high prices:

- During 1990–96, utility facilitation enabled electric customers in Seattle—with the cheapest electricity of any major U.S. city—to save electric load nearly 12 times as fast as those in Chicago, and electric energy more than 3,600 times as fast, even though Seattle's electricity prices are about half of Chicago's.[147] This conclusively shows that making an informed, effective, and efficient market in energy-saving devices and practices—as Seattle City Light's efforts helped to do—can substitute for a bare price signal, and indeed can influence energy-saving choices even more than can price alone. That is, *people and firms can save energy faster if they have extensive ability to respond to a weak price signal than if they have little ability to respond to a strong one*.[148]

People and firms can save energy faster if they have extensive ability to respond to a weak price signal than if they have little ability to respond to a strong one.

- Investor-owned utilities, when rewarded for cutting bills, sold efficiency ever faster and more skillfully despite falling electricity prices. In 1990, New England Electric System captured 90% of a small-commercial pilot retrofit market in two months. Pacific Gas and Electric Company captured 25% of its entire new-commercial-construction market—150% of the year's target—in three months, so it raised its 1991 target… and achieved the entire goal in the first nine days of January.

Costly energy does ultimately improve energy efficiency; that's why high-energy-price countries like Japan approach twice the aggregate energy efficiency of the low-energy-price United States. However, this re-equilibration can be very slow, and higher energy prices do not automatically yield substantial energy savings—as illustrated by the identical electricity-using devices found in U.S. cities that pay severalfold different electric rates, or the identical savings opportunities that DuPont has found in its U.S. and European plants in the 1990s despite longstanding twofold energy price differences across the Atlantic.[149]

Nor conversely, as the Seattle/Chicago comparison shows, do low energy prices preclude rapid energy savings where policy encourages and supports them. Thus higher energy prices do help spur savings and reflect true social costs. But high energy prices are neither a necessary nor a sufficient condition for economically and technically efficient use of energy: not necessary because vast savings are already worthwhile at present prices but blocked by the barriers described earlier, and not sufficient because the same obstacles, if not deliberately removed, would persist even at higher prices.

Honest energy prices do increase economic efficiency: if we don't know what energy really costs, we won't know how much is enough. *Combining* desubsidized and internalized energy prices with policy "trimtabs" that reduce the barriers would yield the fastest possible savings. This means putting a new category at the top of the policy slate: all the public and private policy innovations, some mentioned above, that will specifically turn barriers into profits. It also means recognizing that many new energy-saving technologies—like jet aircraft, laptop computers, and compact disks before them—can be adopted largely because they provide better *service*, not because they save money: their qualitative superiority can largely decouple them from traditional preoccupations with price signals.

Furthermore, the most balanced and farsighted context in which to approach price is not to focus specifically on *energy* prices, but to shift taxation from jobs and income to *all* forms of resource depletion and pollution. The British, Danes, Dutch, Finns, and Swedes are starting to use revenues from environmental taxes to cut taxes on labor. In contrast, today's outmoded U.S. tax system penalizes work and employment while often subsidizing depletion and pollution. The present system rewards, and therefore gets, just the opposite of what we want. In a 21st-century world of more abundant people and scarcer natural capital, it makes good theoretical and practical business sense to rebalance factor inputs by correctly signaling their relative scarcities.[150] This is consistent with recycling carbon-related revenues into reducing distorting taxes on employment, income, and investment—an important policy option well known to improve overall economic efficiency.[151]

ENERGY PRICES AND NATIONAL COMPETITIVENESS

If, for whatever reason, the price of emitting CO_2 into the atmosphere *were* raised above its current value of zero, Americans need not fear damage to national competitiveness. After all, the nations that have traditionally been the toughest competitors, like Japan and Germany, have long had energy prices two to three times U.S. levels. Over the long run, this has simply made them use their energy about twice as efficiently. Learning how to do that drove their industrial innovation on a broad front, further widening the competitive gap against a cheap-fuel America.

Similar flexibility, and more, exists in our own economy—as Americans have already proved by invisibly cutting the nation's annual energy bill by some $150–200 billion[152] compared with 1973 levels of inefficiency. And there's a hidden bonus: just as energy efficiency created the conditions that crashed world oil prices in 1986 and have made them decline ever since, triggering a durable boom,[153] so repeating and accelerating that success can continue to suppress OPEC's cartel power and dampen oil prices. This would cut America's oil trade deficit ($61 billion in 1996 alone) while not causing material adverse trade shifts of other kinds.[154]

What about the flip side of that argument: that launching major energy savings first in the North and then expanding them to the South[155] puts the North at a competitive disadvantage? This superficially plausible contention[156] is simply a relic of the old view that energy efficiency is a burden rather than an advantage. Since efficiency is actually profitable, those who adopt it first will reap the greatest and earliest rewards.

Of course, efficiency has different costs in different places, so the global trading system proposed by the Clinton Administration would enable American firms to buy savings in the South whenever that's cheaper than capturing them first at home. (The World Bank has offered to serve as a market-maker for such transactions.[157]) Such best-buys-first flexibility will further boost U.S. companies' profits while drawing in the South's participation and speeding its economic development. As noted earlier, many countries in the South are *already* rapidly correcting their own energy inefficiencies for just that reason.

Nor need we fear that costlier energy in industrial countries, if it occurred at all, would make American jobs (and carbon emissions) flee to an untaxed South—akin to the "pollution haven" notion that analysts have vainly sought in the data. Electricity prices would be the most sensitive to any carbon tax or emissions trading; yet 1994 electricity bills averaged only 1.3% of the value shipped by average U.S. manufacturing firms, 3.4% for the most electricity-intensive sector (pulp and paper).[158] If electricity is too small a factor cost to worry about saving, it's hardly big enough to justify moving one's factory overseas. Conversely, if its price rises enough to motivate moving abroad, it's certainly a strong enough reason to save most of that electricity, at a profit, and stay home.

