PREFACE

What lies at the bottom of the bottomless well isn't oil, it's logic. Fuels recede, demand grows, efficiency makes things worse, but logic ascends, and with the rise of logic we attain the impossible—infinite energy, perpetual motion, and the triumph of power. It will all run out but we will always find more. Some say this is not good for the planet, but that's how it works, regardless. What we will forever seek, and forever find, is not energy but the logic of power.

Many people don't believe this is true, and would be unhappy if it were. "Giving society cheap abundant energy at this point," Paul Ehrlich declared three decades ago, "would be equivalent to giving an idiot child a machine gun." Most right-thinking pundits have since come around to that same view, though few dare put it quite so truculently. The combustion engines that provide our transportation and electricity pollute the air and warm the planet. Protecting our oil supply lines entangles us with feudal theocracies, their bellicose neighbors, and the fanatical sects they spawn. And in any event, our appetite for energy is simply excessive. America consumes 25 percent of the world's natural gas, 23 percent of its hard coal, 25 percent of its crude petroleum, 43 percent of its motor gasoline, and 26 percent of its electricity. We drive more cars many more miles than any other nation on earth. With energy, we would be better off ourselves, and so would the rest of the world, if we simply sought, found, and consumed less.

There are two main schools of thought as to how we should get to less. Cornucopians maintain that through improved efficiency we can have it all—less energy but more light, refrigerated food, warm homes, and safe miles on the highway. By contrast, Lethargists—those in the Ehrlich camp—harbor no such comforting illusions. They know that less really is less, that most people will take more if they can, and that only taxes and regulations will curb the idiot child's appetite.

Both camps are wrong. The Cornucopians are not merely wrong, they are wrong in a spectacularly self-defeating way—energy efficiency leads to more consumption, not less, and if the U.S. government didn't fund it, the Saudis and the big oil companies would. We ourselves will cheerfully join in this camp's celebration of efficiency; we just won't assert that efficiency curbs demand—because it doesn't. It has quite the opposite effect. The Lethargists are wrong too, but more modestly so.

More energy consumption isn't worse, it's better. The idiot children are right. In the now standard histories, the beginning of the end of the age of oil arrived on October 19, 1973, when King Faisal ordered a 25 percent reduction in Saudi Arabia's oil shipments to the United States, launching the Arab oil embargo. Supplies were destined to tighten, and prices to rise, from there on out. It would take some time, of course, to lower the curtain. But oil was finished.

The second great energy shock came six years later, on March 28, 1979, with the meltdown of the uranium core of the nuclear power plant at Three Mile Island (TMI) in Pennsylvania. This, all discerning pundits agreed, marked the end of civilian nuclear power in the United States. The Chernobyl accident seven years later just added an extra nail to the nuclear coffin. It didn't matter that the TMI containment vessel had done its job and prevented any significant release of radioactivity, or that Soviet reactors operated within a system that couldn't build a safe toaster oven. Uranium was finished, too.

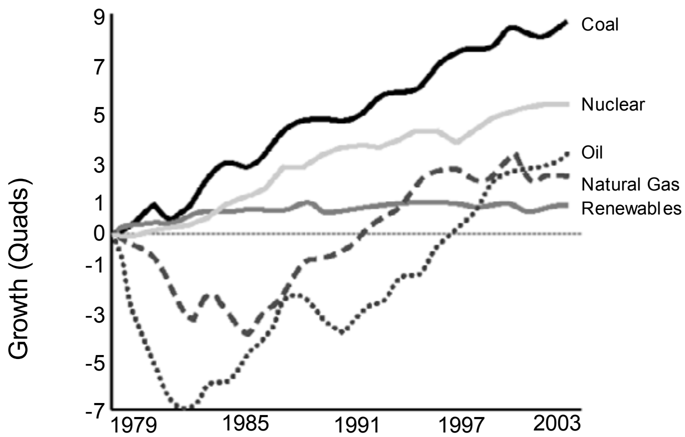
The nation's first secretary of energy summed things up five months after TMI. "The energy future is bleak," James R. Schlesinger declared, "and is likely to grow bleaker in the decade ahead. We must rapidly adjust our economics to a condition of chronic stringency in traditional energy supplies." Fortunately, the United States could manage on less— much less. Smaller, more fuel-efficient cars were gaining favor, and rising gas prices were curbing demand. And the United States certainly didn't need any more gargantuan electric power plants—efficiency, and the development of renewable sources of power, would suffice.

