A Farewell to Fossil Fuels

Answering the Energy Challenge

Amory B. Lovins

Nearly 90 percent of the world's economy is fueled every year by digging up and burning about four cubic miles of the rotted remains of primeval swamp goo. With extraordinary skill, the world's most powerful industries have turned that oil, gas, and coal into affordable and convenient fuels and electricity that have created wealth, helped build modern civilization, and enriched the lives of billions.

Yet today, the rising costs and risks of these fossil fuels are undercutting the security and prosperity they have enabled. Each day, the United States spends about $2 billion buying oil and loses another $4 billion indirectly to the macroeconomic costs of oil dependence, the microeconomic costs of oil price volatility, and the cost of keeping military forces ready for intervention in the Persian Gulf.

In all, the United States spends one-sixth of its GDP on oil, not counting any damage to foreign policy, global stability, public health, and the environment. The hidden costs are also massive for coal and are significant for natural gas, too. Even if oil and coal prices were not high, volatile, and rising, risks such as fuel insecurity and dependence, pollution-caused illnesses, energy-driven conflicts over water and food, climate change, and geopolitical tensions would make oil and coal unattractive.

Weaning the United States from those fossil fuels would require two big shifts: in oil and electricity. These are distinct—nearly half

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of electricity is made from coal, and almost none is made from oil—but power plants and oil burning each account for over two-fifths of the carbon that is emitted by fossil-fuel use. In the United States, three-fourths of electricity powers buildings, three-fourths of oil fuels transportation, and the remaining oil and electricity run factories. So saving oil and electricity is chiefly about making buildings, vehicles, and factories far more efficient—no small task.

But epochal energy shifts have happened before. In 1850, most U.S. homes used whale-oil lamps, and whaling was the country's fifth-biggest industry. But as whale populations dwindled, the price of whale oil rose, so between 1850 and 1859, coal-derived synthetic fuels grabbed more than five-sixths of the lighting market. In 1859, Edwin Drake struck oil, and kerosene, thanks to generous tax breaks, soon took over. Whalers, astounded that they had run out of customers before they ran out of whales, begged for federal subsidies on national security grounds, but Thomas Edison's 1879 invention of electric lighting snuffed out their industry. Whales had been accidentally saved by technological innovators and profit-maximizing capitalists.

As the world shuddered from the 1973 oil shock, the economist Phil Gramm predicted that just as with whale oil, innovators would innovate, capitalists would invest, markets would clear, and substitutes for petroleum would ultimately emerge. He was right. By 2010, the United States was using 60 percent less oil to make $1 of GDP than it had in 1975. Now, the other shoe is dropping: since its use in the United States peaked in 2005, coal has lost one-fourth of its share of the U.S. electric services market to renewable energy, natural gas, and efficient use. After just a few centuries, the anomalous era of oil and coal is gradually starting to come to an end. In its place, the era of everlasting energy is dawning.

Underlying this shift in supply is the inexorable shrinkage in the energy needed to create $1 of GDP. In 1976, I heretically suggested in these pages that this "energy intensity" could fall by two-thirds by 2025. By 2010, it had fallen by half, driven by no central plan or visionary intent but only by the perennial quest for profit, security, and health. Still-newer methods, without further inventions, could reduce U.S. energy intensity by another two-thirds over the next four decades, with huge economic benefits. In fact, as *Reinventing Fire*, the new book

from my organization, Rocky Mountain Institute (RMI), details, a U.S. economy that has grown by 158 percent by 2050 could need no oil, no coal, no nuclear energy, and one-third less natural gas—and cost $5 trillion less than business as usual, ignoring all hidden costs. Today's fossil carbon emissions could also fall by more than four-fifths without even putting a price on them.

This transformation requires pursuing three agendas. First, radical automotive efficiency can make electric propulsion affordable; heavy vehicles, too, can save most of their fuel; and all vehicles can be used more productively. Second, new designs can make buildings and factories several times as efficient as they are now. Third, modernizing the electric system to make it diverse, distributed, and renewable can also make it clean, reliable, and secure. These ambitious shifts may seem quixotic, but sometimes tough problems are best solved by enlarging their boundaries, as General Dwight Eisenhower reputedly advised.