After all, a small saving in such a tiny factor cost is far less important to industrial competitiveness than the manyfold saving that's *already* available in the biggest factor cost—labor. Yet most American jobs have remained here: firms that haven't already exported jobs in search of cheap labor have generally concluded that other countries don't have the infrastructure, skills, local markets, laws, tax rules, or other conditions they need. Differences in energy price would be a much weaker incentive to migrate—as we can infer from American firms' failure to move to the few countries, like Venezuela and Saudi Arabia, that have long had even cheaper energy than we do. Another thought-experiment reveals the absurdity of this notion that energy prices are the sole or main determinant of industrial location: if that were true, then Japan and Europe would long ago have transplanted all their factories to America to take advantage of *our* severalfold lower energy prices. They didn't.

Climate policymakers who prefer pricing to obstacle-busting policy instruments contemplate energy price increases far smaller than the differences that *already* exist: for example, a 1–2¢/kWh rise in electricity price would be less than the differences that already exist between different parts of the United States, or even between some adjacent utilities, without triggering industrial mass migrations. Japanese industry pays about *10¢*/kWh more than its American counterparts, but as Japan long ago discovered, even such a threefold difference in energy price can be offset by more productive energy use. *That* is the durable source of competitive advantage; and it's far easier to sustain amidst the rich infrastructure and skill base of the North than of the South, so migrating Southwards would generally lose advantage, not gain it.

Using energy far more efficiently does mean that less fossil fuel would be sold than if we continued to waste it so profligately. Lower physical volumes may not mean lower profits, but vendors fear that they would make less profit than expected if demand grew more slowly, or stabilized, or even declined—as it would have done eventually from depletion. (For example, a standard model of stabilizing emissions at 1990 levels through a carbon tax[159] shows U.S. coal output 25% below the rapid growth in its baseline projection—but output would still grow.) Where is it written, however, that coal companies or OPEC countries have an inalienable right to sell ever more of their product—or, as their mouthpieces now urge, to be compensated for lost profits if their hoped-for demand growth slackens or reverses?

If coal consumption fell by half, American consumers could afford to make good the miners' entire lost pay—with $10 billion a year left over. Climate policies threaten miners' jobs much less than do the coal companies, which are cutting 8,000 jobs a year.

This nation has never been good at helping workers or industries in transition, and now might be a good time to get better at it. Much of the Rust Belt is now recovering, but little thanks to outside help. In prospective climate-induced shifts, a similar failure to help coal miners, depressed communities, and even disappointed shareholders will encourage them to oppose measures that benefit society. But those measures are also profitable enough that a just society can afford to ease their difficulties. The total payroll of all U.S. coal-miners is about $5 billion, or 1% of the nation's energy bills—less than spontaneous gains in energy efficiency save in any typical year. If the miners' worst nightmares came true and coal consumption fell by half, American consumers could afford to make good the miners' entire lost pay—with $10 billion a year left over. Climate policies threaten miners' jobs much less than do the coal companies, which during 1980–94, while output rose 25%, have eliminated 55% of the miners' jobs for which they profess such concern, and continue to do so inexorably and exponentially at a rate of about 8,000 jobs per year.

As for the shareholders, hard-nosed free-marketeers might say they should have foreseen that climate would become an issue, so they should have invested in natural gas, efficiency, or renewables instead of coal, or in gas pipelines instead of coal-hauling railways. If efficient energy use costs less than coal, then coal will lose in fair competition, and no friend of a thriving economy should wish otherwise. But the best outcome, especially for the workers, would be to structure the incentives so that the companies at risk in the transition will start selling a more profitable mixture of less fuel *and* more efficiency in using it—as a few oil companies and hundreds of electric and gas utilities are already successfully doing to improve both customer service and their own profits. That's the same logic that has already led the likes of BP, DuPont, Ford, Tokyo Electric, Norsk Hydro, and ABB to fund both internal and consortium research to protect the climate while advancing their own business interests.[160]

TIME TO DUMP THE MYTHS

With this understanding of how modern technologies and creatively used markets can profitably protect the climate *and* the economy, we can see the aridity and irrelevance of the myths underlying the conventional climate debate:

- *It's about climate science.* No; it doesn't matter what the climate science says, or even whether it's right, because we ought to be purchasing energy efficiency anyway just to save money.

- *It's about decision-making under uncertainty.* The uncertainty doesn't matter, because the robust economic benefits depend only on private internal costs and benefits, not on any imputed environmental values or risks.

- *It's about carbon taxes.* No; they may be helpful and appropriate, especially as part of a general tax shift from people to resource depletion and from production to consumption, but present prices are ample to elicit all the energy savings we need—if we just get serious about vaulting the barriers that inhibit people from using energy in a way that saves money.

- *It's about command-and-control.* Wrong; it's about helping markets to work properly—and then letting them do their job.

- *It's about who should bear the costs.* What costs? The interesting question is who should get the *profits*. That's a good thing to compete about in the marketplace, but it shouldn't require difficult negotiations.[161] The "polluter pays principle"—OECD doctrine since 1974—remains valid, but this time the polluter can profit.

- *It's about sharing sacrifices for the common good.* On the contrary, it's about helping individuals, firms, and nations to behave in their economic self-interest.

- *It's about "cutting back," shifting to a lifestyle of privation and discomfort*—as the Chairman of Chrysler Corporation recently put it, "dimming the lights, turning off the air conditioning, sacrificing some of our industrial competitiveness and curtailing economic growth.[162]" No; it's about living even better with less cost, by using smarter technologies that yield the same or better service. The showers will be as hot and tingly as now, the beer as cold, the rooms as well-lit, the homes as cozy in winter and as cool in summer, the cars as peppy, safe, and comfortable; but we'll have substituted brains for therms and design for dollars.

