# Treasures Better Hid

## The Making of Our High-Energy World

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Vaclav Smil, *Energy and Civilization: A History*. MIT Press, 568pp., 113 ills., $20 paper.

Richard Rhodes, *Energy: A Human History*. Simon & Schuster, 480pp., $30 cloth.

Maya Rao, *Great American Outpost: Dreamers, Mavericks, and the Making of an Oil Frontier*. Public Affairs, 336pp., $27 cloth.

In 1671, Denis Papin was the manager of the windmill pumping system that powered the fountains in the palace gardens at Versailles. His work caught the attention of Christiaan Huygens, director of the new French academy of sciences, which was tasked with doing research that might lead to useful inventions to increase the king's revenues. The academy had several interests ranging from "the breathing of animals" to the origins of weight, warmth, cold, light and colors. Of particular importance was the quest to understand and harness "the power of gunpowder... [and] of water converted by fire into steam." Huygens hired Papin and tasked him with generating motive force from an engine.

Across the next twenty-seven years, Papin followed the experimental impulse into dead ends, blind alleys, and head-scratching roadblocks. Working with the basic concept of lifting and lowering pistons inside of cylinders strung along a crankshaft, Papin determined that steam was a better working medium than gunpowder (the first oil well would not be drilled for nearly another two hundred years). But to get a practical engine capable of draining coal mines or moving vessels at sea, he required larger cylinders than anyone knew how to manufacture at the time. Papin had the idea of the steam engine, but he didn't have the material. He tried to build a new kind of bellows to

blow a hot-enough fire and a new kind of solder to keep the pipes from ripping apart under the pressures of the steam. He never got a full-scale engine to do practical work.

Ideas can outpace infrastructure. Once built, though, the infrastructure leapfrogs the old ideas and begs for new ones. Papin's model became a reality through the efforts of Thomas Newcomen who built the behemoth engines capable of draining coal mines. James Watt shrunk the engine down and gave it more tasks to do. Then Richard Trevithick put a modified steam engine on wheels in 1801 to create an iron dragon capable of traveling at the mind-boggling speed of 20 mph. Then came the railroads, the factories, the power lines, the highways, the airports, the internet…

In short, then came our fossil-fueled civilization. No one in 1671 could have possibly foreseen the chain of events unleashed by Papin's research project, especially as it folded into other experiments. Papin said it best as he tried to build the machines capable of manifesting his ideas, "And thus one thing leads to another." That is how our high energy world came to be. Not by design, but by tinkering.

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When the Amish consider adopting a new technology, they deliberate about whether it is compatible with their way of life. But for us, technology is our way of life. I don't mean technology as this or that machine, but rather as a *process* that is ever changing and ever growing. We are the children of Thomas Hobbes, who wrote around the time that Papin began his work that "Felicity is a continual progress of the desire from one object to another." Happiness is an accelerating engine where one thing leads, not to a destination, but to another and another and another.

One of the unintended consequences of Papin's labors is the accumulation of greenhouse gasses in the atmosphere. Climate change poses existential questions to our age: can a high energy world of infinite desire be sustained, and can we tinker our way out of all the problems we have tinkered our way into? Three books on energy shed light on these questions from different time scales. They are like the segments of a telescope, one nested into the other, zooming in from the past 10,000 years, to the past 400 years, and finally, in just the past decade, to a remote patch of North Dakota that has become a geopolitical oil giant.

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Bill Gates is trying to save the world. Increasingly, energy has become his focus because it is at the core of our greatest challenge: how to power a global civilization without destroying the planet. Through his new Breakthrough Energy Coalition, Gates is assembling the world's smartest minds and giving them billions of dollars to find the tech solutions that will allow us to continue having our cake (a livable planet) and eating it too (enjoying all the conveniences of energy-intensive lifestyles).

