CHAPTER 12

Climate

Making Sense *and* Making Money

A droplet of air — The atmospheric bathtub — Flapping molecules — A tea-cozy for earth — What we can't model — Protecting climate at a profit — In God we trust; all others bring data — More than efficiency — Why nuclear power can't help — If Karnataka can do it — Almost everyone wins

FROM SPACE, THE EARTH IS BLUE BECAUSE IT IS COVERED MAINLY BY WATER. However, were it not for certain trace gases in the atmosphere, the earth would be a frigid icy white, and life as we know it would not exist.

Our dependable local star radiates energy in all directions, a bit of which[1] falls on our own planet. As it turns and wobbles and wanders through an unimaginably chilly universe, the earth soaks in solar warmth.[2] Billions of years of this cosmic rotisserie nurtured an enormous diversity of living forms and processes that, through photosynthesis and respiration, helped create an atmosphere. It is that band of gases that keeps life as we know it pleasantly warm.

The earth' s atmosphere seems vast to a person sheltered beneath it, but astronauts and cosmonauts see how tissue-thin it is against the black vastness of space. Conservationists Jacques Cousteau and David Brower give us this helpful perspective: If the earth were the size of an egg, then all the water on the planet would be just a drop; all the air, if condensed to the density of water, would be a droplet only one-fortieth as big; and all the arable land would be a not-quite-visible speck of dust. That drop, droplet, and speck are all that make the earth different from the moon.

Incoming solar energy, nearly a fifth of a quadrillion[3] watts, hits the outer atmosphere at about 14,000 times the total rate at which all the people on earth are burning fossil fuels.[4] This ratio makes the amount of fossil fuels being consumed sound insignificant. In fact, though, this burning turns roughly 6½ billion tons a year of carbon — carbon that was fixed by photosynthesis in ancient swamps over tens of millions of years, then locked deep underground as coal, oil, and natural gas — into carbon dioxide.[5] Some advocates argue that even this quantity is insignificant compared to the far vaster amounts of carbon dioxide that are released as part of the natural cycle of life. Indeed, the constant exchange between the growth of green plants and their combustion, digestion, and decay does involve tens of times more annual flow of carbon dioxide than is released by fuel-burning. However, augmenting natural carbon cycles, even with relatively small amounts of fossil carbon, tends to increase disproportionately the amount of CO_2 in the atmosphere. An explanation for this phenomenon can be found in your bathroom.[6] If you fill your bathtub exactly as fast as the water runs down the drain, the flow of water in and out will be in equilibrium. But if you open the tap even a little more, your bathtub will ultimately overflow.

Because there is plenty of room for the CO_2 we're adding, there is no danger of its overflowing. But as it slowly accumulates, it is gradually double-glazing our home planet. Earth's atmosphere, not counting its water vapor, contains by volume about 78 percent nitrogen, 21 percent oxygen, 0.9 percent argon, and 0.039 percent other trace gases. Nitrogen, oxygen, and argon have no greenhouse effect; thus 99 percent of the atmosphere provides virtually no insulation. Of the atmosphere's main natural constituents, only water, carbon dioxide, and ozone have warming properties. These three warming gases share a common characteristic — they each have three atoms. All molecules absorb energy at the frequencies at which they naturally vibrate. Simple two-atom molecules like nitrogen and oxygen vibrate at high frequencies, like tight little springs, so they don't absorb much of the waste heat that leaves the earth as lower-frequency infrared energy. In contrast, CO_2, H_2O, and ozone (O_3) absorb heat rays especially well, because their three atoms create a triad configuration that can flap, shimmy, and shake at the right rate to absorb and re-radiate most of the infrared rays that the warm earth emits.[7] For the same reason, other three-atom pollutants like nitrous oxide (N_2O) and sulfur dioxide (SO_2) are strong greenhouse gases, too.[8]

Carbon dioxide makes up just 1-2,800th of the atmosphere. Together with the other trace gases, even that tiny amount makes the earth's surface[9] about 59F° warmer, so even a relatively small additional amount can raise the temperature of the planet significantly. Before the industrial revolution, trace gases (including carbon dioxide) totaled 0.028

percent of the atmosphere. Since then, burning fossil fuel, cutting and simplifying forests, plowing prairies, and other human activities have increased that CO_2 concentration to 0.036 percent, the highest level in the past 420,000 years, and the CO_2 concentration is steadily rising by half a percent per year.[10]

This concentration matters because energy from the white-hot sun is a mixture of roughly half visible light and half invisible infrared heat rays. If the atmosphere had no greenhouse gases, nearly all solar radiation striking the outer edge of the atmosphere would reach the earth's surface, and all of it would promptly escape back into space. That's what makes the airless moon so frigid: It absorbs solar energy four times better than the earth (partly because the moon has no clouds), but its surface averages 63F° colder because there is no atmosphere to hold the heat. In contrast, the earth's atmosphere, like a superwindow, is relatively transparent to most of the radiation coming in from the sun but is nearly opaque to the very long wavelengths of infrared rays that radiate back to space. The atmosphere holds that heat like a semi-transparent blanket. The resulting exchange of energy back and forth between the atmosphere and the earth is 47 percent larger than the solar energy arriving from the sun, which is why the earth's surface averages about 59°F rather than 0°F. It's also why life is possible. Those few hundredths of one percent of the atmosphere that are carbon dioxide play a critical role in this heat balance.

The warmed surface of the earth tries to radiate its heat back into space, just as a hot teapot radiates heat until it gradually cools to the temperature of the kitchen. Putting more carbon dioxide into the air is like putting a tea-cozy over the pot: It blocks the escaping heat. But this particular teapot is still on the stove, as more solar heat is added daily. The better the tea-cozy blocks the escaping heat, while the stove continues to add more heat at the same rate, the hotter the tea becomes. The atmosphere works in the same way. Suppose we add more heat-trapping CO_2 to the atmosphere. Then more of the outgoing infrared rays get absorbed and reradiated downward to warm the earth's surface. The air above the surface is also warmed, which enables it to hold more water vapor, which means even more greenhouse heat-trapping and possibly more clouds. Depending on their height, latitude, and other factors, those additional clouds may further warm the earth beneath them or may cool it by bouncing away more incoming sunlight. Either way, more water vapor in the air means more precipitation.[11] Hotter air makes the water cycle and the weather machine run faster, which leads to more intense storms and more rainfall. In round numbers, each Fahrenheit degree of global warming will increase global mean precipitation by about one percent, but some places will get much more.