- *It's about keeping the poor down.* Quite the opposite; if equitably provided as the cornerstone of the development process,[163] both abroad and at home, energy efficiency could be a special boost for those most burdened with the least efficient buildings and equipment, and least able to afford such waste. Even if the price of fossil fuels did rise, that's not very regressive, because poor people spend more of their income directly on energy but less indirectly (embodied in goods and services). Any disproportionate harm to the poor could be corrected by straightforward adjustments elsewhere in the tax or welfare systems.[164] Equity issues do merit careful attention, but they're no reason to keep on subsidizing energy for the rich.

- *It's about consuming too much in the North and not enough in the South.* That's a real issue, and we in the North should start thinking about what we want, how much is enough, how to meet nonmaterial needs by nonmaterial means, what will make us better human beings, and the difference between a good life and what scripture calls "vanity." But the resource-efficiency revolution[165] can buy much time by simultaneously sustaining or enhancing Northern *and* greatly improving Southern living standards while dramatically reducing the use of energy and materials.

It doesn't matter what the climate science says, or even whether it's right, because we ought to be purchasing energy efficiency anyway just to save money.

Protecting the Climate for Fun and Profit

A proper grasp of the practical engineering economics of energy efficiency (and of other climate-stabilizing opportunities) can thus give nearly all the parties to the climate debate what they want. Those who worry about climate can see it stabilized. Those who don't will still make more money. Those who worry about costs and burdens will see them replaced by profits. Those who want improved jobs, productivity, competitiveness, quality of life, public and environmental health, and individual choice and liberty will get those things too. Two emphases—energy efficiency, and climate-protecting farming and forestry practices that treat nature as model and mentor—can deal profitably not only with climate but with about 90% of EPA's pollution and public-health concerns. These actions are therefore are not inimical but vital to a vigorous economy, a healthful environment, sustainable development, social justice, and a livable world. In short, as eight Nobel economists supported by more than 2,600 of their colleagues recently concluded, "policy options exist that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run."[166]

The true pragmatists in this debate are those who suggest that we have at hand—and should elevate to the central role in climate policy—the market-transformation tools that can turn climate into a business opportunity, at home and abroad. This can, but need not, include changing energy prices. Innovative, market-oriented public policies, especially at a state and local level, can focus chiefly on barrier-busting to help markets work properly and reward the economically efficient use of fuel.[167] This requires much *less* intervention in the market than we now have with regulatory rules and standards: it properly assumes that the role of government is to steer, not row, and that market actors guided by clear and simple rules can best figure out what will make sense and make money. But we need to steer in the right direction—the line of least resistance and least cost—guided by a detailed and exact understanding of the barriers that now block energy efficiency, and thereby damage global development and national security.[168]

A bizarre irony lurks beneath the climate debate. Why do the same people who favor competitive markets in other contexts seem to have the least faith in their efficacy for saving fossil fuels? Let's recall what happened the last time this gloom-and-doom attitude overcame those people's better instincts. Just before Congress approved in 1990 the cap-and-trade system for reducing sulfur dioxide emissions,[169] environmentalists predicted that reductions would cost about $350 a ton, or ultimately (said the optimists) perhaps $250. Government economic models predicted $500–750; the higher figure was the most widely cited. Industry models upped the ante to about $1,000–1,500. In fact, though the comparison between predicted and actual values is more complex than meets the eye,[170] the sulfur-allowance market opened in 1992 at about $250 a ton; in 1995, it cleared at $130 a ton; in 1996, at $66.[171] Moreover, national sulfur emissions have fallen 37% in just the past decade—and 38% faster than the Clean Air Act envisaged, because of simple incentives to reward early achievers. Much the same thing is happening with CFCs.[172]

The genius of private enterprise and advanced technologies found a way billions of dollars cheaper than command-and-control regulation. It would do so again if we competed to save the most carbon in the cheapest ways. In fact, an environmental double bonus for business would emerge: we'd automatically and profitably meet most of the stringent new ozone and fine-particle standards too, via the same reduced combustion that helps the climate and cuts our energy bills; and we could easily use similar incentives for doing so early.

In the past half-century, global carbon emissions have quadrupled. But in the next half-century, the climate problem could become as faded a memory as the energy crises of the '70s are now[173]—because it's not an inevitable result of normal economic activity, but an artifact of energizing that activity in irrationally inefficient ways.

Let's vault the barriers, use energy in a way that saves money, and put enterprise where it belongs: in the vanguard of sound solutions. Climatic change is a problem we can't afford, don't need—and can avoid at a resounding profit.