In all of this, Gates' go-to guru is Vaclav Smil: "I wait for new Smil books the way some people wait for the next Star Wars movie." Smil, Distinguished Professor Emeritus at the University of Manitoba and Fellow of the Royal Society of Canada, has forty books to his name, most of them about energy. His latest, *Energy and Civilization: A History*, is an extensively updated version of his 1994 *Energy in World History*. The book is like a pointillist painting in the way it manages to compose a panorama out of thousands of detailed bits of data. Smil takes us across the globe through thousands of years to show us how energy has shaped society. His organizing logic is the tangled transitions along the path from foraging to farming to fossil fuels and, maybe, beyond.

Here are the key transitions in their bare mathematics. For nearly all of human existence, the only prime mover was the human body with a capacity of roughly 100 watts (W). Beginning in the third millennium BCE, draft animals supplied about 400 W of power. By 1000 CE, the biggest prime mover was a 5,000 W horizontal water wheel. In 1800, the steam engine could supply 100,000 W of power. In 1960, steam turbines were rated at 1,000,000,000 W (1 GW) of power. Note the 10,000 fold increase in power in that last transition over just eighty years. We live in portentous times.

Smil takes a biologist's approach to civilizations, calling them simply "the largest and most complex organisms in the biosphere". From this vantage point, he holds that the history of successive civilizations has operated by its own kind of natural selection to increase total mass, rate of matter circulation, and total energy flux through the system. There is an energetic imperative at work that was first formulated by the chemist Wilhelm Ostwald in 1912: "Do not waste any energy, make it useful." The result is ever greater human control of—*and dependence on*—ever higher energy flows.

This means that the energy resources and technologies of a given culture profoundly structure its way of life. It does not mean (as many have supposed) that more energy means a better way of life or a higher quality culture. Smil notes that "Higher energy use by itself does not guarantee anything except greater environmental burdens." Beyond a certain level, more energy does not make society more secure or people subjectively happier or (I might add) morally virtuous.

Americans consume roughly three times as much energy per capita as Italians, but they are not any happier on average. As for the quality of culture, perhaps it is not too unfair to ask the reader to compare the typical strip mall in Dallas to the sidewalk culture of Rome. (And before you decry the impacts of excessive tourism, remember that is also a symptom of what we might call hyper-energy, in this case cheap jet fuel.)

Human bodies, like all animal bodies, make themselves out of food. This is the primordial energy conversion. Unlike other animals, though, humans systematically harness energy resources beyond their somatic metabolisms. It begins with fire for the direct use of heat and then its conversion into mechanical and chemical forms of energy. Tools convert small input forces into larger output forces to provide mechanical advantage. These unique abilities are the product of the human brain, which is something of an evolutionary gamble as it consumes 20-25 percent of our resting metabolic energy (that figure is just 8-10 percent in other primates). Civilization itself is the payout from that wager.

The first great energy transition from foraging to farming remains something of a mystery from an energetic standpoint. Often, the net energy returns for farming were inferior to foraging. Once it got underway, however, agriculture did evolve largely in response to the energetic imperative to increase productivity to feed growing populations. A variety of innovations proved vital in this quest for greater yield, which Smil demonstrates through his usual tactic of saturation-bombing the reader with data. Water ladder treading (a form of irrigation in Qing dynasty China) returned 30 times more food energy than its food cost. A small water wheel manned by ten people in Renaissance Europe could grind enough grain in a day to feed 3,500 people—a feat that would otherwise take 250 laborers with hand milling. Labor productivity for American wheat, as measured in the minutes required to produce one kilogram of grain, went from 7.2 in 1800 to 0.1 in 2000. In 1900, 75 percent of girls aged 10 to 15 in the U.S. were engaged in some form of agricultural employment. In 1918, the U.S. draft animal herd reached its maximum size of 26.7 million and would decline as the internal combustion engine rose. And so on.

