

REINVENTING FIRE

AMORY LOVINS

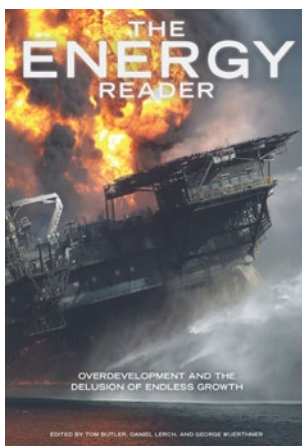


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ABOUT THE AUTHOR

Energy visionary AMORY LOVINS is the author of hundreds of scientific papers and 31 books, the latest of which is the 2011 “grand synthesis” *Reinventing Fire: Bold Business Solutions for the New Energy Era*. He cofounded and chairs Rocky Mountain Institute, an independent, nonpartisan, nonprofit think-and-do tank that collaborates with the private sector to drive the efficient and restorative use of resources.

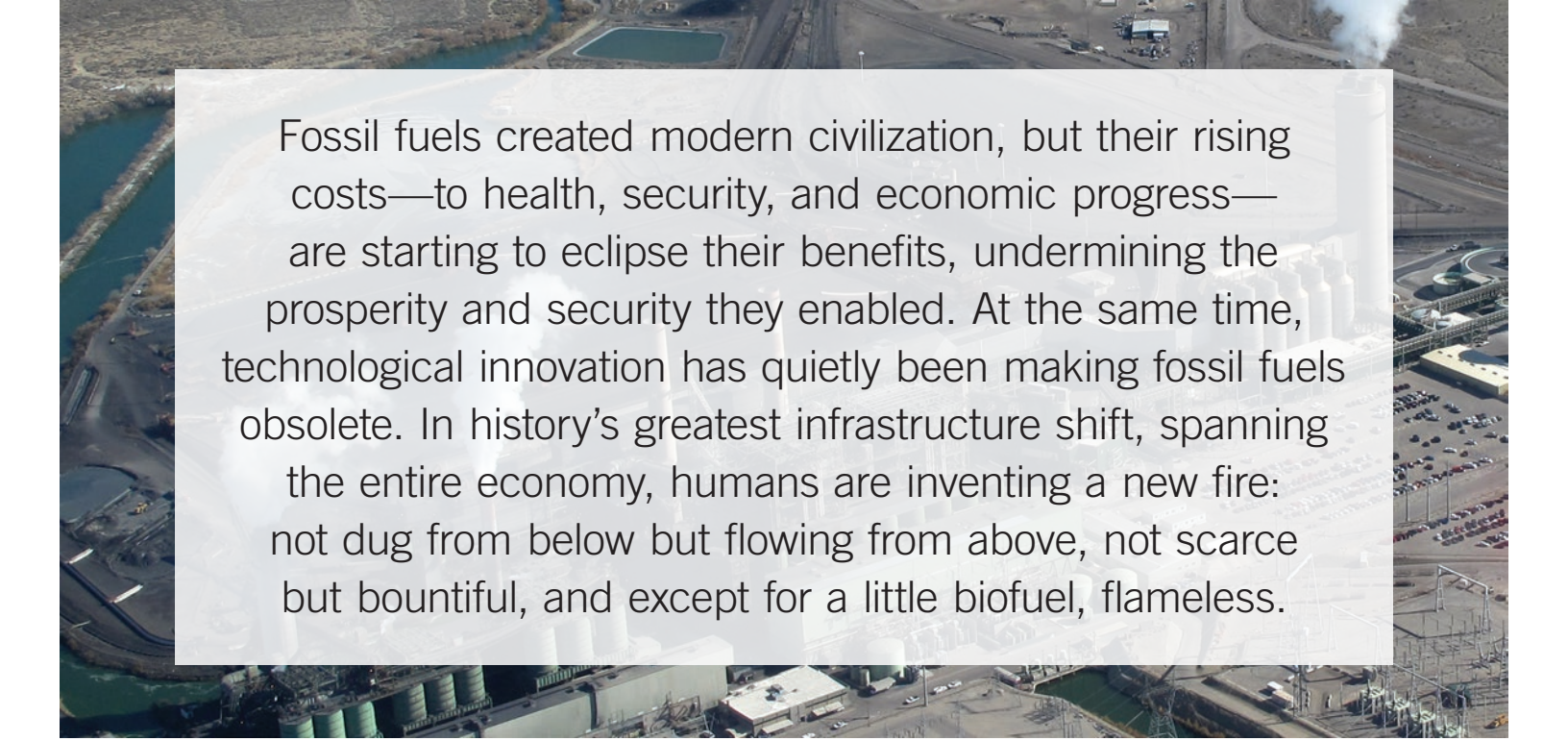
Amory Lovins adapted his essay “Reinventing Fire” from *Reinventing Fire: Bold Business Solutions for the New Energy Era* (Chelsea Green Publishing), produced by Lovins and his Rocky Mountain Institute colleagues; © 2011 by Rocky Mountain Institute.