Over the past century, as accumulating greenhouse gases have trapped two to three more watts of radiant heat over each average square meter of the earth, its surface has become about 1F° warmer.[12] Amazing the climatologists, in the single year 1998 — the hottest year since record-keeping began in 1860, and, according to indirect evidence, in the past millennium — the earth's average temperature soared by another quarter of a Fahrenheit degree, to about 1¼F° warmer than the 1961–90 average. *Each* of the 12 months through September 1998 set a new all-time monthly high-temperature record.[13] Seven of the ten hottest years in the past 130-odd years occurred in the 1990s — the rest after 1983 — despite such strong countervailing forces as the eruption of Mt. Pinatubo, a dip in solar energy, and the depletion of stratospheric ozone, a greenhouse gas. In 1998, at least 56 countries suffered severe floods, while 45 baked in droughts that saw normally unburnable tropical forests go up in smoke from Mexico to Malaysia and from the Amazon to Florida.[14] Many people's intuition that weather is shifting and becoming more volatile is confirmed by meteorological measurements. Spring in the Northern Hemisphere is coming a week earlier; the altitude at which the atmosphere chills to freezing is rising by nearly 15 feet a year; glaciers are retreating almost everywhere.[15]

Warming the surface of the earth changes every aspect of its climate, especially the heat-driven engine that continually moves vast seas of air and water like swirls in hot soup. Some places get hotter, others colder, some wetter, others drier. Rainfall patterns shift, but when it does rain, it tends to rain more heavily. A warmer earth probably also means more volatile weather with more and worse extreme events of all kinds. Nobody knows *exactly* how these changes will play out, especially in a particular locality, but some of the general trends are already apparent.

Warmer oceans, for example, can cause currents to shift and change, more frequent and severe tropical hurricanes and typhoons to form, and perhaps more frequent or more intense El Niño events to occur. Warmer oceans kill coral reefs (which when healthy metabolize and thus sequester CO_2). The warmed ocean can actually release more CO_2, just as happens when you open a soda warmed by the sun. This is important because oceans contain about 60 times as much CO_2 as the atmosphere does. Warmer soil, especially at high latitudes, speeds up plant decomposition, releasing more CO_2. It also means drier soil and hence shifts in vegetation. In any given ecosystem, more CO_2 increases growth of those plants that can best take up more CO_2, but at the competitive expense of other plants. This unpredictably changes the composition of plant populations, hence that of animal populations and soil biota. Different vegetation also alters the land's ability to absorb sunlight and to hold rainwater. This can affect erosion patterns under heavier rains. Parched forests, bad grazing practices, and late rains cause more forest and grassland fires, more carbon release, and more smoke, as happened in Southeast Asia and Australia in 1997–98.

As the planet traps more heat, it drives more convection that transports surplus heat from equatorial to the polar areas (heat flows from hotter to colder), so temperature changes tend to be larger at the poles than at midlatitudes. Warmer poles mean changes in snowfall, more melting icecaps and glaciers (five Antarctic ice sheets are already disintegrating),[16] and more exposed land and oceans. Ice-free oceans, being dark, absorb more solar heat and therefore don't refreeze as readily. Rising amounts of runoff from high-latitude rivers lower ocean salinity. This can shift currents, including the Gulf Stream, which makes northern Europe abnormally cozy for its Hudson's Bay latitude, and the Kuroshio Current, which likewise warms Japan.[17] Warmer oceans raise sea levels, as ice on land melts and warmer water expands; sea levels have risen by about four to ten inches in the past century. Warmer oceans probably bring more and worse storms, more loss of coastal wetlands that are the nurseries of the sea, and more coastal flooding. "Thirty of the world's largest cities," writes Eugene Linden, "lie near coasts; a one-meter rise in the oceans . . . would put an estimated 300 million people directly at risk."[18] That would include 16 percent of Bangladesh — a country that spent much of the summer of 1998 up to two-thirds underwater.

Now consider the contributions of the many other trace gases that also absorb infrared rays. Methane comes from swamps, coal seams, natural-gas leaks, bacteria in the guts of cattle and termites, and many other sources. Its concentration has risen since the eighteenth century from 700 to 1,720 parts per billion and is increasing at a rate of about one percent a year. Methane is a greenhouse gas 21 times more potent per molecule than CO_2. Nitrous oxide is over 100 times as potent as CO_2; CFCs (the same synthetic gases already being phased out because they also destroy stratospheric ozone), hundreds to thousands of times; their partly or completely fluorinated substitutes, hundreds to tens of thousands of times. Near-surface ozone and nitric oxide, familiar constituents of smog, absorb infrared, too. Together, all these gases have had a heat-trapping effect about three-fourths as significant as that of CO_2 alone.

Many trace gases can react chemically with others and with one another to make new gases. The resulting 30-odd substances can undergo more than 200 known reactions. These occur differently at different altitudes, latitudes, seasons, concentrations, and, of course, temperatures, which is what the very presence of the gases affects. How various gases dissolve in or react with the oceans also depends on temperatures, concentrations, and currents. Warmer oceans, for example, hold less nitrate, slowing the growth of carbon-absorbing phytoplankton. Also, if high-latitude tundras get much warmer, ice-like compounds called methane hydrates trapped deep beneath the permafrost and offshore in the Arctic could ultimately thaw and start releasing enormous amounts of methane — more than ten times what is now in the atmosphere. Long before that could happen, though, even slight changes in Arctic bogs' water levels can increase their methane production by 100-fold. Meanwhile, the mass of frigid air above the North Pole could get even colder and more persistent, favoring ozone-depleting chemical reactions that could destroy up to 65 percent of Arctic ozone — a deeper loss than has occurred in the Antarctic.[19]

The dance of heat between sun, sky, and earth is affected not only by transparent gases and clouds but also by dust from volcanoes, deserts, and the burning of fossil fuel. Most dust, like the clouds of sulfate particles that are also produced by fossil-fuel combustion, tends partly to offset CO_2's heat-trapping effect. So far, on a global basis the dust has approximately canceled the warming effect of additional non-CO_2 greenhouse gases.

The atmosphere, ocean, land, plant, and animal systems all interact in countless complicated ways, not all of which are yet known and many of which are not yet fully understood. Most of the interactions are nonlinear, and some appear to be unstable. Modern computer models are sophisticated enough to be able to model some historic shifts in climate quite well, but they're far from perfect, and getting them close to perfection will take longer than performing the global climate experiment already under way.[20] Many scientists suspect that relatively small changes in certain forces that drive the climate — notably CO_2 concentrations, especially if they happen fast enough — may trigger large and sudden changes in the world's weather, for example by shifting ocean currents. Such changes could even lead to the onset of ice ages in mere decades: They seem to have happened this abruptly before, and therefore must be possible, but such situations are difficult to model reliably.