By the early nineteenth century, the power potential of the pre-industrial world was just about maxed out. It was a world powered by animal muscles, windmills, and water wheels. And it was a wood-powered world with rapidly disappearing forests. In 1700, Massachusetts was 85 percent forested. In 1870, that figure was 30 percent. But as Papin noted, one thing leads to another. The scarcity of wood for smelting iron prompted the large-scale use of coke (a solid fuel made by heating coal). More generally, the limits of phytomass fuels (wood) and animate energies led to the age of fossil fuels and inanimate prime movers. It was this second energy transition that ushered in a different world almost overnight.

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The rate of change caused by fossil fuels is hard to comprehend. In 1900, carbon emissions from combustion of fossil fuels globally was 534 Megatons. Today that number is around 10 Gigatons, or roughly 20,000 times greater. In 1850, rural labor was 60 percent of the American workforce. Now it is 1.5 percent. In 2000, an average acre of cropland received about 90 times more energy subsidies than it did in 1900. Suddenly, our potatoes are made of oil. Check that; our world is made of oil.

The scope of change is also impressive. In foraging societies, food was basically the only energizer. In the early Roman Empire, food accounted for 45 percent of total energy. In Europe around 1820 food was still about 30 percent of all energy. By 1960, food was less than 2 percent of the total energy supply for human civilization. In 1776 when Thomas Jefferson penned the Declaration of Independence, the world's prime mover capacity was basically the same as it had been for thousands of years. Smil guesses that 97 percent of total power was provided by people and animals. In 1850, the animate labor of bodies still provided about 80 percent of total power. By 1910, that number had dropped to 60 percent. Now it is roughly 1 percent. All the rest of the world's available power is installed in internal combustion engines and electricity generators – machines that didn't exist just a handful of generations ago. Machine slaves have replaced Jefferson's slaves.

Smil surveys all of these enormous changes with an analyst's equanimity. Yes, much has been gained that is "fabulously liberating and admirably constructive" but the modern high energy world is "also uncomfortably constraining, horribly destructive, and, in many ways, self-defeating." Smil cites the philosopher Ivan Illich, who argued that if you take into account the time spent earning money to buy or lease a car, fuel it, maintain it, and insure it, the average speed of U.S. car travel amounts to less than 8 km/h, which is comparable with walking. Illich called this "counterproductivity." Again, there is no guarantee that a high-energy civilization necessarily ranks high on other metrics like rationality, beauty, or justice.

And it is here that I will take Smil's caution and skepticism over the gushing optimism of his biggest fan. Gates ventures only one disagreement with Smil: he thinks Smil underestimates how quickly we will transition away from fossil fuels to clean energy. From the lofty stage of civilizational history, this does seem like the next step in an inevitable progression. But have you seen the current U.S. presidential administration? And did you catch those riots in France in response to

a modest gasoline tax? What about that new regime in Brazil with its knife poised at the throat of the Amazon? Civilizations do not, in fact, behave like organisms. When an organism faces a threat, it moves as one unified being to get out of the way. Not so for us.

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There is also something dark lurking under Smil's use of biology to explain the way civilization has climbed toward ever more energy consumption. The phrases "survival of the fittest" and "natural selection" don't quite capture it. It's more like "the will to power," where 'power' should be read with all of its meanings in mind. Our present power-mad world is largely the child of one particular civilization: "the West," that world of Greeks, Romans, Christianity, Enlightenment, and Industrialism. The Chinese had been sitting on mountains of coal for thousands of years, but they only started really chewing into them after "opening-up" to the West. Native Americans knew about oil seeps in the land currently called Pennsylvania for thousands of years, but never drilled for oil there. Other tribes hunted whales, but never built a fleet of 740 ships carrying an annual burden of 233,000 tons of whale oil like the Quakers of Nantucket did.