This publication is an excerpted chapter from *The Energy Reader: Overdevelopment and the Delusion of Endless Growth*, Tom Butler, Daniel Lerch, and George Wuerthner, eds. (Healdsburg, CA: Watershed Media, 2012). *The Energy Reader* is copyright © 2012 by the Foundation for Deep Ecology, and published in collaboration with Watershed Media and Post Carbon Institute.

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Photo: EcoFlight. *The old fire: The San Juan Generating Station, a coal-burning power plant in New Mexico, typifies the old energy economy.*



Fossil fuels created modern civilization, but their rising costs—to health, security, and economic progress—are starting to eclipse their benefits, undermining the prosperity and security they enabled. At the same time, technological innovation has quietly been making fossil fuels obsolete. In history's greatest infrastructure shift, spanning the entire economy, humans are inventing a new fire: not dug from below but flowing from above, not scarce but bountiful, and except for a little biofuel, flameless.

Fire made us human; fossil fuels made us modern. Now we need a new fire that makes us secure, safe, healthy, and durable.

Oil and coal built our civilization. Fossil energy became the foundation of our wealth, the bulwark of our might, the unseen metabolic engine of modern life. Yet this enabler of our civilization, this magic elixir that has enriched and extended the lives of billions, has also begun to make our lives more fearful, insecure, costly, destructive, and dangerous. It puts asthma in our children's lungs and mercury in their lunchbox tuna. Its occasional mishaps can shatter economies. Its wealth and power buy politicians. It drives many of the world's rivalries, corruptions, despotisms, and wars. It is changing the composition of Earth's atmosphere faster than at any time in the past 60 million years.

In short, the rising costs of fossil fuels are starting to eclipse their benefits, undermining the prosperity and security they enabled. Fortunately, these problems are not necessary to endure, either technologically or economically. We can avoid them in ways that tend to *reduce* energy costs—because technological progress has quietly been making fossil fuels obsolete.

What's driving this transformation is basic economics. By 2009, making a dollar of U.S. gross domestic product used 60 percent less oil than in 1975, 63 percent

less (directly used) natural gas, 20 percent less electricity, and 50 percent less total energy. Oil is becoming uncompetitive even at low prices before it becomes unavailable even at high prices: Peak oil has emerged in demand before supply. Oil use in the industrialized nations represented by the Organization for Economic Cooperation and Development (OECD) peaked in 2005, U.S. gasoline use in 2007. In 2009, Deutsche Bank said world oil use could peak around 2016.