* * *

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NOTES

[1] Browne 1997.
[2] Samuelson 1997.
[3] *E.g.*, Lovins *et al*. 1981, ICF 1990, Okken *et al*. 1991, Evans 1992, IPSEP 1993 & 1994–8, Koomey *et al*. 1994, Krause 1996, Brown & Levine 1997.
[4] It is not necessary that *every* carbon mitigation be profitable, since those that are can help offset the cost of those that do incur a net cost, greatly increasing the total quantity of carbon saved at no net cost: Lovins & Lovins 1991.
[5] The switch to pollution prevention saves $8 billion in the pulp and paper industry alone: AFPA 1994. Similar findings of a USDOE/industry joint exploratory process during 1994–97 include 20% energy savings in glass, 50% in aluminum, and 15% in chemicals: Romm 1997.
[6] Now at El Paso Energy, 1565 Woodington Court, Suite 202, Lawrenceville GA 30044, 770/806-9432, FAX -9482, epemga@bellsouth.net.
[7] Nelson 1993; now at KENTEC, Inc., PO Box 45910, Baton Rouge LA 70895, 504/273-1524, FAX 504/275-7207.
[8] These case-studies are from DOE 1996.
[9] Petzinger 1997.
[10] Romm 1997.
[11] *Id*.
[12] Detailed documentation on each of these matters, omitting only the newest developments such as hypercars, is in the 188 references of an earlier survey paper in the journal of record: Lovins & Lovins 1991. Many older but still useful references are in its decade-earlier predecessor, Lovins *et al*. 1981.
[13] The exact percentages don't matter because such big and profitable savings are available in each gas, source, and sector (*id*.).
[14] NRC 1989, Lovins & Lovins 1991.
[15] But with localized spurts, like New England's 6%/y gains during 1978–80 (the period of the second oil shock). To be sure, national improvements were much faster before the 1986 price crash than since, but if a lower-than-historic rate is to be assumed because greater energy efficiency will continue to lower energy prices, then the stimulative effect of that cheaper energy, and the resulting faster turnover of capital stocks, must also be considered.
[16] Manne & Richels 1990.
[17] OTA 1991, Evans 1992, IPCC 1996, Brown & Levine 1997.
[18] Krause 1996.
[19] Lovins 1995, 1996, 1996a.
[20] Newell *et al*. 1996, Grubb *et al*. 1995, Goulder & Schneider 1996.
[21] Kassler 1994.
[22] Repetto & Austin 1997 at 23–26.
[23] Repetto & Austin 1997.
[24] Nordhaus 1993 & 1994, Nordhaus & Yang 1996, Jorgensen *et al*. 1995.
[25] EPA's 1994 *Emission Trends Report* states that conventional energy use causes 95% of U.S. CO_2 and NO_x emissions, 73% of volatile organic compounds, and 70% of CO, so as *The Economist* remarked in June 1990, "Using energy in today's ways leads to more environmental damage than any other peaceful human activity."
[26] IPPC 1996a.
[27] Ekins 1995, Jorgenson *et al*. 1995, Boyd *et al*. 1995, Statistics Norway 1995.
[28] Repetto & Austin 1997. Such a long-term change is quite small in annual terms: a review of nearly 100 modeling studies showed that holding long-term CO_2 emissions at about current levels (much more stringent than current proposals for stabilizing emissions) "may if carried out in an efficient manner be expected to reduce…average GNP growth rates over the period [to the mid-21st century] by less than 0.02–0.03% per year": Grubb *et al*. 1993 at 472.
[29] Welch 1995.
[30] Average U.S. industrial electricity in 1996 cost the heat-equivalent of oil at about $79 per barrel, over three times the world crude-oil price. Commercial and residential electricity prices averaged respectively 75% and 83% higher yet. Electricity is therefore the most lucrative form of energy to save. It is also the form whose savings yield the greatest climatic leverage: each unit saved saves 3–4 units—in developing and socialist economies, more like 5–6 units—of power-plant fuel, and that fuel is mainly the most carbon-intensive kind—coal. (U.S. electricity is 52% coal-fired, and 89% of U.S. coal makes electricity.) For these reasons, our case-studies focus on new ways to save electricity, although similarly large savings are profitable for most directly used fuels too: Lovins & Lovins 1991.
[31] Mr. Lee is Technical Director of Supersymmetry Services Pte Ltd, Block 73 Ayer Rajah Crescent #07/06-09, 0513 Singapore, 65/777-7755, FAX 779-7608.
[32] RMI 1991.
[33] Davis Energy Group 1994 & 1995, von Weizsäcker *et al*. at 15–19. The lower capitol cost assumes widespread adoption.
[34] Boonyatikarn 1997.
[35] von Weizsäcker *et al*. 1997 at 62, Houghton *et al*. 1992 at 9; the 97% saving assumes the ultimate replacement of the office equipment by more efficient models, as well as the insulation and improvement of existing ducts.
[36] *Id*. at 25–26, ENSAR Group 1991.
[37] Lovins 1995, von Weizsäcker *et al*. at 21–23.
[38] The negative figure means the building would have saved (compared with normally required renovation) a capital investment equivalent to five months' worth of operating cost before it was even turned on.
[39] Howe *et al*. 1996.
[40] Rosenfeld *et al*. 1996.
[41] *Id*. at n8.
[42] The engines are especially inefficient when running air conditioners in cars stuck in traffic (*i.e*., most cars most of the time), and all of the 5–6 GW of electricity brought into the city ends up as heat. Prof. Suntoorn Boonyatikarn of Chulalongkorn University notes in a personal communication (6 June 1997) that together, these heat sources add nearly as much artificial heat per square meter as is delivered by all the sunlight striking

the city. In the nearby countryside, ingenious ventilative and radiative passive designs still work fine.

[43] Shepard *et al*. 1990, RMI 1991.

[44] Lovins & Sardinsky 1988, Piette *et al*. 1989.

[45] Lovins *et al*. 1989, Fickett *et al*. 1990.

[46] For example (Lovins *et al*. 1989): immediately retrofitting an in-service standard induction motor to a premium-efficiency model, without waiting for it to burn out, is commonly assumed to incur an unattractively long (~10–20-y) payback. Yet many U.S. motors are so grossly oversized that probably half never exceed 60%, and a third never exceed 50%, of their rated load. This oversizing often makes actual at-load efficiency lower than the nameplate rating implies, further increases energy waste by spinning fans and pumps too fast, and often enables the replacement motor to be smaller, hence cheaper. Making the new motor the right size therefore reduces the average simple payback of immediate retrofit to ~3 y—frequently less. Counting also the new motor's longer life (because it runs cooler and may have higher-quality bearings) typically makes the immediate-retrofit cost become negative.

In addition, the new motor automatically eliminates any increased magnetic losses that may have been caused by improper repair of the old motor (a widespread practice that GE measurements imply is costing the U.S. about $1–3 billion per year). This plus proper motor sizing yields direct electrical savings roughly twice as big as would be expected from the new motor's better nameplate efficiency alone. The high-efficiency motor also has better power factor and greater harmonic tolerance (hence better operation at variable speed). Thus it provides a half-dozen important operational advantages—but need be paid for only once.