Another option was to burn an additional 400 million tons of coal a year, which is what we are in fact doing today, over thirty years later. Appliances, air conditioners, refrigerators, and light bulbs grew 30 to 50 percent more efficient in the interim, but all that saving notwithstanding, we still managed to almost double our total consumption of electricity during the same period. Over the same thirty years, the world's oil fields boosted aggregate production by 2.5 billion barrels a year. Oil prices went up and down only modestly in those ensuing years, never approaching the $200/barrel forecast for today by experts in 1980.[*] And Americans today are burning more of it than ever before.

Most of the new demand for oil was met with imports, but by no means all. U.S. fields, the oldest in the world with many predating World War I, had been scheduled to run dry by the 1990s—only about 30 billion barrels of "proven reserves" remained in 1979, after a century in which about 160 billion barrels (cumulatively) had been pumped out of those same wells. Nevertheless, in the quarter century since 1979, U.S. wells alone yielded another 67 billion barrels. The big oil fields of Oklahoma had been discovered in 1859; the reserves in those fields were assessed at 125 million barrels in 1969. Yet in the next quarter century they yielded 4.5 billion additional barrels.

[*] "Energy: A Special Report in the Public Interest," National Geographic, February 1981, p. 2—"Conservative estimates project a price of $80 a barrel, even if peace is restored to the Persian Gulf and an uncertain stability maintained." In inflation-adjusted terms, this "conservative" forecast was for $200/barrel in 2003.

Figure P.1 Growth in Total U.S. Fuel Consumption – Post-TMI



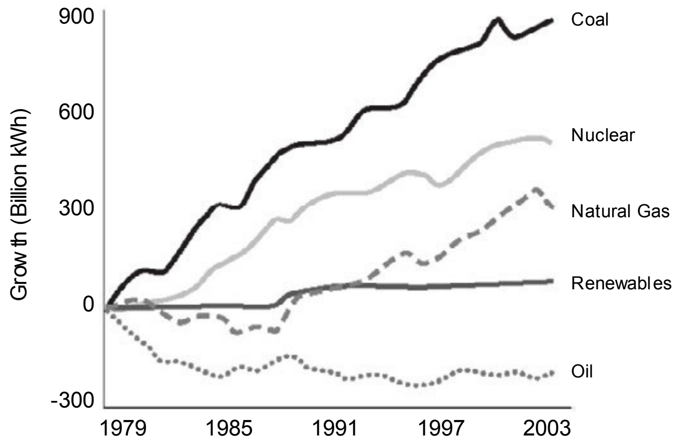
Source: EIA *Annual Energy Review 2003*.

After the 1979 accident at the Three Mile Island nuclear power plant, many energy pundits concluded that efficiency would curb future demand, and renewable sources would accommodate any future growth. Efficiency did improve dramatically, but demand far outpaced new supplies of renewable fuels. The U.S. now burns an additional 400 million tons of coal every year.

As for electricity, coal took care of half of the new demand during that same period, and thus continued to supply over half of our wired power. Electricity generated with natural gas, the fossil fuel grudgingly favored by most environmentalists, dropped sharply for a time but then rose again; it is now back at the 18 percent share it had three decades ago. Astonishingly, it was uranium that advanced the most, pushing its share up from 11 to 20 percent of the electric power generated in the United States. There were seventy-one civilian power plants running in 1980; no new nuclear plants were commissioned after TMI, but others were already under construction. The nuclear count peaked at 112 in 1990. TMI impelled plant operators to develop systematic procedures for sharing information and expertise, and plants that used to run seven months per year now run almost eleven. Uranium thus displaced about 8 percentage points of oil and 5 points of hydroelectric in the expanding electricity market.