With today's technologies, it is possible to build uncompromised, safe, roomy, peppy, electric autos. Redesigning the entire U.S. automobile fleet to be superefficient and electrified by 2050 could achieve automotive fuel economy equivalent to 125–250 miles per U.S. gallon (1.0–1.9 L/100 km) and would save oil at an average cost below \$18 per saved barrel—just one-fifth of today's world oil price. Buying that efficiency and electrification instead of burning oil to provide the same services from today's and officially forecast autos would save \$4 trillion. Such “drilling under Detroit” can win the equivalent of 1.5 Saudi Arabias or half an OPEC, and those “negabarrels” are all domestic, secure, clean, safe, and inexhaustible. The investments required for these four- to eightfold more efficient and oil-free autos and for tripled-efficiency trucks and airplanes could yield a 17 percent internal rate of return (IRR) while greatly reducing risks to the oil and automotive sectors and to the whole economy. The trucks and planes could

use advanced biofuels or hydrogen, the trucks could even burn natural gas, but no vehicles would need oil. Despite 90 percent more automobility, 61 percent more flying, and 118 percent more trucking, the most bio-fuel the United States might need would be less than one-fourth its current use of mobility fuel. That little biofuel could be produced two-thirds from wastes and one-third from cellulosic or algal production that needs no cropland and protects both soil and climate.

Coal—America’s #4 source of energy services after efficiency, oil, and gas—is a “dead man walking,” says Deutsche Bank’s Kevin Parker. Ignoring coal’s \$180–530 billion annual hidden costs, mainly to public health, America’s coal-fired power plants now cost more to run than the cost of displacing them by running existing gas-fired plants more and adopting a level of electrical productivity that ten states, on average, already achieved in 2005. That’s why U.S. coal use peaked in 2005, and in 2005–2010, coal lost 25 percent of its share of U.S. electrical services to gas, efficiency, and renewables. Nonnuclear alternatives cheaper than new coal plants could displace U.S. coal power more than 23 times. Once suffices.

Asia is the world leader in adding renewable power; in 2010 only 59 percent of China’s net new capacity was coal-fired (versus 38 percent renewable, 2 percent nuclear) and coal’s share of China’s new generation capacity is shrinking. China’s net new orders of coal-fired plants fell by half during 2006–2010. China now leads the world in five renewable energy technologies, and it aims to lead in all of them as the core of its next economy. America, where coal now employs fewer people than wind power, remains politically preoccupied with its previous economy.

Yet solar and wind power have become market winners as their prices plummet—by three-fourths in three years for photovoltaic modules. In roughly 20 states and even in cloudy Holland, entrepreneurs now offer to install solar power on your roof for no money down, and thereby to beat your utility bill. The tipping point where alternatives win on pure price is not decades in the future; it is here and now, forming the fulcrum

of economic transformation. Across all energy uses, efficiency and renewables now offer effective, reliable, secure, and affordable replacements for fossil fuel. Rapidly scaling those solutions will define winners and losers between firms—and among nations.

Renewable power, with its lower risk and competitive cost, added half the world’s 2008–2010 new generating capacity. In 2010 worldwide, renewable generators other than big hydro dams got \$151 billion of private investment and surpassed nuclear power’s total installed capacity by adding more than *60 gigawatts*. That much solar capacity is now manufacturable *every year*.

In this global race, the United States’ capital, technology, and entrepreneurship equip it for success. Yet it’s been held back by lack of coherent vision and overdependence on gridlocked government. In 2010, congressional wrangling helped halve U.S. wind power installations, while China doubled its wind power capacity for the fifth year running and blew past its 2020 wind power target. During 2008–2010, America slipped from #1 to #3 in clean-energy investment, then temporarily rebounded to #1 in 2011 thanks to federal initiatives trying to fill gaps in the wounded capital markets—but those initiatives expire in 2011–2012, while China’s policy remains consistent. Since 2005, U.S. electricity’s renewable share crawled from 9 percent to 10 percent while Portugal’s soared from 17 percent to 45 percent. Germany, with less sun than Seattle, added more solar power capacity in June 2010 than the United States did in all of 2010, and more in December 2011 than the United States did in all of 2011. By mid-2011, more workers made German solar equipment than made American steel. Germany’s efficiency-and-renewables strategy has helped cut its unemployment rate to an eleven-year low.