Many of these savings, however, depend on others. For example, not only efficiency but also motor life depends on other energy-saving improvements: reducing voltage imbalance between the phases, improving shaft alignment and lubrication practice, reducing overhung loads (sideways pulls) on the shaft (*e.g*., by substituting toothed, non-stretch, low-tension "synchronous" belts for v-belts), and improving housekeeping—not siting motors in the sun or next to steam pipes, not smothering them beneath multiple coats of paint, etc. Motor choice, life, sizing, controls, maintenance, and associated electrical and mechanical elements all interact intricately. A few interactions are unfavorable, but most make the savings of the whole drivepower package far larger and cheaper than would appear from considering just a few fragmented measures, as most analyses do.

[47] The official 39% saving during 1974–88 was distorted by the 1987 revision to the SIC manual: DOE 1991 at 15.

[48] Just the temperature optimization typically saves 50% in new plants, and pays back in six months in retrofits: Brown & Levine 1997 at 4.36.

[49] Lovins 1995, 1996.

[50] Casten 1997. The emission reduction would be even larger if not conservatively adjusted for plants that might be difficult to convert to cogeneration, those that may meanwhile retire, and premature nuclear-plant retirements.

[51] Groscurth & Kümmel 1989.

[52] Brown & Levine 1997.

[53] Hypercar-like heavy road vehicles look attractive too, and new uses of information technology to smooth or displace the flow of goods can make much freight traffic unnecessary. Major savings are also available in other transport modes. Ships and passenger aircraft doubled their efficiency in the 1970s and '80s and can do it again; the National Research Council has called for 40% less fuel per seat by 2010–15: Brown & Levine 1997 at 5.29. As one hint of what's possible, a 1996 Lock heed-Martin Skunkworks fighter-plane design, made of 95% carbon-fiber and the like, cut weight 35% and cost 65%. Other new vehicles are starting to enter the market, from tenfold lighter and cheaper trains to convertible road-rail vehicles (like GM's Roadrailer) and Lufthansa's freight dirigible to hybrid-electric bikes.

[54] Lovins 1996a, Moore 1996, Lovins *et al*. 1997, Cumberford 1996.

[55] A sophisticated model perhaps a decade or two from now could combine Lexus comfort and refinement, Mercedes solidity and stiffness, Volvo safety, Porsche acceleration, roughly Taurus price, 100–200 miles per gallon-equivalent (the upper range using hydrogen fuel cells), and zero or equivalent-zero emissions. All the technologies needed to do this exist today.

[56] This fiberglass-and-PET-thermoplastic (recycled bottles) material gives much lower performance than the advanced composites, based chiefly on carbon fiber, that hypercars would use to ensure high crashworthiness.

[57] Lovins & Lovins 1991.

[58] Shepard *et al*. 1990.

[59] Johansson *et al*. 1993, Romm & Curtis 1996.

[60] Mansley 1995.

[61] Costing only one reactor's worth ($3 billion) spread over 20 years. Federal renewable-energy R&D was slashed 89% (real) during 1979–89 and remains under attack. In consequence, American industry must already import many renewable energy technologies that were invented here, then left to wither on the vine. Efficiency R&D has a similar history, with drastic cuts, slow rebuilding interrupted by continual sniping, and little attention to the $28 billion energy saving achieved through 1996 from just five of the numerous technologies developed or demonstrated with DOE's $28-billion efficiency RD&D budget during 1975–95: Brown & Levine 1997 at 2.14–2.15.

[62] SERI 1990.

[63] Brown & Levine 1997, *e.g*. at 1.15.

[64] This potential is economically consistent with the National Academy of Sciences' 1992 findings (Evans 1992) but about one-fourth to one-third as large, because the Academy examined long-term potential without regard to timing, while the five-Labs study explicitly counted retrofit and replacement dynamics.

[65] *Id*. at 3.5. Savings in 2010, measured in constant and undiscounted 1995 dollars.

[66] Sørensen 1979, Lovins *et al*. 1981, Reddy & Goldemberg 1988, Johansson *et al*. 1989 & 1993.

[67] Brown *et al*. 1997 at 52.

[68] Lovins & Lehmann 1998.

[69] Johansson *et al*. 1993 at 23ff.