A few scientists believe there might be a number of still unknown climate-stabilizing mechanisms at work. However, no important ones have yet been found, and all the promising candidates have been eliminated one by one. Instead, almost all the known climate feedback mechanisms appear to be positive — warmer begets warmer still. Many uncertainties remain, but uncertainty cuts both ways. The climate problem may be less serious than most scientists fear, or it could be even worse. Stratospheric ozone depletion turned out to be worse, once the unexpected "ozone hole" over the Antarctic was noticed and found to be growing rapidly. It required emergency action in the 1980s to phase out the proven culprit — CFCs and a few related compounds, such as Halon in fire extinguishers.

What's beyond doubt is that the composition of the atmosphere is now being altered by human activity, more rapidly than it's changed at any time in at least the past 10,000 years. The present state of knowledge suggests that, even if emission rates are reduced somewhat below their 1990 levels, we will still gradually reach about triple the preindustrial CO_2 concentration. If the world's nations wanted to stabilize the atmosphere in its present disrupted state, they would need to cut CO_2 emissions immediately by about three-fifths. To return to preindustrial levels, we'd have to reduce emission rates promptly to severalfold *below* current ones. Further research may disclose either bigger safety margins, allowing that ambitious goal to be relaxed, or smaller ones, requiring it to be tightened. For now, no one knows what might constitute a "safe" rate of, or limit to, changing the atmosphere's CO_2 concentration. What is clear is that the transformations now under way are part of a risky global experiment, and that their effects on the planet's life-support systems, whatever they turn out to be, may be irreversible.

A broad scientific consensus has already acknowledged the existence of a potentially serious climate problem.[21] About 99.9 percent of the world's qualified climate scientists agree that the infrared-absorbing gases that human activity is releasing into the air are cause for concern — if not now, then soon. Most believe that those emissions are probably already beginning to disrupt the earth's climate in observable ways. The many remaining scientific uncertainties create plenty of room for interpretation about exactly what might happen, how, and when, let alone its effects on people and other life-forms. All these issues are vigorously debated among thousands of climate scientists because that's how science works: From debate, observation, hypothesis, experiment, mistake, discovery, more debate, and reassessment ultimately emerges truth. The laypeople who don't like what the science is predicting, or who don't understand the scientific process, can easily seize on details of that debate and conclude that climate science is too immature and uncertain a discipline to support any broad conclusions yet. They'd be wrong.

However, the terms and outcome of the climate-science debate don't ultimately matter. Because of the resource productivity revolution, the actions and requirements needed to protect the climate are profitable for business right now, no matter how the science turns out and no matter who takes action first. Arguments that it would be too expensive and economically harmful to mitigate the rate of increase in greenhouse gases are upside down. It costs less to eliminate the threat to our global climate, not more.

REFRAMING THE CLIMATE DEBATE

On May 19, 1997, John Browne, the chief executive of British Petroleum — then the world's third-largest, now its second-largest, oil company — announced at Stanford University: "[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."[22] Obviously, "what should be done" is mainly to stop raising and start lowering the rate of burning of fossil fuels, the source of 84 percent of America's and 75 percent of the world's energy.[23] Mr. (now Sir John) Browne went on to announce that BP had increased its investments in solar technology, which it expects to grow markedly in the decades to come. His lead on both the climate issue and energy alternatives has since been followed by several other oil companies.

Three months earlier, eight Nobel laureates had led some twenty-seven hundred fellow economists in declaring what all mainstream studies have found: Market-oriented policies to protect the climate by saving energy can raise American living standards and even benefit the economy.[24] They were largely ignored. Instead, a coal-led industrial lobby, the Global Climate Coalition, saturated the airwaves with ads that scared almost the entire press corps and the U.S. Senate into *presuming* that protecting the climate would be prohibitively costly. The prospect of having to reduce carbon emissions has subsequently aroused dismay, foreboding, and resistance among many in the business community, who fear it would hurt earnings and growth.

As economic columnist 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."[25] In Samuelson's widely held view, carbon emissions would probably be cut only if companies were levied with a tax of roughly one hundred dollars for each metric ton of carbon they emitted. Even then, he warns, such a burdensome tax might only reduce 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, wrote Samuelson, "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."

Samuelson, like many businesspeople, believes climate protection is costly because the best-publicized (though not most broadly accepted) economic computer models say it is. Few people realize, however, that those models find carbon abatement to be costly *because that's what they assume.* This assumption masquerading as a fact has been so widely used as the input for supposedly authoritative models, which have duly disgorged it as their output, that it's often deemed infallible.

What is less well publicized is that other economic models derive the opposite answer from more realistic assumptions (including what international treaties and U.S. policy actually say), rather than from worst-case hypothetical conditions. Better yet, an enormous body of overlooked empirical data, including government-sponsored studies[26] and the results of worldwide business practice, tells an excitingly different story, one more positive than *any* of the theoretical models predict. As previous chapters have described, the technological breakthroughs that Samuelson seeks have already happened. America could shed $300 billion a year from its energy bills using existing technologies that deliver the same or better services and are rewarding at today's prices. The earth's climate can thus be protected *not at a cost but at a profit* — just as many industries are already turning the costs of environmental compliance into gains from pollution prevention.

America is confronted, as Winston Churchill said, by insurmountable opportunities. Because there are practical ways to mitigate climatic concerns *and* save more money than such measures cost, it almost doesn't matter whether you believe that climate change is a problem or not: These steps should be taken simply because they make money. Together, the following opportunities can turn climate change into an unnecessary artifact of the uneconomically wasteful use of resources:[27]

· Well over half of the threat to climate comes from the CO_2 released by burning fossil fuels. It disappears if customers use energy as efficiently as is cost-effective. Alternatively, much of this part of the threat disappears if low-carbon fuels (natural gas) or no-fossil-carbon fuels (biomass or other renewables) are substituted for more carbon-intensive fossil fuels (coal and oil) and if fossil fuels are converted more efficiently into electricity. These complementary approaches are all profitable in most circumstances. In general, it's cheaper to save fuel than to buy it, no matter what kind it is. Moreover, even inefficiently used low-carbon and some no-carbon fuels are increasingly competitive with oil and coal.