Japan is moving the same way, but not as fast as India. Brazil and Korea are jumping rapidly into clean energy. As wind power wins power auctions across South America and an unsubsidized solar power plant (the world’s most productive) in Chile’s northern desert beats the grid price, Chile, with perhaps the world’s best portfolio of renewable energy options, is trying to decide

whether to let them (and energy efficiency) outcompete traditional projects that are attempting to use political clout to make up for their lack of cost effectiveness.

Worldwide, distributed electricity production is running away with the electric-generation market: About 91 percent of new electricity in 2008 came from renewables (excluding big hydro dams) and combined-heat-and-power. All renewables now deliver a fifth of the world's electricity from a fourth of the world's generating capacity. In 2011, the clean-energy market won \$260 billion of investment and attracted its trillionth dollar since 2004. All countries hoping to build or retain economic dynamism must catch up with this multi-trillion-dollar, once-in-a-civilization business opportunity.

How? Use our most effective institutions—private enterprise, coevolving with civil society and sped by military innovation—to end-run ineffective institutions like the U.S. Congress. In autumn 2011, such a strategy was detailed in Rocky Mountain Institute's independent energy vision for American leadership, *Reinventing Fire*, with forewords by the CEO of Shell Oil and the chairman of Exelon. Its fresh competitive strategies can win the clean energy race, not forced by public policy but led by business for durable advantage.

Reinventing Fire maps market-based paths for running a 158 percent-bigger U.S. economy in the year 2050 (an assumed growth target based on official projections, not personal preferences) with no oil, no coal, no nuclear energy, one-third less natural gas, and no new inventions. Moreover, this could be accomplished at a net-present-value cost of \$5 trillion *below* business as usual, assuming all externalities are valued at zero (a conservatively low estimate, as oil's hidden economic and military costs alone exceed \$1.5 trillion a year, excluding any damage to public health and environment).

The business case for efficiency is so compelling that adopting it would require no new federal taxes, subsidies, mandates, or laws. Policy innovations that unlock and speed the transition could be implemented with no Act of Congress—instead by federal administrative actions and at the state level, where utilities are already

largely regulated (but 36 states still reward them for selling more energy and penalize them for cutting your bill). The key automotive reform could also be readily adopted by states: *Feebates*, a revenue-neutral way to help auto buyers use societal discount rates, tripled the speed of improving new French autos' efficiency in just two years.

If General Dwight Eisenhower couldn't solve a problem, he made it bigger, expanding its boundaries until added options and synergies made it soluble. In the same vein, *Reinventing Fire* integrates all four energy-using sectors—transportation, buildings, industry, and electricity—and four kinds of innovations—technology, design, policy, and business strategy. Together these are much more than the sum of the parts.

The auto and electricity problems, for example, are easier to solve together than separately. New design and manufacturing methods can make ultralight, ultra-safe autos cost-competitive. Needing half or a third the power for the same pep then lets electric propulsion compete too. (BMW, VW, and Audi plan to mass-produce electrified carbon-fiber cars by 2013.) But carbon fiber and electrification are cheaper when combined: three steep and synergistic learning curves—in carbon fiber, automaking, and electric power trains—together create a game changer as potent as the shift from typewriters to computers.

Adding tripled-efficiency trucks and planes, and using all vehicles more productively, enables greatly expanded mobility fueled by a mixture of electricity, hydrogen, and advanced biofuels, but needing no oil. Smart vehicles, buildings, and grids could make electric autos not a burden but a valuable flexibility and storage resource. That is, by buying electricity from the grid or selling it back at the right times, a smart electric auto fleet can help smooth out variations in solar and wind power generation, reducing the need for fossil-fueled generation and making an 80-100 percent renewables-powered electricity grid reliable and competitive.