Thus, it is easier to solve the problems of all four energy-using sectors—transportation, buildings, industry, and electricity—together than separately. For example, electric vehicles could recharge from or supply power to the electricity grid at times that compensate for variations in the output from wind and solar power. Synergies likewise arise from integrating innovations in technology, policy, design, and strategy, not just the first one or two.

This transition will require no technological miracles or social engineering—only the systematic application of many available, straightforward techniques. It could be led by business for profit and sped up by revenue-neutral policies enacted by U.S. states or federal agencies, and it would need from Congress no new taxes, subsidies, mandates, or laws. The United States' most effective institutions—the private sector, civil society, and the military—could bypass its least effective institutions. At last, Americans could make energy do their work without working their undoing.

MOBILITY WITHOUT OIL

THE UNITED STATES burns one-fourth of the world's oil, half in automobiles (which comprise cars and light trucks). Two-thirds of cars' fuel use is caused by their weight, yet for the past quarter century, U.S.

cars have gained weight twice as fast as their drivers. Now, lighter metals and synthetic materials are reversing automotive obesity. Ultralight, ultrastrong carbon-fiber composites can trigger dramatic weight savings, improve safety, and offset the carbon fiber's higher cost with simpler automaking (needing four-fifths less capital) and smaller powertrains. In 2011, lightweighting became the auto industry's hottest trend. Ford's strategy rests on it, and the United States could lead it. So far, however, Germany has taken the lead: Volkswagen, BMW, and Audi all plan to be mass-producing carbon-fiber electric cars by 2013.

Ultralight, aerodynamic autos make electric propulsion affordable because they need fewer costly batteries or fuel cells. Rather than wringing pennies from old steel-stamping and engine technologies, automakers could exploit mutually reinforcing advances in carbon fiber, its structural manufacturing, and electric propulsion—a transition as game changing as the shift from typewriters to computers. BMW, whose chief executive has said, "We do not intend to be a typewriter-maker," has confirmed that its planned 2013 electric car will pay for its carbon fiber by needing fewer batteries.

Electric autos are already far cheaper to fuel than gasoline autos, and they could also cost about the same to buy within a few decades. Until then, "feebates"—rebates for more efficient new autos, paid for by equivalent fees on inefficient ones—could prevent sticker shock. In just two years, France, with the biggest of Europe's five feebate programs, saw its new autos get more efficient three times as fast as before. Well-designed U.S. feebates, which could be enacted at the state level, need not cost the government a penny. They could expand customers' choices and boost automakers' and dealers' profit margins.

Autos could also be used more productively. If the government employed new methods to charge drivers for road infrastructure by the mile, its insolvent Highway Trust Fund would not need to rely on taxing dwindling gallons of fuel. Information technologies could smooth traffic flow, enhance public transit, and promote vehicle- and ridesharing. Better-designed layouts of communities could increase affordability, livability, and developers' profits. Together, these proven innovations could get Americans to their destinations with half the driving (or less) and $0.4 trillion less cost.

RMI's analysis found that by 2050, the United States could deliver far greater mobility by making vehicles efficient, productive, and oil-free. Autos powered by any mix of electricity, hydrogen fuel cells, and advanced biofuels could get the equivalent of 125 to 240 miles per gallon of gasoline and save trillions of dollars. By 2050, "drilling under Detroit" could profitably displace nearly 15 million barrels of oil per day—1.5 times as much as Saudi Arabia's current daily output.