· Another one-fourth or so of the climatic threat is the result of carbon dioxide and other trace gases that are embodied in soil, trees, and other biological capital and put into the air through soil erosion, logging, and poor grazing, farming, or ranching practices. This problem can be addressed by adopting farming and forestry practices that do not release carbon from the soil, but take carbon out of the air and put it back where it belongs. Most soil-conserving and -building practices simultaneously decrease other greenhouse gas emissions, notably of methane and nitrous oxide from biological sources. These superior practices are generally at least as economical as soil-depleting, chemical-dependent methods,[28] making all their climatic benefits at least an economic break-even.

· The rest of the climatic threat nearly vanishes if CFCs are replaced with the new substitutes that are already required by a ratified and functioning global agreement, the 1988 Montreal Treaty, in order to protect the stratospheric ozone layer on which all life depends. Thanks to industrial innovation, these substitutes, including some with little or no greenhouse effect, now work the same as or better than their predecessors and typically cost about the same or less. Similar opportunities exist for the whole range of non-CO_2 heat-trapping synthetic gases.[29]

In December 1997, the world's national governments met in Kyoto, Japan, to negotiate a treaty to start dealing seriously with climate change. Its details, which will be elaborated and probably strengthened in the coming years, create a framework in which reduced emissions of any significant greenhouse gas — carbon dioxide, methane, nitrous oxide, and three kinds of fluorinated gases — can be traded between companies and between countries under agreed national emissions caps. The U.S. target is to reduce its net emissions in 2010 to 7 percent below 1990 levels. Countries that want to emit more than their quota will be able to buy permits at a market price from those that are emitting less. As with any market, trading will mean the least expensive ways of abating carbon will tend to be purchased first. It means you can undertake initiatives such as increasing energy efficiency or reforestation, and get paid extra for them by selling their carbon reductions to a broker. Improved farming, ranching, and forest practices emitting less CO_2, nitrous oxide, and methane will also earn credits under Kyoto trading rules. Thus, such carbon "sinks" as adding trees and building topsoil can produce a steady additional income, invigorating ecological restoration. The sequestration of CO_2 by injecting it into secure underground reservoirs will also become a business opportunity.

The menu of climate-protecting opportunities is so large that over time, they can overtake and even surpass the pace of economic growth.[30] Over the next half-century, even if the global economy expanded by 6- to 8-fold, the rate of releasing carbon by burning fossil fuel could simultaneously decrease by anywhere from one-third to nine-tenths below the current rate.[31] This is because of the multiplicative effect of four kinds of actions. Switching to natural gas and renewable energy, as fast as Shell Oil planners consider likely, would cut by one-half to three-quarters the fossil-fuel carbon in each unit of primary energy consumed. The efficiency of converting that energy into delivered forms, notably electricity, could meanwhile rise by at least half, thanks to modern power plants and recapturing waste heat. The efficiency of converting delivered energy into desired services would also increase by about 4- to 6-fold if improvements simply continued at rates that have been historically sustained, in the United States and abroad, when people were paying attention.[32] Finally, the amount of satisfaction derived from each unit of energy service might remain unchanged, or might perhaps be doubled by delivering higher-quality services and fewer unwanted ones. All four of these steady, long-term improvements are profitable and already under way. Together, and combined with ways to abate or store other greenhouse gases, they will make it feasible to achieve not merely the modest interim targets set at Kyoto, but also the far greater ones needed to stabilize the earth's climate.

IN GOD WE TRUST; ALL OTHERS BRING DATA

The common assumption of diminishing returns — more efficient means costlier, cheap savings will quickly be exhausted, and efficiency is a dwindling rather than an expanding resource — stalls action. Yet actual experience is a strong antidote.

In 1981, Dow Chemical's 2,400-worker Louisiana division started prospecting for overlooked savings. Engineer Ken Nelson[33] set up a shop-floor-level contest for energy-saving proposals, which had to provide at least a 50 percent annual return on investment (ROI). The first year's 27 projects averaged 173 percent ROI. Nelson was startled, and supposed this bounty must be a fluke. The following year, however, 32 projects averaged 340 percent ROI. Twelve years and almost 900 implemented projects later, the workers had averaged (in the 575 projects subjected to audit) 204 percent ROI. In later years, the returns and the savings were both getting *larger* — in the last three years, the average payback fell from six months to only four months — because the engineers were learning faster than they were exhausting the cheapest opportunities. By 1993, the whole suite of projects taken together was paying Dow's shareholders $110 million every year.

Almost everyone responsible for buying new equipment *assumes* that more energy-efficiency models will cost more. In fact, careful scrutiny of actual market prices reveals that even at the component level, many technical devices — motors, valves, pumps, rooftop chillers, et cetera — show no correlation whatever between efficiency and price.[34] A 100-hp American motor, for example, can be cheaper at 95.8 percent efficiency than an otherwise identical 91.7 percent-efficient model.[35]

But if you didn't know that to be true — if you assumed, as economic theory and engineering handbooks predict, that more efficient models always cost more — then you probably wouldn't have shopped for a more efficient model. It is easy to calculate the cost of not getting just one more efficient motor. If it's to run continuously, using electricity that costs 5 cents a kilowatt-hour, just multiply its percentage points of potential efficiency gain by its horsepower rating. Multiply the result by $50. That will give you roughly how many dollars you just failed to add to your company's bottom line (over the long term, but expressed as a lump sum worth the same today, called the "present value"). In this example, not choosing the most efficient 100-hp motor can cost a company $20,000. Many factories contain hundreds of such motors. They're the tip of a gigantic iceberg. Motors use three-fourths of industry's electricity, and slightly more U.S. primary energy than highway vehicles. This consumption is highly concentrated: About half of all motor electricity is needed by the million largest motors, and three-fourths in the 3 million largest. Since big motors use their own capital cost's worth of electricity every few *weeks*, switching to more efficient models can pay back quickly. Adding another 30-odd improvements to make the whole motor *system* optimally efficient typically saves about half its energy with about a 190 percent annual after-tax return on investment.[36]

Whether at the level of a single component or an entire factory, previous chapters documented an unexpectedly large potential to increase energy efficiency in almost every application. Profitable and demonstrated Factor Four, Factor Ten, or greater improvements were described for commercial and residential buildings and equipment, lighting, heating, cooling, pumping, and ventilation. Carbon-saving opportunities were large in industries ranging[37] from microchips to potato chips, refineries to foundries — all further amplified by dramatic reductions in materials flows to deliver the same services. Such opportunities for *using* delivered energy more productively can also be compounded by *supplying* that energy in lower-carbon and more efficient ways[38] — a combination that in microchip fabrication could profitably cut CO_2 per chip by about 99 percent.[39] Across the whole economy, two supply-side improvements alone could about meet America's Kyoto targets:

America's power stations turn fuel, mostly coal, into an average of 34 percent electricity and 66 percent waste heat, throwing away an amount of heat equal to the total energy use of Japan, the world's second-largest economy. In contrast, Denmark, which gets two-fifths of its electricity from "cogeneration" plants that recover and use the heat as well (and projects this fraction will increase to three-fifths by 2005), converts 61 percent of its power-plant fuel into useful work. The American firm Trigen does even better: Its small, off-the-shelf turbines produce electricity, then reuse their waste heat to provide other services. Such a system now powers, heats, and cools much of downtown Tulsa, Oklahoma. Such "trigeneration" can increase system efficiency by about 2.8-fold. It harnesses 90–91 percent of the fuel's energy content, and hence provides very cheap electricity (half a cent to two cents per kilowatt-hour). Fully adopting just this one innovation wherever feasible would reduce America's *total* CO_2 emissions by about 23 percent.[40]

However industrial processes are fueled and powered, reselling their waste heat to other users within affordable distances[41] could cost-effectively save up to about 30 percent of U.S. industrial energy or 11 percent of America's total energy.

WHAT IF EFFICIENCY ISN'T ENOUGH?

Such firms as British Petroleum, Shell, and Enron are investing heavily in renewable sources of energy, for good reason.[42] As London's Delphi Group has advised its institutional-investor clients, alternative energy industries not only help "offset the risks of climate change" but also offer "greater growth prospects than the carbon fuel industry."[43] Group Planning at Royal Dutch/Shell considers it "highly probable" that over the next half century, renewables could become so competitive a commodity that they'd grow to supply at least half the world's energy.[44] Even today, renewable energy is Europe's fastest-growing source,[45] and California gets 9 percent of its electricity from renewable sources other than hydroelectricity.[46] The world's fastest-growing energy technologies, outpacing even energy savings, are windpower, increasing by about 26 percent a year,[47] and photovoltaics (solar cells), whose annual growth has lately exceeded 70 percent as manufacturers struggle to keep pace with strong demand.

These and similar private-sector conclusions are echoed by the two most thorough assessments conducted by the United States, or probably any other, government. In 1990 five U.S. National Laboratories reported that either fair competition plus restored research priority, or a proper accounting of its environmental benefits, could enable renewable energy to supply three-fifths of today's total U.S. energy requirements at competitive prices. Renewables could even supply one-fifth *more* electricity than the United States now uses.[48] In 1997, the labs further sharpened these conclusions.[49]

Sunlight is most abundant where the majority of the world's poorest people live. Numerous scientific studies have shown that in every part of the globe between the polar circles, this freely distributed renewable energy, if efficiently used, is adequate to support a good life continuously, indefinitely, and economically using present technologies.[50] The potential of solar photovoltaic power, once considered visionary, is starting to be validated in the marketplace. The cost of solar cells has fallen by 95 percent since the 1970s and is expected to fall by a further 75 percent in the next decade through straightforward scaling up of established production technologies. Bostonians can now buy electricity from Sun Power Electric, an entirely photovoltaic utility. Auctions to supply the Sacramento Municipal Utility District have yielded contracts to cut the delivered price of solar electricity to 9–11 cents per kilowatt-hour (1999 $) — competitive with conventional retail residential electricity.[51] If one counts some of the dozens of kinds of "distributed benefits," those cells are cost-effective right now in many uses.[52] The Sacramento electric utility even found it cheaper to hook alley lights to solar cells than to the existing wires. Most electric utilities could cut their carbon emissions by as much as 97 percent by adding solar cells and other advanced renewables, with comparable reliability and essentially unchanged cost.[53]

Meanwhile, doubled-efficiency combined-cycle gas turbines, with half the cost and only one-fourth the carbon intensity of coal-fired power plants,[54] have quietly seized most of the electric utility market for new power stations. Closing fast on the outside, the new dark horse in this area is the low-temperature polymer fuel cell being developed also for Hypercars. Fuel cells are at least as efficient but are silent, clean, reliable, scaleable to virtually any size desired, and ultimately capable of costs five to ten times below those of combined-cycle gas turbines.[55]

In contrast, the energy technologies that are the product of socialized costs and central planning have not fared well. The world's slowest-growing energy source is nuclear power — under 1 percent in 1996, with no prospect of improvement.[56] Its global capacity in 2000 will be a tenth, and orders for new plants are now a hundredth, of the lowest official forecasts made a quarter century ago. America's civilian nuclear technology cost a total of a trillion federal dollars yet delivers less energy than wood. It is dying of an incurable attack of market forces: *The Economist* says of nuclear power plants that "not one, anywhere in the world, makes commercial sense."[57] The only question is whether at least a third of U.S. nuclear plants will retire early. Many have already done so (operable units have been declining since 1990, with twenty-eight closed by the end of 1998), because their operating and repair bills make them uncompetitive to run. Worldwide, 90-odd nuclear plants have already retired after serving fewer than seventeen years. Even in France, the world's acknowledged leader in nuclear dependency, nuclear expansion has been outpaced two to one by 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 a setback for climate protection. Actually it's good news. Since nuclear power is the costliest way to replace fossil fuels, every dollar spent on it displaces less climatic risk than would have been avoided if that same dollar were spent instead on techniques to use energy more efficiently, because those methods cost far less than nuclear power.[58] For example, if a kilowatt-hour of nuclear electricity cost six cents (optimistically low), while saving a kilowatt-hour through efficiency cost two cents (pessimistically high), then the six cents spent to buy a single nuclear kilowatt-hour could instead have bought three kilowatt-hours of savings, displacing three times as much coal-burning. This opportunity cost is why investing in nuclear power does not address climatic threats effectively but on the contrary retards their abatement.

FROM THE FIRM TO THE NATION

Whole countries, especially heavily industrialized ones, can attain big energy savings and climatically benign energy supplies simply by adding up many small individual achievements. During the years 1979–86, in the wake of the second oil shock, America obtained nearly five times as much new energy from savings as from all net expansions of supply. In those years the country got 14 percent more energy from sun, wind, water, and wood and 10 percent less from oil, gas, coal, and uranium. The economy grew 19 percent, but total energy use shrank 6 percent. By 1986, CO_2 emissions were one-third lower and annual energy costs were about $150 billion lower than they would have been at 1973 efficiency levels. Sustaining that pace today would by itself meet America's Kyoto target on time and at a profit; additional opportunities could achieve manyfold more.