Doubled energy productivity in industry (with a 21 percent IRR), tripled or quadrupled in buildings

(33 percent IRR), can profitably shrink electricity demand despite 84 percent more industrial production and 70 percent more floor space. Just investing \$0.5 trillion to fix buildings, which use three-fourths of U.S. electricity, can save \$1.9 trillion. The recent retrofitting of the Empire State Building and its resultant two-fifths energy savings with a three-year payback illustrate how integrative design can often yield *expanding* returns, making big energy savings cheaper than small ones: Remanufacturing all 6,514 windows onsite in a temporary window factory on a vacant floor made them pass light but block heat, reducing winter heat loss by two-thirds and summer heat gain by half. Adding better daylighting, lighting systems and controls, and office equipment saved a third of air conditioning on hot days. This in turn saved \$17 million of capital cost because the old chillers could be renewed and reduced rather than replaced and enlarged. That capital saving helped pay for the other improvements, cutting the payback to three years. Applying this approach to a twenty-year-old glass office tower could even save three-fourths of its energy, slightly cheaper than the normal twenty-year renovation that saves almost nothing.

The key to this economic magic is “integrative design”—designing a building, factory, device, or vehicle as a whole system and optimizing it for multiple benefits, rather than optimizing isolated components for single benefits. For example, the middle of my own house, high in the Rockies where outdoor temperatures used to fall as low as -47°F (-44°C), is currently ripening its 37th through 39th banana crops with no furnace during a January snowstorm. The house is about 99 percent passive-solar heated, but the superwindows, superinsulation, and ventilation heat recovery that eliminated its heating system added less construction cost than eliminating the heating system saved. Responding that saved capital cost plus a bit more also saved about 90 percent of the household electricity and 99 percent of the water-heating energy, all with a ten-month payback using 1983 technology. Today’s technology is much better, so we’ve just retrofitted it and are measuring its performance; unfortunately, the monitoring system seems to be using more electricity than the lights and appliances it’s measuring.

An even more striking example comes from pumping—the main use of motors, which use three-fifths of the world’s electricity. Using fat, short, straight pipes rather than narrow, long, crooked pipes saves typically 80–90 percent of the friction in the pipes. Shrinking the pumps, motors, inverters, and electrical systems more than pays for the fatter pipes, decreasing total capital cost. In my own house, this tactic cut friction by about 97 percent. Fans and ducts, the second biggest use of motors, offer similar opportunities. And every unit of friction saved in pipes or ducts saves about ten times more fuel, cost, and what Hunter Lovins calls “global weirding” back at the power station.

Industry is already ripe in opportunities for better motor systems and pumps, fans and controls, heat recovery and insulation. Dow Chemical has already saved \$19 billion on \$1 billion of efficiency investments. But integrative design can make savings bigger yet cheaper, turning diminishing returns into expanding returns. Rocky Mountain Institute’s latest \$30-odd billion worth of integrative redesign of equipment and processes across diverse industries—from refineries to mines and data centers to chip fabs—has typically reduced expected energy use by about 30–60 percent with a few years’ payback on retrofits, or by about 40–90+ percent with generally lower capital cost in new factories. Integrative design isn’t yet included in official studies of energy-saving potential, but smart firms are realizing how it can drive competitive advantage. RMI’s Factor Ten Engineering (10xE) initiative aims to use it to transform how design is done and taught.

Combining modern ways to wring more work out of each kilowatt-hour could power a 2.6-fold bigger U.S. economy with one-fourth less electricity than now, eliminating not just coal-fired but also nuclear power production. That’s good, because as those old plants retire (virtually all by 2050), replacing them with more of the same would be so costly and risky that no business case can be made for it. All 34 new proposed nuclear plants in the United States can’t raise any private capital despite 100+ percent construction subsidies: At most a few units may be built, entirely financed by mandatory payments from customers and taxpayers. All

66 reactors under construction worldwide at the end of 2010 were bought by centrally planned power systems. Nuclear power's death of an incurable attack of market forces strengthens climate protection, because new nuclear plants are so costly and slow that they would save about 10–20 times less carbon per dollar, about 20–40 times slower, than investing in efficiency and renewables instead.