[70] Williams *et al*. 1997.
[71] Williams 1996.
[72] Edwards 1997.
[73] Keepin & Kats 1988, 1988a.
[74] Patterson 1987.
[75] Rosenfeld *et al*. 1990.
[76] Bodlund *et al*. 1989.
[77] Reddy & Goldemberg 1990. This is possible because efficiency is so abysmal to start with that when a South Indian village switched from kerosene to fluorescent lamps, illumination rose 19-fold, energy input decreased ninefold, and household lighting expenditure fell by half: Reddy *et al*. 1997 at 70.
[78] Reid & Goldemberg 1997.
[79] Gadgil *et al*. 1991.
[80] Lovins & Gadgil 1991.
[81] Levine *et al*. 1993 at 425ff.
[82] Reid & Goldemberg 1997.
[83] Reddy *et al*. 1997 at 72.
[84] Yergin 1997.
[85] Calwell *et al*. 1990.
[86] Krause *et al*. 1992.
[87] IPSEP 1993, 1994—98. Careful national and regional studies found that "Carbon emissions in 2020–2030 could be cut by about 50–60 percent relative to baseline projections at zero or negative net cost"—2–5 times the IPCC consensus: Krause 1996.
[88] Lovins *et al*. 1981, Goldemberg *et al*. 1988.
[89] DPA Group 1989.
[90] Greene 1990.
[91] Though opposite to the views of the current government of Australia, this conclusion is consistent with a more recent analysis: Walker 1996. The ample room for savings is illustrated by Australia's having decreased its carbon intensity (energy-related CO_2 emissions per unit real GDP) by only 13% during 1970–92 while the OECD average fell by 36%: Hamilton 1997.
[92] Alliance to Save Energy *et al*. 1997.
[93] Brown & Levine at 1.3, 2.10. This range depends on what fraction of the 1973–96 reduction in primary-energy/GDP ratio is due to improved technical efficiency; the consensus is upwards of two-thirds. The rest is due to shifts in composition of economic output and to minor (and often temporary) behavioral changes.
[94] In round numbers, only 15–20% of the fuel energy reaches the wheels, and 95% of that tractive energy moves the car itself.
[95] DeCanio 1994.
[96] Jaffe & Stavins 1994, Sanstad & Howarth 1994, Krause 1996.
[97] von Weizsäcker *et al*. at 143–209.
[98] Brown & Levine 1997 at 2.11.
[99] DeCanio 1994.
[100] Levine *et al*. 1995.
[101] DOE 1997.
[102] Howe 1993. Dominant models are ~96–98.5% efficient, the best amorphous-iron model 99.33%, but it costs $680 instead of $320, so its market share is only 10%. Compared with the best standard model, it yields a 14%/y aftertax ROI, a 20-year saving more than twice its marginal cost, a longer life, and far greater service flexibility. This analysis assumes 25-kVA oil-filled units, 0.50 load factor, 0.95 power factor, 6¢/kWh, 5%/y real discount rate, and 36% marginal tax rate. The misallocation is assessed as the present value, over a 20-y minimum life, of avoided generation at 2¢/kWh and generation-plus-transmission at $700/kW (busbar) with 3% transmission loss. Each 10,000 transformers sold at 98.44% instead of 99.33% waste 2.5 peak MW and ~22 GWh/y: Howe 1993. One-third are bought by nonutilities; 35 million units are in U.S. service; and virtually all electricity flows through similar transformers.
[103] GDS 1997.
[104] Implicit real annual discount rates for buying efficiency typically range around 30–60+%: Rosenfeld & Hafemeister 1988; Koomey *et al*. 1991, Hausman 1979, Hartman & Doane 1986, Wolf *et al*. 1983. The highest values prevail at low incomes. In contrast, big energy supply firms have traditionally been content with 5–6% if regulated, perhaps ~10% if not.
[105] Some theorists argue that "transaction costs"—the supposedly prohibitive cost and hassle of searching out every little source of energy inefficiency and negotiating with its owner to correct it—will eat up any profits and make further energy savings impractical. Nonsense. Transaction costs in some poorly designed early utility programs, among those surveyed by Nadel 1990, were up to tens of percent of total costs—which were still severalfold smaller than the savings they achieved. But more mature programs cut those transaction costs by tenfold, to just a few percent overhead (*e.g*., Lovins & Lovins 1991 at 3n, SCE 1985), making the net profits even juicier. Similarly, "the total cost of developing and implementing federal efficiency standards for U.S. appliances and other products amounted to…[0.1%] of the estimated net present value benefits of these standards in the period till 2015": Krause 1996 at n14.
[106] Nadel 1990, Lovins 1994.
[107] von Weizsäcker *et al*. at 166–167.
[108] Lovins & Gadgil 1991. Most of the misallocation is driven also by enormous personal profits for dealmakers. Those transactional rewards drive many investments with unsound fundamentals (like most recent Asian project-financed power plants), just as they propelled the '80s real-estate bubble and S&L fiasco. Those tens of billions of dollars per year get tied up for a decade or more and can't be invested instead in cheaper efficiency. But efficiency doesn't offer fat commissions.
[109] Lovins & Lehmann 1998.
[110] Audin & Howe 1994.
[111] Rajendran 1997.
[112] Lenssen 1995.
[113] DeCanio 1993, 1994, 1994a, 1994b. Firms are not individuals and are not of a single mind—hence often experience the "divergence between goals and actions" familiar in all bureaucracies: DeCanio 1993 at 907ff. Indeed, economic theory correctly states that in general, "rational, self-interested individuals will not act to achieve their common or group interests." Corporate inefficiency may be invisible if profits are positive and competitors use similarly inefficient practices. As Nobel economist Herbert Simon convincingly describes, firms do not in fact fully maximize profits but rather resort to "satisficing" because of the inherent complexities of their environment and the limits of their processes for making and executing decisions. Sharehold-

ers hold diversified asset portfolios, but managers whose careers ride on the success of specific projects are far more risk-averse, so they go only for extremely high-return investments—and so on down the hierarchical chain of control, where subordinates bear the personal risks of failure while superiors see the results and know which projects were chosen but not why. This leads to systematic suboptimization—to second-best solutions perceived as less risky individually, but less profitable overall than they should be. (Mitsubishi Electric has done well with a countermeasure since 1994—a "new evaluation system, which…encourages employees to take more risks by explicitly balancing…mistakes with…achievements": *Wall St. J.* 1997.) In summary, the reasons for corporate (or for that matter government) underinvestment in energy efficiency are described by economists as bounded rationality, principal-agent problems, and "moral hazard" (an old insurance term for situations where behavior can take advantage of and thereby change actuarial odds or prices, as where people are more likely to abuse a rental car than one they own, forcing the rental firm to raise its price). Overlaid on these is widespread myopia—hurdle rates for capital budgeting generally (not just to save energy) well above investors' required returns. The complex reasons for this relate mainly to takeover and investment-analyst pressures.

[114] When regulators convert revenue requirements for a fair return on and of capital into a schedule of tariffs (cents charged per kWh used by various customers), they must assume how much energy will be sold. If the utility then sells more energy than assumed, its profits go up; if less, its profits go down. The solution is to decouple profits from sales volumes via a simple balancing account, so the utility is no longer rewarded for selling more energy nor penalized for selling less. This also eliminates the incentive to game the forecast (lowball sales forecasts so you can sell more), and does not make utilities' profits depend on things they cannot control such as weather: Lovins 1996.

[115] Moskovitz 1989, Lovins 1996.

[116] Simpson 1997.

[117] Brown & Levine 1997 at 4.32.