Renewable fuels, by contrast, made no visible dent in energy supplies during this period. About a half billion kilowatt-hours (kWh) of electricity were produced from solar power in 2002, or about 0.013 percent of the U.S. total. Wind power contributed another 0.27 percent. There were subsidies, tax breaks, and government-funded research, but most of the private capital pursued conventional fuels. Fossil and nuclear fuels still completely dominate energy supply in the United States, just as they do in all other industrialized economies.

Figure P.2 Growth in Fuels Used to Generate Electricity – Post-TMI



Source: EIA *Annual Energy Review 2003*.

Coal-fired plants accommodated half of the growth in demand for electricity in the 25 years after Three Mile Island, and continue to satisfy half of the total demand. The accident notwithstanding, nuclear output rose steadily, too. By comparison, gas-fired power has lagged; by and large, gas has merely displaced oil.

And what about efficiency? It increased too throughout this period— very rapidly, in fact. Car engines, light bulbs, refrigerator motors—without exception, they all contrived to do much more, with much less. The Cornucopians delivered on every promise but the last. Tremendous improvements in efficiency culminated in more demand, not less.

LETHARGY IN PURSUIT

How about the Lethargists? To be fair, they did at least grasp what would work and what wouldn't. The way to get people to use less energy was to mandate that directly. While it lasted, the national 55 mph speed limit slowed people down and thus limited how far we drove and (indirectly) what we opted to drive. For a while, the Lethargists also made political headway with "fuel-economy" standards for cars and the equivalent for home appliances. Slower trips, dimmer bulbs, smaller refrigerators, and such aren't more efficient; they're slower, smaller, darker—they nudge us toward a less frenetic, peripatetic, and physically expansive way of life. Perhaps this is a good thing. But it is not more efficient, it is more sedentary, calm, and quiet—in short, more lethargic.

It didn't work—at least not on the highway. No one honored the 55 mph speed limit, or the small-car mandates implicit in the fuel-economy standards, which drivers evaded by buying car-like trucks. Ordinary citizens had no direct control over the construction of new power plants, however—this arena is controlled by regulators and those who influence them, and here, the advocates of less did have a real impact.

The advocates succeeded, politically, by making confident projections about the future that we now know were altogether wrong. "Only minor increases in electricity consumption [will] occur" in the future, the Union of Concerned Scientists confidently assured us in 1980. "'Electricity-specific' needs are already met by present capacity with a good deal left over," the ever-quotable Amory Lovins declared in the early 1980s. "The long-run supply curve for electricity is as flat as the Kansas horizon." Pronouncements like these persuaded some regulators, most notably in California, that the nation had built the last big power plant it would ever need. With too many power plants chasing too little demand, prices were bound to hold steady, or fall, even if no new plants were built. The regulated retail price of electricity could be kept very low—this was politically essential—while the construction of new coal furnaces, uranium reactors, and transmission lines could be delayed indefinitely.

But, in fact, electricity consumption would almost double in the two decades after no-more-growth predictions reached their climax. Rising demand collided with flat supply, most dramatically in California in 2000, when prices surged and blackouts rolled across the state. Honest Lethargists could have predicted as much, and perhaps even wished for it. They understood all along that it isn't rising efficiency that curbs demand, still less regulations that keep prices *down*—what curbs demand is whatever pushes prices *up*.

What Lethargists have favored all along are energy taxes.[*] A tax on energy plainly does promote its antithesis—lethargy. For better or worse, the United States today imposes substantial taxes on fuels and electricity. Taxes increase the average cost of gasoline by 40 percent, and of electricity by 20 to 80 percent, depending on where you live. The first comprehensive U.S. tax on fossil fuel consumption was finally proposed by the Clinton administration in 1993—25.7 cents per million British Thermal Units (Btus), with a 34.2 percent surtax added to oil, gasoline, and diesel fuel, though not to coal, natural gas, hydroelectric power, or nuclear power. Windmills and solar cells were to be exempt from both taxes. These proposals would certainly have curbed energy consumption. They were resoundingly rejected, however, by both houses of Congress, both controlled at the time by Democrats.

European Lethargists have been much more successful—they have pushed energy taxes to the point where their citizens pay roughly twice as much for gasoline and electricity as Americans do. Some Europeans would gladly push them higher still. Germany's Green Party has advanced proposals to triple gasoline prices over the next decade, and to jack up aviation fuel prices apace, so that Germans will fly on holiday no more than once every five years.