All that impressive progress in the 1980s was only a first step toward what was possible from thoroughly applying cost-effective efficiency measures. 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).[59] The study found that if the country fully used only mid-1980s energy efficiency technologies, it could save half of its electricity, at an average cost 78 percent lower than that of making more. Adopting that strategy plus switching to less carbon-intensive fuels and relying most on the least carbon-intensive power stations could enable Sweden simultaneously to

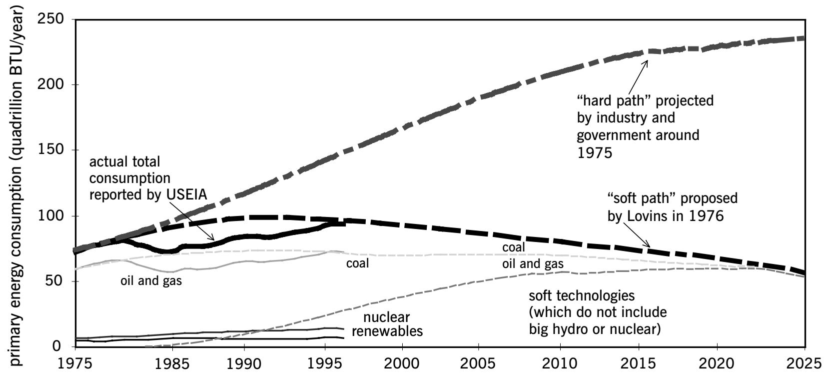
- achieve the forecast 54 percent GDP growth during the years 1987–2010,
- complete the voter-mandated phaseout of the nuclear half of the nation's power supply,
- reduce the utilities' carbon releases by one-third, and
- reduce the private internal cost of electrical services by nearly $1 billion per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

If this is possible in a country that is full of energy-intensive heavy industry, cold, cloudy, very far north, and among the most energy-efficient in the world to start with, then nations not so handicapped can obviously make even more impressive advances. Indeed, a year later, a study for the Indian state of Karnataka found that simple efficiency improvements, small hydroelectric plants, cogeneration of electrical power from sugarcane waste, methane gas generated from other wastes, a small amount of natural gas, and solar water heaters would achieve far greater and earlier development progress than would the fossil-fueled plan of the state utility. The alternatives would require two-fifths less electricity, cost two-thirds less money, and produce 95 percent less fossil-fuel CO_2.[60] These Indian and Swedish analyses studied two dramatically different types of societies, technologies, climates, wealth, and income distribution. Yet they both found that efficiency combined with renewable energy could meet each country's energy needs with greater savings and lower carbon emissions. Similar findings have emerged worldwide.[61]

The Karnataka study exposes the error made by critics of climate protection when they point to the growing world population, many of its members desperately poor, and argue that these people must use far more energy to attain a decent standard of living. In this view, climate change is a problem of industrial countries, and reducing developing countries' carbon emissions would inequitably cripple economic growth. In fact, the only way developing countries will be able to afford to increase their living standards is to avoid the wasteful practices of the industrialized nations. Investing now in greatly increased energy efficiency offers even greater advantages in the South than in the North, and meets an even more urgent developmental need, because the South, on average, is three times less energy-efficient to begin with, yet is far less able to afford such inefficiency. That's why key developing countries, including China, have been quietly saving carbon about twice as fast in percentage terms as the Western developed countries have committed to do, and possibly faster than the West even in absolute terms.[62]

Among the strongest economic advantages of focusing on energy productivity instead of energy production is that building, for example, superwindow and efficient-lamp factories instead of power stations and transmission lines requires about a thousandfold less capital per unit of extra comfort or light, yet these businesses are considerably more labor-intensive.[63] Such demand-side investments also pay back their cost about ten times as fast for reinvestment, reducing the effective capital needs by closer to ten thousandfold. This best-buys-first strategy can liberate for other development needs the one-fourth of global development capital now consumed by the power sector.[64] An important way to support this outcome would be for industrialized countries to stop the "negative technology transfer" of exporting obsolete equipment to developing countries. Denmark has recently led in this respect by banning the export of technologies (such as a coal-fired plant to India) that it would not consider economically and environmentally sound to use on its own territory. Companies and countries should do as some smart American utilities already do: Buy up obsolete appliances and scrap them, because they're worth far more dead than alive. Extending this euthanasia to inefficient old industrial equipment would be a major step for global development.[65]

What of America's own progress toward a sound long-term energy future? The graph on page 252 shows how the half-century transition along a "soft energy path" outlined in 1976 is already well under way. At

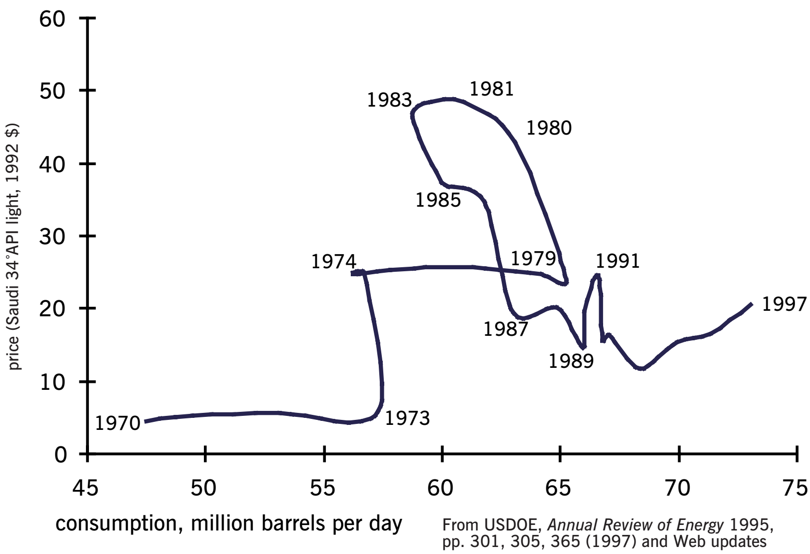


TWO ALTERNATIVES FOR U.S. ENERGY FUTURES AND PROGRESS SO FAR

the time, the energy industries heavily criticized the heretical suggestion[66] that rather than following official forecasts of rapid energy growth for inefficient use (top curve), the United States could stabilize and then reduce its energy consumption by wringing out losses in converting, distributing, and using it (next curve down). Meanwhile, efficiently used fossil fuels would bridge to appropriate renewable sources — "soft technologies" — that would gradually take over. That's roughly what happened. The actual total of U.S. energy use (third line down) is now virtually identical to this "soft-path" trajectory: with energy efficiency, as with water efficiency, the savings are being realized pretty much on schedule. However, the potential for efficient use of energy is now far greater than anyone imagined in 1976 or even in 1996. Despite falling energy prices and often hostile government policy, renewable energy has also made great strides. Balancing its delay against today's even brighter prospects for the next quarter-century, the natural-capitalist energy goals envisaged in this 1976 graph — a prosperous economy fueled by efficiently used, benign, and restorative energy sources — now seems more achievable and advantageous than ever.