Heavy vehicles present similar opportunities. From 2005 to 2010, Walmart saved 60 percent of its heavy-truck fleet's fuel through smarter designs and changes in driver behavior and logistics. Aeronautical engineers are designing airplanes that will be three to five times as efficient as today's. Superefficient trucks and airplanes could use advanced biofuels or hydrogen, or trucks could burn natural gas, but no vehicles would need oil. Advanced biofuels, two-thirds made from waste, would require no cropland, protecting soil and the climate. The U.S. military's ongoing advances in efficiency will speed all these innovations in the civilian sector, which uses over 50 times as much oil, just as military research and development created the Internet, GPS, and the microchip and jet-engine industries.

U.S. gasoline demand peaked in 2007; the oil use of the countries of the Organization for Economic Cooperation and Development peaked in 2005. With China and India pursuing efficient and electric vehicles, Deutsche Bank forecast in 2009 that world oil use could begin to decline after 2016. In fact, the world is nearing "peak oil"—not in supply but in demand. Oil is simply becoming uncompetitive even at low prices before it becomes unavailable even at high prices.

SAVING ELECTRICITY

THE NEXT big shift is to raise electricity productivity faster than the economy grows—starting with the United States' 120 million buildings. Even though U.S. buildings are projected to provide 70 percent more total floorspace in 2050, they could use far less energy. Investing an extra $0.5 trillion on existing or emerging energy-efficiency technologies and better-integrated designs could save building owners $1.9 trillion by tripling or quadrupling energy productivity. These straightforward improvements range from installing

insulation, weather-stripping, and caulking to using more efficient equipment and controls, adopting better lighting design, and simply making new buildings the right shape and facing them in the right direction.

An even more powerful innovation, called "integrative design," can often save far more energy still, yet at lower cost. Integrative design optimizes a whole building, factory, vehicle, or device for multiple benefits, not isolated components for single benefits. For example, in 2010, the Empire State Building remanufactured its 6,514 windows onsite into "superwindows," which pass light but block heat. Requiring a third less air conditioning on hot days saved $17 million of the project's capital cost immediately, partly funding this and other improvements. In just three years, energy savings above 40 percent will repay the owners' total energy-saving investment.

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Integrative design's expanding returns are even more impressive when built in from scratch. From tropical to subarctic climates, new passively heated and cooled buildings can replace furnaces and air conditioners with superinsulation, heat recovery, and design that exploits the local climate. European companies have built 32,000 such structures at roughly normal capital cost and cost-effectively retrofitted similar performance into Swedish apartments constructed in the 1950s and into century-old Viennese apartments. The business case would be even stronger if it included the valuable indirect benefits of these more comfortable, pleasant, and healthful buildings: higher office labor productivity and retail sales, faster learning in classrooms, faster healing in hospitals, and higher real estate values everywhere.

Integrative design can also help double industrial energy productivity, saving $0.5 trillion. Pumps, for example, are the world's biggest user of electric motors. Pumps, motors, and controls can improve, but first replacing long, thin, crooked pipes with short, fat, straight ones often avoids 80–90 percent of the usual friction, saving ten times as much coal back at the power plant. When RMI and its industrial partners recently redesigned existing factories valued at more than $30 billion, our designs cut predicted energy use by about 30–60 percent with payback times of

a few years. In new facilities, our designs were expected to save around 40–90 percent of energy use while usually reducing capital costs. This is not rocket science—just elegantly frugal whole-system thinking.

Adopting energy-saving innovations as quickly nationwide as some U.S. states do today will require patiently fixing perverse incentives, sharing benefits between landlords and tenants, allocating capital wisely, and designing thoughtfully—not just copying the old drawings ("infectious repetitis"). None of this barrier busting is easy, but the rewards are great. Since the Dow Chemical Company embraced efficiency innovation in the 1990s, its $1 billion investment has returned $19 billion. Savings and returns, far from petering out, often kept rising as the engineers learned new tricks faster than they exhausted old ones.

REPOWERING PROSPERITY

The United States must replace its aging, dirty, and insecure electric system by 2050 just to offset the loss of power plants that are being retired. Any replacement will cost about $6 trillion in net present value, whether it is more of the same, new nuclear power plants and "clean coal," or centralized or distributed renewable sources. But these differ profoundly in the kinds of risks they involve—in terms of security, safety, finance, technology, fuel, water, climate, and health—and in how they affect innovation, entrepreneurship, and customer choice.