Whatever else it may be, this is Lethargy policy at its most candid and straightforward. The problem is defined forthrightly—the problem is energy itself, cheap, abundant energy, efficiently extracted and efficiently used. We humans have too much

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[*] "Since energy use, especially use of energy derived from fossil fuels, is central to virtually all of humanity's assaults on its own life-support systems, more general taxes on it would be appropriate." Paul Ehrlich and Anne Ehrlich, *One with Nineveh: Politics, Consumption, and the Human Future* (Island Press, 2004), p. 231.

energy—too much power over creation. Our ever-rising ability to do more things faster, and impose more order of our own choosing anywhere we like, is bad for the rest of the planet, and thus bad in the long run for us too. The only solution is to make energy expensive and scarce.

Western Europe has done much to implement national Lethargy policies; in America, however, we still pursue energy. And because we use the most, we are the most productive and the most powerful. As a result of which, we can, and do, use still more. Perhaps some Lethargists take bitter comfort in the thought that it can't last, the fuels are running out, and the faster we extract and burn them, the sooner the inevitable end must come. But it won't. Humanity is destined to find and consume more energy, and still more, forever.

SEVEN HERESIES

It has not escaped our notice that this proposition, like most of the others we advance, is flatly contradicted by an enormous literature on energy generated since the two great "energy crises" of 1973 and 1979. Most of these books start out with counts of oil wells, coal beds, and gas reserves. Then they observe that conventional supplies are finite and will surely be exhausted sooner or later. They lament our ever-rising demand for energy, expound on how demand could be curbed through readily achievable improvements in efficiency, and demonstrate how much the environment suffers from our failure to curb it. They take it that the nature of "energy" is well understood. Any well-governed society can only want so much of it. One form of energy is much like another, except that some forms are exhaustible and dirty while others are renewable and clean. Energy technology is important, but only insofar as it can raise efficiency, lower demand, reduce pollution, and hasten the transition from old fuels to new.

They are all wrong, except where they aren't even good enough to be wrong, which many of them aren't, much of the time. The best that can be said in their defense is that it is easy to be wrong when writing about energy. "Energy is a very subtle concept," physicist Richard Feynman once observed. "It is very, very difficult to get right. What I mean by that is it is not easy to understand energy well enough to use it right, so that you can deduce something correctly, using the energy idea." Famously plain-spoken though he was, Feynman could have been even more blunt. Most of what most people think they know about energy is so very wrong that their convictions, heartfelt though they may be, lie beyond logical contradiction or refutation.

What most of us think about energy *supply* is wrong. Energy supplies are unlimited; it is *energetic order* that's scarce, and the order in energy that's expensive. Energy supplies are determined mainly by how cleverly we're able to impose logic and order on the mountains and catacombs of energy that surround and envelop us. Supplies do not ultimately depend on the addition of reserves, the development of new fuels, or the husbanding of known resources. Energy begets more energy; tomorrow's supply is determined by today's consumption. The more energy we seize and use, the more adept we become at finding and seizing still more.

What most of us think about energy *demand* is even more wrong. Our main use of energy isn't lighting, locomotion, or cooling; what we use energy for, mainly, is to extract, refine, process, and purify energy itself. And the more efficient we become at refining energy in this way, the more we want to use the final product. Thus, more efficient engines, motors, lights, and cars lead to more energy consumption, not less. Finer, more delicate machines and tasks consume more energy, not less. The transportation of perfectly weightless bits—which are themselves highly ordered packets of energy—accounts for an already significant and rapidly growing fraction of our energy consumption. And however much energy we consume, we will always want more. Demand for energy is as insatiable as demand for information, time, order, and life itself.

Finally, what most of us think we know about the machines that use and transform energy—the *engineering* of energy—is wrong too. Since the dawn of the industrial revolution, the machines have been getting more efficient—and in the aggregate, they have been burning more fuel, too. There is no end in sight to the seeming paradox of rising efficiency and rising consumption; to the contrary, both will rise more in the next few decades than they did in the two centuries since James Watt perfected his steam engine.