ENERGY PRICES, NATIONAL COMPETITIVENESS, AND THE MARKETPLACE

Companies now dump carbon into the air without paying for it (except in their fuel bills). Even if they did have to pay, and even if not all countries had to pay, neither Americans nor anyone else need fear losing the



WORLD CRUDE-OIL CONSUMPTION *VS.* REAL PRICE, 1970–1997

ability to compete in global markets, for three main reasons: The price difference would be small, would be offset by efficiency gains it would stimulate, and wouldn't impel firms to relocate.[67]

Moreover, the basic premise is mistaken: Protecting the climate doesn't require higher energy prices in the first place. Sharp price hikes do get everyone's attention and have driven major shifts in the energy system since 1970. The graph above shows the almost textbook-perfect relationship worldwide between the price of oil and the consumption of oil. The first price shock in 1973 cut the rate of growth in consumption by 58 percent; the second in 1979 caused consumption to shrink, creating so much excess supply that prices went back down, whereupon consumption resumed its upward drift.

Between about 1975 and 1985, most new U.S. energy-using devices — cars, buildings, refrigerators, lighting systems, et cetera — *doubled* their efficiency. Many utilities became very skilled at delivering efficiency to their customers.[68] Their success fueled 35 percent economic growth with essentially zero energy growth during the years 1973–86. But then the resulting 1986 energy price crash dampened further savings,[69] virtually stagnating U.S. energy efficiency for the next decade. It was as if the price signal were the spigot that turned efficiency gains first on and then off. Seeing such evidence, it's easy to assume that the only way to return to rapid energy savings is to return also to costly energy.[70] Yet price, while helpful, isn't the only tool available: Energy efficiency can be improved very rapidly by raising prices, or paying attention, or both. Alert companies can pay attention without being hit over the head by a price signal. Even with cheap energy, efficiency gains can regain their former momentum through today's better technologies, smarter delivery methods,[71] and keener competitive and environmental pressures.

The importance of influences other than price is proven by the experience of two American metropolises.[72] From 1990 through 1996, Seattle City Light, which delivers the cheapest power of any major U.S. city, helped its customers save electricity via a variety of incentives and educational tools. Those customers' smarter choices reduced their need for electricity at peak load periods nearly twelve times faster than people in Chicago achieved, and reduced annual electric usage more than 3,600 times as fast as in Chicago, even though Seattle's electricity prices are about half of Chicago's. This behavior is the opposite of what conventional economists would have predicted from relative prices. But it proves that creating an informed, effective, and efficient market in energy-saving devices and practices can be an even more powerful stimulus than a bare price signal. That is, *price is less important than ability to respond to it.* (The reverse is also true: Higher energy prices do not automatically yield major energy savings, even after long adjustment times. That's why identical electricity-using devices and practices prevail in different cities that pay severalfold different electricity prices, and why DuPont found identical efficiency potential in its U.S. and European plants in the 1990s despite long-standing energy prices that are twice as high in Europe.)[73]

By now, most readers are probably wondering why, if such big energy savings are both feasible and profitable, they haven't all been exploited. The simple and correct answer is that the free market, effective though it is, is burdened by many subtle imperfections that inhibit the efficient allocation and use of resources. The following chapter details scores of specific obstacles to using energy in a way that saves money. But it also specifies the sensible "barrier-busting" public policies and corporate practices that can turn those obstacles into business opportunities. Mindful of this need to make markets work properly, national climate policy already emphasizes the need "to tear down barriers to successful markets and . . . create incentives to enter them" so that "protecting the climate will yield not costs, but profits; not burdens, but benefits; not sacrifice, but a higher standard of living."[74] As George David, chairman of United Technologies, put it, "we can be efficient, much, much more efficient in both our energy production and . . . the operation of equipment consuming that energy. . . . Greenhouse gases are a problem, and it's time for the usual and effective American solution"[75] — intelligent use of highly productive technologies.

ALMOST EVERYONE WINS

Using energy far more efficiently does mean that less fossil fuel would be sold than if we continued to consume it at current rates. Lower physical volumes sold do not necessarily mean lower sales for fuel vendors, but most vendors do fear that they would make less money than expected if demand grew more slowly, or stabilized, or even declined — as it would have done eventually from depletion. Where is it written, however, that coal companies or OPEC countries have an inalienable right to sell ever more quantities of their product — or, as their apologists and OPEC itself now urge, to be compensated for lost profits if their hoped-for growth in demand slackens or reverses?

The United States has never been good at helping workers or industries in transition, and now might be a good time to improve that record with regard to prospective climate-induced shifts in policy. A failure to help coal miners, depressed communities, and even disappointed shareholders would encourage them to oppose measures that benefit society as a whole. But those measures should generate sufficient revenues to enable society, if it chooses, to afford to ease their difficulties.[76] Actually, climate policies threaten miners' jobs much less than do the coal companies, which during the years 1980–94 eliminated 55 percent of their miners' jobs, while coal output rose 25 percent. The companies continue reductions at a rate that, with no climate policy even in place, has eliminated more than nine thousand mining jobs per year.

Sound public policies can and do readily cope with much larger job losses than that.[77] As Professor Steven DeCanio, senior staff economist for President Reagan's Council of Economic Advisers, notes:

> . . . [T]he U.S. economy creates about one and a half to two million net new jobs per year, and the gross number of jobs created and destroyed through the normal process of economic change is larger. . . . If the rate of job decline in coal were to double[,] it would still be less than 1.5 percent of the normal

> annual rate of total net job creation. Without minimizing the hardships of adjustments to displaced coal workers, this sort of incremental change in the sectoral distribution of jobs would not be difficult for the economy to absorb, and it would be sensible to include transitional support for displaced workers (such as retraining expenses) as an integral part of any national greenhouse-gas reduction policy. . . .
>
> Instead of a threat to jobs, reducing the economy's dependence on fossil fuels can be seen as an investment and job-creation *opportunity,* because of the new equipment and technologies that will be required. The conversion can be accomplished without any net loss of jobs; the role of policy is to minimize transition costs and to ensure that any such costs do not fall disproportionately on narrow segments of the population such as coal industry employees.[78]

As for the shareholders, hard-nosed free-marketeers might argue that they should have foreseen climate would become an issue (some of us have been saying so since 1968), so they should have invested earlier 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 proponent of a thriving economy should wish otherwise.