Choosing electricity sources is complicated by copious disinformation, such as the myth that nuclear power was thriving in the United States until environmentalists derailed it after the March 1979 Three Mile Island meltdown. In fact, bad economics made orders for nuclear power plants in the United States fall by 90 percent from 1973 to 1975 and dry up completely by 1978. Indeed, soaring capital costs eventually halted nuclear expansion in all market-based power systems, and by 2010, all 66 reactors under construction worldwide had been bought by central planners.

Even after the U.S. government raised its subsidies for new reactors in 2005 to at least their construction costs, not one of the 34 proposed units could attract private capital; they simply had no business case. Neither do proposed "small modular reactors": nuclear reactors do not scale down well, and the economies sought from mass-producing

hypothetical small reactors cannot overcome the head start enjoyed by small modular renewables, which have attracted $1 trillion since 2004 and are adding another $0.25 trillion a year. After the 2011 Fukushima nuclear disaster, John Rowe, chair of Exelon (the United States' biggest nuclear power producer), pronounced the nuclear renaissance dead. In truth, market forces had killed it years earlier.

New coal and nuclear plants are so uneconomical that official U.S. energy forecasts predict no new nuclear and few new coal projects will be launched. Investors are shunning their high costs and financial risks in favor of small, fast, modular renewable generators. These reduce the financial risk of building massive, slow, monolithic projects, and needing no fuel, they hedge against volatile gas prices. Already, wind and solar power's falling costs are beating fossil-fueled power's and nuclear power's rising costs. Some solar panels now sell wholesale for less than $1 a watt (down 75 percent in three years), some installed solar-power systems in Germany sell for $2.80 a watt, and some U.S. wind-power contracts charge less than three cents per kilowatt-hour—all far below recent forecasts. Solar power's plummeting cost, a stunning market success, is ruining some weaker or slower solar-cell-makers, but solar and wind power are extinguishing the prospects of coal and nuclear power around the world. So is cheap new natural gas—a valuable transitional resource if its many uncertainties can be resolved, but not a serious disappointment if they cannot, since higher efficiency and renewable energy should lower the demand for gas.

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Skeptics of solar and wind power warn of their fluctuating output. But the grid can cope. Just as it routinely backs up nonworking coal-fired and nuclear plants with working ones, it can back up becalmed wind turbines or darkened solar cells with flexible generators (renewable or not) in other places or of other kinds, or with systems that voluntarily modulate demand. Even with little or no bulk power storage, diversified, forecastable, and integrated renewables can prove highly reliable. Such integration into a larger, more diverse grid is how in 2010 Denmark had the capacity to produce 36 percent of its electricity from renewables, including 26 percent from wind (in an average wind year), and how four

German states were 43–52 percent wind-powered. But U.S. and European studies have shown how whole continents could make 80 percent or more of their power renewably by operating existing assets differently within smarter grids, in markets that clear faster and serve larger areas.

Diverse, dispersed, renewable sources can also make the grid highly resilient. Centralized grids are vulnerable to cascading blackouts caused by natural disaster, accident, or malice. But grid reorganizations in Denmark and Cuba have shown how prolonged regional blackouts become impossible when distributed renewables, bypassing vulnerable power lines (where most failures start), feed local "microgrids," which can stand alone if needed. The Pentagon, concerned about its own reliance on the commercial grid, shares this goal of resilience and this path to achieving it.

Individual households can also declare independence from power outages and utility bills, as mine has. In many parts of the United States, a private company can now install rooftop solar power with no money down and charge the customer less money per month to pay for it than the old electricity bill. These and other unregulated services could eventually create a "virtual utility" that could largely or wholly bypass power companies, just as cell phones bypassed landline phone companies—a prospect that worries utility executives but excites venture capitalists. Today, solar power is subsidized, although often less than fossil-fueled or nuclear plants and their fuel. But sooner than those rivals could be built, solar power should win out even without subsidies.