[118] CDA 1996, assuming a continuous 15-A single-phase lighting load, 100-foot average panel-to-load distance, half-inch conduit, a switch from #12 to #10 AWG THHN wire, full-sized grounding wire in both cases, September 1996 prices, 7¢/kWh electricity, no correction for space-conditioning loads, and 36% marginal tax rate.

[119] See reference CDA.

[120] Developing countries subsidize their energy by an estimated $111 billion per year, but America subsidizes just its car drivers by more than that (the gap between their public direct costs and their fee and tax payments): Roodman 1997. We pay to create the problem and we pay to deal with it. It would be cheaper and smarter to pay no subsidy and thus avoid the problem.

[121] MacKenzie *et al.* 1992, Ketcham & Komanoff 1992.

[122] Shoup 1997.

[123] Lopez Barnett & Browning 1995, GDS 1997.

[124] Shoup 1997.

[125] *Id.*

[126] Dr. Alan Meier of Lawrence Berkeley National Laboratory has recently proven this by simply measuring the differences in standby power drawn by the range of appliances (TVs, VCRs, faxes, etc.) now on the U.S. market: Rosenfeld 1997.

[127] See reference EPA.

[128] EPA 1993.

[129] Rosenfeld 1997.

[130] See reference CyberTran.

[131] Geller & Nadel 1994.

[132] Houghton *et al.* 1992.

[133] Eley 1997.

[134] Lovins 1994.

[134A] Romm & Browning 1994.

[135] DeCanio 1994b.

[136] von Weizsäcker *et al.* 1997 at 191–197.

[137] Lovins & Gadgil 1991.

[138] Koplow 1993.

[139] Shelby *et al.* 1995.

[140] The military costs of forces whose primary mission is intervention in the Persian Gulf totaled at least $73 billion in 1994—plausibly 3+ times that if one recognizes that all U.S. war games in recent years have assumed the Gulf as one of two conflict theaters (Cavallo 1996; *cf.* Fuller & Lesser 1997 at 43, who authoritatively but more narrowly estimate $30–60 billion a year, "depending on how you cost it"). Allocating Cavallo's cost estimate generously to all U.S. oil use, not just Gulf imports, is equivalent to a hidden shift of about $2–7 per million BTU, or $13–37 per barrel, from energy bills to tax bills.

[141] The U.S. wouldn't have needed a drop of oil from the Gulf if it had kept on saving oil as fast after 1986 as it did for the previous nine years. During 1975–87, the U.S. had boosted its oil productivity four-fifths faster than it had to in order to match both economic growth and declining domestic oil output. By 1986, the annual energy savings, chiefly in oil and gas, were providing two-fifths more energy than the entire domestic oil industry, which had taken a century to build; by 1995 the savings had surpassed *all* oil use. But after doubling, new-car efficiency stagnated for a decade and is now declining again under the weight of inefficient light trucks, vans, and sport-utilities.

[142] Reddy *et al.* 1997 at 137.

[143] Lovins 1985 at 180–83, Fickett *et al.* 1990.

[144] Brown & Levine 1997 at 2.9.

[145] *Id.* at 2.10.

[146] *Id.* at 1.3.

[147] Seattle City Light's measured savings achieved through 1990–96 investments in demand-side management, emphasizing energy rather than peak-load savings, were 313 GWh/y or 38 average MW—3.2% of 1996 energy sales and average load: Todd 1997. By 1996, but nearly all during 1995–96, the nearly tenfold larger Chicago utility Commonwealth Edison saved 51 peak MW (0.27% of its ~19-GW peak load), or an 11.8-fold smaller fraction of load. ComEd made essentially no effort to save electrical *energy*, yielding savings of only 800 MWh/y, or 0.00088% of its sales—a 3,640-fold smaller fraction than in Seattle: Brandt 1997. The ComEd figures are not corrected for any offsetting sales increases resulting from promotional tariffs and practices. In 1996, big customers paid 1.9 times less and small customers

paid 2.3–2.4 times less per kilowatt-hour in Seattle than in Chicago.

[148] This is not surprising, since "nonprice measures have an important role in improving economic efficiency….All markets in open societies and in all sectors of economic activity …function within a framework of laws,…standards and public and private information services designed to improve the clarity and integrity of economic transactions and in so doing improve economic efficiency….[P]ure market transactions, in which prices, along with other economic variables such as income and wealth are the sole variables, are rare": Anderson 1995 at 563–564.

[149] Stewart 1997.

[150] Environmental taxes certainly work: as *The Economist* summarized on 28 June 1997, "the OECD says that in Sweden, where dirtier automotive diesel has been taxed relatively heavily since 1991, almost all diesel is now of the cleanest type and sulfur emissions from diesel vehicles have fallen by 75%. In Norway, the carbon-dioxide tax has prompted a switch away from fossil fuels, cutting emissions from power stations and factories by one-fifth since 1991." Making "labor taxes less damaging…is worthwhile anyway." Tax-shifting simply combines both benefits. Phased-in, revenue-neutral tax shifts offer rich potential for strengthening the public and private economy and for avoiding many social costs whose remediation now increases the total burden of taxation: Hammond *et al.* 1997. Tax-shifting would signal managers to fire the unproductive tons, gallons, and kilowatt-hours, and thereby help them to keep the people, who'd then have more and better work to do. There is an intimate link between the waste of people, resources, and money—and the solutions to all three problems are also intertwined: Hawken 1997, Hawken *et al.* 1998.

[151] Repetto & Austin 1997.

[152] Brown & Levine 1997 at 1.3.

[153] Schwartz & Leyden 1997.

[154] Repetto & Austin 1997 at 9.

[155] This principle was agreed by both North and South in the 1995 Berlin Mandate implementing the 1992 Rio Treaty, which the United States was the fourth country, and the first developed country, to ratify. Its moral basis was that although the South is expected to account for most of the future growth in CO_2 emissions, the North was responsible for most of the historic emissions. These conditions, and debates about who should go first, were considered relevant only in the context of the then-prevalent belief that burning less fossil fuel would be disadvantageous. Of course, advanced technologies adopted in the North set a good example and will inspire emulation by the South.