But the best outcome, especially for the workers, would be to encourage the companies at risk in the transition to start selling a more profitable mixture of less fuel *and* more efficiency in using it. A few oil companies and hundreds of electric and gas utilities are already successfully doing so to improve both customer service and their own earnings. It is this logic that has also led the likes of ABB, BP, DuPont, Ford, Norsk Hydro, Shell, Tokyo Electric, and Toyota to fund both internal and consortium research into how to protect the climate while advancing their own business interests.[79]

PROTECTING THE CLIMATE FOR FUN AND PROFIT

A proper understanding 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 the threats to it ameliorated. Those who don't can still make money. Those who worry about the costs and burdens of redesigning their businesses will see those investments rewarded. Those who want improved jobs, competitiveness, quality of life, public and environmental health, and individual choice and liberty can get those things, too. By emphasizing energy efficiency, and climate-protecting grazing, farming, and forestry practices based on natural systems, we can responsibly and profitably address not only climate but about 90 percent of EPA's pollution and public-health concerns — smog and particulate emissions, toxic emissions, runoff from agrichemicals, and many more. These actions are vital to a vigorous economy, national security,[80] a healthful environment, sustainable development, social justice, and a livable world.

Pragmatists 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. These can, but need not, include raising energy prices. (In fact, both the Kyoto Protocol and the Clinton administration's climate policy *exclude* the carbon taxes that critics of both plans have been attacking.) Innovative, market-oriented public policies, especially at a state and local level, can focus chiefly on barrier-busting — the alchemy of turning implementation obstacles into business opportunities — to help markets work properly and reward the economically efficient use of fuel.[81] This strategy would require much *less* intervention in the market than is now mandated by 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. (Two millennia ago, Lao-tzu rightly counseled: "Govern a great country as you would fry a small fish: Don't poke at it too much.") But we need to steer in the right direction — the line of least resistance and least cost — guided by a detailed and precise map that charts the barriers now blocking energy efficiency. The next chapter begins to draw that map.

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? Recall what happened the last time such a gloom-and-doom attitude prevailed. In 1990, just before Congress approved the trading system for reducing sulfur-dioxide emissions[82] — the model for the international trading framework adopted in the Kyoto climate treaty seven years later — environmentalists predicted that sulfur 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 $1,000–1,500 or more. The sulfur-allowance market opened in 1992 at about $250 a ton; in 1995, it cleared at $130 a ton; in 1996, it fell to $66; by 1999, it had been bid back up to $207. National sulfur emissions have fallen 37 percent in just the past decade despite an unprecedented economic boom.

In short, Congress's fierce 1990 debates about where to set the target for sulfur reductions are long forgotten, because modelers can't reliably plan how economies work. What mattered is that Congress set up an efficient trading mechanism to reward sulfur reductions and to reward early achievers. As a result, the United States is now two-fifths ahead of its sulfur target, *at a small fraction of the projected cost.* Electric rates, which industry feared would soar, have instead fallen by one-eighth and show every sign of continuing to fall indefinitely. Much the same is happening with CFCs, whose replacement was predicted to wreck the economy. The targeted CFC cuts have actually been surpassed in every year, with no significant cheating, at roughly zero net cost.[83]

The genius of private enterprise and advanced technologies reduced sulfur and CFC emissions billions of dollars more cheaply than by using government regulation. It can do so again, now that the Kyoto Conference has adopted the principle of encouraging international competition to save the most carbon at the lowest cost. The Kyoto Protocol sent a strategic message to business: Pay attention to carbon reductions and they can improve the bottom line. In boardrooms around the world, savvy executives are already planning: If we're going to have carbon trading, how can our company benefit?[84] America's largest producer of chemicals, DuPont, has already answered that question. While the United States was reluctantly agreeing in Kyoto to cut its annual greenhouse-gas emissions to 7 percent below their 1990 level by around 2010, DuPont's technologists were planning how their firm, as it recently announced, will cut its own emissions to "much less than half" of their 1991 level by 2000. These reductions lead to direct savings — each ton of avoided carbon (or equivalent) emissions has so far saved DuPont over $6 in net costs — but better yet, under the Kyoto trading regime, DuPont could become able to earn marketable emissions credits that could someday contribute billions to its net earnings.[85] Moreover, many firms in related businesses are exploring a further business opportunity unrelated to either cutting energy costs or trading emissions: gaining market share by marketing "climate-safe" products,[86] as some electricity providers are already successfully doing.[87]

There are strong reasons to predict that the framework adopted in Kyoto in 1997 for trading carbon reductions will work even better than the one adopted by Congress in 1990 for trading sulfur reductions. First, carbon trading will rely mainly on how efficiently many end users employ their resources. Buying and selling sulfur permits was set up as a business for utilities, and opportunities for energy efficiency to compete with top-of-smokestack sulfur reductions were limited. With carbon trading, however, factories, cities, farms, ranchers, foresters, and myriad other users and savers of carbon will be allowed to participate. Further, saving carbon, unlike saving sulfur, is intrinsically profitable, because saving fuel costs less than buying fuel.

The hypothesis that saving carbon will prove cheaper than saving sulfur (or indeed will cost less than zero because of savings on fuel bills) is empirical and testable. The test has already begun. By the end of 1998, a dozen private market-makers were already trading carbon reductions and sequestrations. Undaunted by diplomats' wrangling over the details of international trading rules, the traders simply did what traders do: They made their own rules in rough-and-ready ways adequate to protect their own financial interests. So how long did top traders think it would take before they'd learned enough from actual market transactions to foresee the actual cost of meeting the Kyoto Protocol's goals? Around twelve to eighteen months.[88] Thus well before the climate negotiators and politicians have decided how to implement carbon trading, the marketplace is likely to have leapfrogged over the negotiations and set an actual price. This will expose the gloomy theoretical economic models — which underlie so much of the political friction over climate protection — to what may prove a withering market test.

In just the past fifty years, the world's annual 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 seventies are now, because climate change is not an inevitable result of normal economic activity but an artifact of carrying out that activity in irrationally inefficient ways. Climate protection can save us all money — even coal miners, who deserve the just transition that the nation's energy savings could finance a hundred times over.

If we vault the barriers, use energy in a way that saves money, and put enterprise where it belongs, in the vanguard of sound solutions, climate change will become a problem we can't afford, don't need, and can avoid with huge financial savings to society.