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In 2010, renewable sources, except for big hydropower dams, produced only three percent of the world's electricity, but for the third year running, they were responsible for nearly half of all new capacity. That same year, they won $151 billion of private investment and surpassed the total generating capacity of nuclear plants worldwide by adding over 60 billion watts of capacity. The world can now manufacture that much new photovoltaic capacity every year, outpacing even wind power.

The United States is a leader in developing renewable technology but lags in installing it. In June 2010 alone, Germany, with less sun than

Seattle, added 142 percent more solar-cell capacity than the United States did in all of 2010. Stop-and-go congressional policies sank U.S. clean-energy investments from first place globally to third between 2008 and 2010. (Federal initiatives expiring in 2011–12 temporarily restored the U.S. lead in 2011.) From 2005 to 2010, while the renewable fraction of the United States' electricity crawled from nine percent to ten percent, that of Portugal's soared from 17 percent to 45 percent. In 2010, congressional wrangling over the wind-power tax credit halved wind-power additions, while China doubled its wind capacity for the fifth year running and beat its 2020 target. The same year, 38 percent of China's net new capacity was renewable. China now leads the world in five renewable technologies and aims to in all.

Legacy industries erect many anticompetitive roadblocks to U.S. renewable energy, often denying renewable power fair access to the grid or rejecting cheaper wind power to shield old plants from competition. In 34 U.S. states, utilities earn more profit by selling more electricity and less if customers' bills fall. In 37 states, companies that reduce electricity demand are not allowed to bid in auctions for proposed new power supplies. But wherever such impediments are removed, efficiency and renewables win. In 2009, developers offered 4.4 billion watts of solar power cheaper than electricity from an efficient new gas-fired plant, so California's private utilities bought it—and in 2011, they were offered another 50 billion watts.

A COOLER AND SAFER WORLD

THIS NEW energy future offers a pragmatic solution to climate change. Often assumed to be costly, reducing carbon emissions is actually profitable, since saving fuel costs less than buying fuel. Profits, jobs, and competitive advantage make for easier conversations than costs, burdens, and sacrifices, and they need no global treaties to drive them.

In 2009, the consulting firm McKinsey & Company found that projected greenhouse gas emissions could be cut by 70 percent by 2030 at a trivial average cost of $6 per metric ton of carbon dioxide equivalent (the standard unit of global-warming impact). Including newer technologies and integrative designs could save even more carbon more cheaply, and thus could more than meet the United

States' obligations under the 1992 UN Framework Convention on Climate Change while saving $5 trillion.

Getting the United States off fossil fuels would transform its foreign policy. A world where the United States and other countries buy no oil because its price and price volatility exceed its value would have less oil-fed tyranny, corruption, terrorism, tension, and war. Washington, no longer needing an oil-centric foreign policy, could maintain normal relations with oil-exporting countries and treat diplomatic issues on their merits. The Pentagon would be pleased, too. Today, every one of the U.S. military's nine combatant commands must protect oil assets and transportation routes—fighting tanker-hijacking pirates off the coast of Somalia or pipeline-attacking militants from Latin America to Central Asia. The U.S. Army would love Mission Unnecessary in the Persian Gulf; the U.S. Navy would no longer need to worry as much about conflicts from the Arctic to the South China Sea. Proliferators, meanwhile, could no longer hide their intent behind civilian nuclear power in a world that acknowledged its marketplace collapse and the superiority of nonnuclear competitors. Nor could they draw on civilian skills, materials, and equipment.

Phasing out fossil fuels would turbocharge global development, which is also in the United States' interest. Energy inefficiency is one of the biggest causes of persistent poverty. Oil purchases underlie much of the developing world's debt, and wasted energy diverts meager national and household budgets. Developing countries are on average one-third as energy efficient as rich ones, and the poor often spend far more of their disposable income on energy than does the general population. Some 1.6 billion people live without electricity, leaving many basic needs unmet, hobbling health and development, and trapping women and girls in uneducated penury.