Productive and timely use of electricity, combined-heat-and-power, reallocated saved natural gas, and a modern renewables portfolio can enable a diverse, distributed, reliable, resilient electricity future that costs about the same as business as usual but manages all its risks, including economy-shattering blackouts. Replacing America's aging, dirty, obsolescent, insecure electricity system by 2050 will cost about \$6 trillion in net present value no matter how we do it. So let's re-architect and rebuild it to power not just lights and motors but also competitive advantage, profits, jobs, national security, environmental stewardship, and public health, while making the grid so resilient that big cascading blackouts become impossible. Whichever of those outcomes you care most about, *Reinventing Fire's* pragmatic business strategy makes sense and makes money.

Recent experience and practice also confirm that even with little or no bulk power storage, diversified and forecastable renewable generators, integrated with flexible supply and voluntarily modulated demand, can deliver highly reliable power at competitive cost. Four German states in 2010 got 43–52 percent of their electricity from wind power by integrating it with the strong German grid. But even on a continental scale, diverse renewables can provide 80+ percent of electricity by operating utilities' existing assets differently within smarter grids and using markets that clear faster and serve larger areas.

Reinventing Fire's U.S. findings are highly adaptable and adoptable elsewhere. The European Climate Foundation has presented a similarly ambitious road map for Europe's energy transition, as have many countries. Governments from California (the world's #8 economy) to Germany (#4) and from Denmark to Sweden

are successfully implementing aggressive efficiency-and-renewables strategies. California shrank greenhouse gas emissions per dollar of GDP by 30 percent in 1990–2006, and has held per capita use of electricity flat for three decades while real income per capita grew by four-fifths. Denmark's GDP grew by two-thirds during 1980–2009 while energy use fell back to its 1980 level and carbon emissions fell 21 percent. In an average wind year, Denmark in 2010 could produce 36 percent of its electricity renewably and 53 percent from combined-heat-and-power. The average Dane, releasing half the carbon of the average American, enjoyed a good life, the most reliable electricity in Europe, and some of its lowest pretax prices. Denmark is even reorganizing its grid in “cellular” fashion (as Cuba successfully did) to make power supply highly resilient—and plans to be entirely off fossil fuels by 2050.

Developing countries are buying the majority of the world's new renewable generating capacity, often in distributed forms like solar cells that bring efficient lighting and other vital services to the 1.6 billion humans who have no electricity—leapfrogging over the power line phase just as cell phones leapt past landline phones. If developing countries buy efficiency whenever it's cheaper than new electricity supply, they can turn the power sector, which now devours a fourth of global development capital, into a net exporter of capital to fund other development needs. Why? Because making super-efficient lamps, windows, and the like takes about a thousand times less capital, and repays it about ten times faster, than investing instead in supplying more electricity. Investing in cheap “negawatts” instead of costly megawatts is the most powerful, though invisible, financial lever available to speed global development.

The international Super-efficient Equipment and Appliance Deployment project (SEAD), supported by 23 countries, targets the four appliances—lights, refrigerators, air conditioners, and televisions—that use three-fifths of household electricity in China, India, the United States, and the European Union. Most of those appliances haven't yet been built or bought, and three-fourths are made by just 15 firms. SEAD aims to build them right, saving up to \$1 trillion and avoiding

300 coal plants. That's just four household appliances—not the rest, not the other sectors. There are lots more negawatts to capture.