These are the seven great energy heresies we propound in this book:

1. *The cost of energy as we use it has less and less to do with the cost of fuel.* Increasingly, it depends instead on the cost of the hardware we use to refine and process the fuel. Thus, we are now witnessing the twilight of fuel.

2. *"Waste" is virtuous.* We use up most of our energy refining energy itself, and dumping waste energy in the process. The more such wasteful refining we do, the better things get all around. All this waste lets us do more life-affirming things better, more cleanly, and more safely.

3. *The more efficient our technology, the more energy we consume.* More efficient technology lets more people do more, and do it faster—and more/more/faster invariably swamps all the efficiency gains. New uses for more efficient technologies multiply faster than the old ones get improved. To curb energy consumption, you have to lower efficiency, not raise it.

4. *The competitive advantage in manufacturing is now swinging decisively back toward the United States.* Steam engines launched the first industrial revolution in 1774; internal combustion engines and electric generators kicked off the second in 1876 and 1882. The third, set in motion by two American inventors in 1982, is now propelling the productivity of American labor far out ahead of the competition in Europe and Asia.

5. *Human demand for energy is insatiable.* We will never stop craving more, nor should we ever wish to. Life is energy in unceasing pursuit of order, and in tireless battle against the forces of dispersion and decay.

6. *The raw fuels are not running out.* The faster we extract and burn them, the faster we find still more. Whatever it is that we so restlessly seek—and it isn't in fact "energy"—we will never run out. Energy supplies are infinite.

7. *America's relentless pursuit of high-grade energy does not add chaos to the global environment, it restores order.* If energy policies similar to ours can be implemented worldwide, our grandchildren will inhabit a planet with less pollution, a more stable biosphere, and better-balanced carbon books than at any time since the rise of agriculture some five thousand years ago.

THE LOGIC OF POWER

"Energy" appears in the subtitle of this book because that's how the issues we discuss are invariably framed. But in the strict, technical sense of the word, "energy" is completely irrelevant. This book is a chronicle of humanity's struggle against the second law of thermodynamics, not in theory but in the real world, where engineers build practical engines that turn shafts, drive generators, propel cars, run microprocessors, replicate DNA, power heart defibrillators, and project beams of light, radio waves, and X-rays—and yes, of course, engines that also extract the raw fuels that fire the engines themselves. It is a story of ingenious valves and gates that flip open and closed, with just the right timing, to push energy up the thermodynamic hill, to structure our environment, and to add order to our lives.

The book sets out a vision, as well, of the dramatic changes that lie immediately ahead. Energy technology is now poised to evolve faster than at any time before in human history—faster than in 1765, when James Watt invented his steam engine; faster than in 1876, when Nikolaus Otto invented the internal combustion engine; faster than in 1879, when Thomas Edison patented his light bulb. The power of the new millennium is centered on semiconductors: the same materials that made possible digital information have emerged as the enabling materials of digital power. The new technologies of power exploit altogether new physical phenomena to process fantastically concentrated streams of electrons and photons, millions of times faster and far more efficiently than the old technologies they are rapidly displacing.

Over the broad arch of human history, from the nomadic hunter-gatherer to Rome to modern America, the rise of population, life expectancy, great cities, military might, and scientific knowledge has been propelled by rising energy consumption. It is by mastering power itself— the capture and release of energy—that societies master everything else. We rank civilizations accordingly: agricultural societies above nomadic ones, and fossil fuel societies above those that live off the surface of the land. Should they ever become economical, wind, solar, and other green energy technologies will increase our rate of energy capture still more. If they don't, ascendant societies won't adopt them. They will instead favor other technologies that do.

Over the long term, societies that expand and improve their energy supplies overwhelm those that don't. The paramount objective of U.S. energy policy should be to promote abundant supplies of cheap energy and to facilitate their distribution and consumption. Civilization, like life, is a Sisyphean flight from chaos. The chaos will prevail in the end, but it is our mission to postpone that day for as long as we can and to push things in the opposite direction with all the ingenuity and determination we can muster. Energy isn't the problem. Energy is the solution.