Investments in new electricity devour one-fourth of the world's development capital. There is no stronger nor more neglected lever for global development than investing instead in making devices that save electricity. This would require about one-thousandth the capital and return it ten times as fast, freeing up vast sums for other development needs. If the United States, Europe, China, and India merely adopted highly efficient lights, air conditioners, refrigerators, and TVs, they could save $1 trillion and 300 coal plants. That is the goal of the

Super-efficient Equipment and Appliance Deployment Initiative, an effort announced in 2009 and supported by 23 major countries.

Developing countries, with their rural villages, burgeoning cities and slums, and dilapidated infrastructures, especially need renewable electricity, and they now buy the majority of the world's new renewable capacity. Some remote villages are not waiting for the wires but leapfrogging the grid: more Kenyans are getting electricity first from solar-power entrepreneurs than from traditional utilities. Such efforts as the U.S. Department of Energy's Lumina Project have helped bring efficient and affordable solar-powered LED lights to millions across Africa. These projects improve education; free up kerosene budgets for mosquito nets, clean water, and other necessities; and could eventually prevent 1.5 million deaths from lung disease annually. Just by switching from kerosene lamps to fluorescent ones, one Indian village got 19 times as much light with one-ninth the energy and half the cost.

GETTING UNSTUCK

THE UNITED STATES cannot afford to keep waiting for a gridlocked Congress to act while the global clean-energy revolution passes it by. While U.S. fossil-fuel industries guard their parochial interests, Denmark is planning to get entirely off fossil fuels by 2050; Sweden has even aimed for 2020. Germany's campaign for renewables and energy efficiency helped push unemployment in the country to its lowest rate in a decade. German Chancellor Angela Merkel is winning her bet that the Russian company Gazprom is a less worthy recipient of German energy expenditures than German engineers, manufacturers, and installers. Brazil, Japan, and South Korea, meanwhile, are catching up in renewables. India has passed Japan and the United Kingdom in renewables investments and aims to rival China's global leadership in the sector.

As Washington's clean-energy research-and-development budget has shrunk, Beijing's has soared. In 2005, China's 11th five-year plan made lower energy intensity the top strategic priority for national development. In 2010, the 12th five-year plan launched a $0.8 trillion decarbonization effort, created the world's largest carbon-trading zone, and effectively capped China's carbon emissions. The country's

net additions of coal plants fell by half between 2006 and 2010, and the overall efficiency of its coal plants pulled ahead of that of the United States'. No treaty compelled Beijing's leadership—just enlightened self-interest.

The United States' halfheartedness raises a conundrum: if the vision of an efficient clean-energy economy is so compelling, what keeps all U.S. citizens, firms, and institutions from embracing it as vigorously as a few states have? The answer is that markets outpace understanding, disinformation and parochial politics abound, and the road remains strewn with barriers, myths, and pervasive favoritism for incumbents. But must Thucydides' lament become Americans' fate—that each politician pursues self-advantage while "the common cause imperceptibly decays"?

The chief obstacle is not technology or economics but slow adoption. Helping innovations catch on will take education, leadership, and rapid learning. But it does not require reaching a consensus on motives. If Americans agree what should be done, then they need not agree why. Whether one cares most about national security, health, the environment, or simply making money, saving and supplanting fossil fuels makes sense.

Wise energy policy can grow from impeccably conservative roots—allowing and requiring all ways to save or produce energy to compete fairly at honest prices, regardless of their type, technology, size, location, or ownership. Who would oppose that? And what if the United States reversed the runaway energy-subsidy arms race, heading toward zero? Let those energy producers that insist they get no taxpayer largess explain why they are so loath to give it up.

Moving the United States off oil and coal will require Americans to trust in their own resourcefulness, ingenuity, and courage. These durable virtues can give the country fuel without fear; help set the world on a path beyond war, want, or waste; and turn energy from worrisome to worry-free, from risk to reward, from cost to profit.