[156] This view is often advanced both by opponents of climate protection in the North (spearheaded by the coal industry) and by their counterparts in the South, chiefly OPEC, which has adroitly grabbed the diplomatic microphone of almost all developing countries—many dependent on its aid—and put its self-serving message in others' mouths.

[157] Wolfensohn 1997.

[158] EEI 1995 at 82. Moreover, less than half the price of electricity is fuel, and under a mere \$20–40/ton carbon tax, coal-fired electricity would be quickly displaced by modern gas-fired plants that emit only one-fourth as much CO_2 per kWh and are hence only one-fourth as sensitive to the tax—or even by competitive renewable sources.

[159] Jorgenson *et al.* 1992.

[160] *Christian Science Monitor* 1997.

[161] As chief U.S. negotiator Tim Wirth put it, "probably the most complicated scientific, environmental, economic and political challenge in history": *Intl. Envtl. Reporter* 2 Oct 1996.

[162] Eaton 1997.

[163] Lovins & Gadgil 1991.

[164] Repetto & Austin 1997 at 8, 32–33.

[165] von Weizsäcker *et al.* 1997, Hawken *et al.* 1998. The European Union, German, and Dutch Environment Ministers have endorsed the Factor Four approach as a new basis for sustainable development—the only dissent coming from Sweden which, farsighted as ever, prefers a Factor Ten goal, as do the OECD Environment Ministers. Fair enough: the latest technical findings described in *Natural Capitalism* do make that a realistic goal. But four is on the way to ten and is much better than zero, so while en route to four, we needn't argue about which goal is best.

[166] Arrow *et al.* 1997.

[167] However, extensive European research suggests that a combination of price and market-transformation initiatives may interactively boost economic efficiency and welfare more than the sum of their parts: Krause 1996.

[168] Nitze 1997.

[169] NREL 1997.

[170] Bohi & Burtraw 1997.

[171] The price subsequently spiked up to \$115 in spring 1997 as Enron and other traders bought the cheap allowances. By mid-1997 it had fallen back to \$90. (Sulfur has not only a spot market but also futures and options, which are already starting to be thinly traded for carbon too: Sandor 1997.) One could well conclude that "If pollution reduction is so cheap, perhaps society should buy more of it": Ackerman & Moomaw 1997. Some analysts now suggest that despite the high cost estimates when the legislation was being debated, by the time it had passed, the official models were predicting ~\$170–200/t, and that most of the further actual drop was due to other factors, notably railroad deregulation that made low-sulfur Western coal far more accessible. However, such factors could as well be interpreted as rational responses to the emerging market incentive for saving sulfur.

[172] With both CFCs and leaded gasoline (also phased by an extremely successful refinery-level trading system in the 1980s), as with many other forms of pollution reduction or prevention, the affected industries' prior predictions of prohibitive cost proved groundless. There are few if any important counter-examples.

[173] In the 1970s, experts were nearly unanimous that energy use and GDP must forever march in lockstep. The Chairman of Chrysler Corporation still holds this view and more: although he acknowledges that "new technology will allow us to continue to grow our economy while managing the level of CO_2 output," he also states that curtailing fossil-fuel use "in the

next dozen years by more than 20 percent" by obliging ourselves to "heavily tax or somehow rigidly ration our own energy use" would have the "certain consequence" of "a decline in the country's economic growth by a similar amount," so without sustaining historically high levels of energy use, the U.S. is "not likely to remain" a developed country: Eaton 1997. Of course, GDP and energy have long since parted ways—we now produce 44% more GDP per unit of energy than we did in 1970—and that's only the beginning. Even those who wonder how much further such progress can persist should be happy to try the experiment; both economically and politically, they have nothing to lose but their waste.

ACKNOWLEDGEMENTS

This research was largely supported by The Energy Foundation, which is not responsible for the views expressed. The authors are grateful to the sponsor, to numerous informants (chiefly in the private sector), and to the several dozen peer-reviewers who provided helpful comments and corrections. Any errors remaining are the sole responsibility of the authors. Suggestions for further improvement are welcome at the address below.

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Amory Lovins has worked on climate and energy issues for the past three decades, chiefly in the private sector. A consultant physicist educated at Harvard and Oxford, he received an Oxford MA (by virtue of being a don), six honorary doctorates, a MacArthur Fellowship, and the Onassis Prize, and has briefed nine heads of state. *The Wall Street Journal*'s Centennial Issue named him among 28 people in the world most likely to change the course of business in the 1990s. His wife and colleague L. Hunter Lovins (BA, BA, JD, LHD *h.c.*) is a sociologist, political scientist, forester, and member of the California Bar. In 1982, the Lovinses cofounded Rocky Mountain Institute—a 45-person, independent, nonprofit, market-oriented resource policy center (www.rmi.org). They have shared the Nissan and Mitchell Prizes, the Right Livelihood Award (usually called in Europe the "alternative Nobel Prize"), and visiting academic chairs. Singly or jointly, the Lovinses have published 26 books, including *Least-Cost Energy: Solving the* CO_2 *Problem* (1981), and several hundred papers, and have consulted for scores of industries and governments worldwide on the interlinked issues of energy, resources, environment, development, and security. Much of their current research focuses on transforming the car, real-estate, and electricity industries.

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Rocky Mountain Institute is a nonprofit research and educational foundation with a vision across boundaries. Seeking ideas that transcend ideology, and harnessing the problem-solving power of free-market economics, its goal is to foster the efficient and sustainable use of resources as a path to global security. The Institute addresses problems and solutions in the areas of energy, water, agriculture, security, community economic development, transportation, sustainable corporate practices, and environmentally responsive real-estate development.

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