China made energy efficiency its top strategic priority in 2005, not compelled by a treaty but because leaders like Wen Jiabao understood that China couldn't afford to develop otherwise. China had already fueled about 70 percent of 1980–2001 economic growth by cutting energy intensity more than 5 percent per year, and is now regaining that pace. The United States has long averaged 2–4 percent lower energy intensity (primary energy used per dollar of GDP) each year. Just averaging 3–4 percent worldwide could prevent further climate damage. Why should that pace be hard, since most of the growth is in countries like China and India that are building their infrastructure from scratch and can more easily build it right than fix it later? And since virtually everyone who does energy efficiency makes money, why should this be costly?

The global climate debate has focused on cost, burden, and sacrifice because negotiators assumed from economic theory that energy efficiency must cost more than the energy it saves, or we'd have bought it already in their theoretically perfect markets. But actually, most efficiency isn't yet bought, even in the most competitive market economies, because of 60–80 kinds of widespread and well-documented market failures that we now know how to turn into business opportunities. In truth, *saving fuel costs less than buying fuel, so climate protection is not costly but profitable*. Talking instead about the resulting profits, jobs, and competitive advantages so sweetens the conversation that any remaining resistance should melt faster than the glaciers.

In history's greatest infrastructure shift, humans are verily inventing a new fire: not dug from below but flowing from above, not scarce but bountiful, not local but ubiquitous, not transient but permanent, not costly but free—and except for a little biofuel, grown in ways that sustain and endure, flameless.

Efficiently used, this new fire, harnessed by ingenuity and enterprise, can make energy do our work without

working our undoing. The new energy era can be a story not of danger, restriction, and impoverishment but of astounding wealth creation, choice, and opportunity.

ENERGY

Overdevelopment and the Delusion of Endless Growth

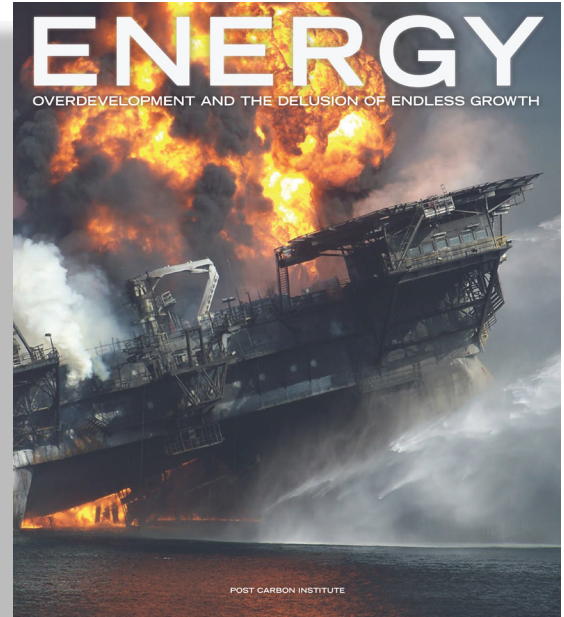
Edited by Tom Butler and George Wuerthner

We have reached a point of crisis with regard to energy... The essential problem is not just that we are tapping the wrong energy sources (though we are), or that we are wasteful and inefficient (though we are), but that we are overpowered, and we are overpowering nature.

— from the Introduction, by Richard Heinberg

In a large-format, image-driven narrative featuring over 150 breathtaking color photographs, **ENERGY** explores the impacts of the global energy economy: from oil spills and mountaintop-removal coal mining to oversized wind farms and desert-destroying solar power plants. **ENERGY** lifts the veil on the harsh realities of our pursuit of energy at any price, revealing the true costs, benefits, and limitations of all our energy options.

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The ENERGY Reader

Edited by Tom Butler, Daniel Lerch, and George Wuerthner



What magic, or monster, lurks behind the light switch and the gas pump? Where does the seemingly limitless energy that fuels modern society come from? From oil spills, nuclear accidents, mountaintop removal coal mining, and natural gas “fracking” to wind power projects and solar power plants, every source of energy has costs. Featuring the essays found in **ENERGY** plus additional material, **The ENERGY Reader** takes an unflinching look at the systems that support our insatiable thirst for more power along with their unintended side effects.

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