The imperative of growth, in other words, seems less like a universally shared driver of every civilization and more like the obsession of just one. That energy growth has taken a global hold, then, tells us that this is a story about the vectors of cultural dominance: imperialism, colonialism, capitalism, and later simply 'development.' That these terms are absent from Richard Rhodes' *Energy: A Human History* is a striking failure for an otherwise brilliant book. The stories he tells all come from the past four-hundred years and they all originate in Europe and North America, but he never asks: why did this civilization conquer the world? Did it have something to do, perhaps, with their new scientific understanding of energy as a resource and a universal currency? In short, there are philosophical depths here that go unsounded both by Smil and Rhodes.

Nonetheless, Rhodes has written a book that is impressively researched and delightful to read. His focus on the inventors and scientists who have made our world is a perfect complement to Smil's emphasis on metrics and machines. Rhodes begins with a glimpse of an earlier morality that once kept the quest for energy and riches in check. In *Paradise Lost*, published a few years before Papin's experiments, Milton condemns those mining men who:

> Ransacked the center, and with impious hands
> Rifled the bowels of their mother Earth
> For treasures better hid.

Rhodes disagrees with that part about "treasures better hid." He thinks that the post-Milton high energy civilization has all been "mostly for the better." Besides, this trajectory was already set in motion by the time Milton was writing. In 1700, 467,000 tons of coal were shipped to London, a city forced to invent zoning laws in an effort to keep air-fouling industries at arm's length. Draining the coal mines had become the greatest engineering challenge. This is where Huygens and Papin come in, though there are many other players, including Otto von Guericke a Prussian engineer who pumped air of out of a hollow copper globe in 1654. Only atmospheric pressure held the two hemispheres of the globe together, but a team of eight horses hitched to the globe could not muster enough power to pry the hemispheres apart. The idea that the very atmosphere we breathe has weight, and might be enlisted to do work for us, eventually led to the steam engine and beyond.

The chapters on electricity are masterful in the ways they link Benjamin Franklin, Luigi Galvani, and Alessandro Volta to Mary Shelley's harrowing images of a monster of dead flesh brought to life. Lightning, frog legs, magnets, and Niagara Falls all play their parts in the drama of electrifying the world. It is plain to see how Rhodes won the Pulitzer Prize and the National Book Award for his 1987 book, *The Making of the Atomic Bomb*. He has a gift for uncovering the hidden history of all the machines we have sadly come to take for granted—all the stunning powers at our fingertips that prior ages would have considered magical, and that elicit from us at most a yawn—at least, that is, until the power goes out.

Indeed, the now taken-for-granted ability to light a dark street or a dark room with the flick of a switch is the outcome of a long, tortured process to develop a network of ideas and infrastructures. Rhodes is at his best in his chapters on the history of light, which begin with the naturalist Gilbert White buying a pound of dry rushes (a perennial plant with hollow stems) and six pounds of grease in the late 1700s. For three shillings, a poor man could have eight hundred hours of light with these ingredients for makeshift candles.

In 1800, the story of illumination takes a detour into medicinal gasses, because the same Watt generator used to develop pneumatic medicine would play a crucial role in delivering steady streams of gas to streets, factories, and homes. The intoxicating effects of nitrous oxide, Rhodes hints, may have loosened up the necessary creativity here. The French engineer Philippe Lebon, boasted of his illuminating gas system: "You can control it, order it to appear or disappear, and it will obey as even the most obedient servant will not." Of course, gaslight also allowed the extension of the factory working 'day,' sometimes up to fourteen hours behind locked doors. If there is one consistent moral to the story of high energy, it is that we often wind up the servant of our servants.

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A memoirist asked in the 1850s how they would light their lamps "when all the whales had been killed." The contenders were numerous: castor, rapeseed, peanut oil, tallow, lard, wood and grain alcohol, and turpentine from the longleaf pine. For a while, the winner was coal oil from tar sands converted into kerosene. But then the chemist Benjamin Silliman Jr. toured a rock oil seep near Titusville, Pennsylvania. A local told him that they knew there was oil there, but that it didn't count for much because it "didn't seem to be good for much." Silliman started distilling and cracking (breaking long-chain hydrocarbons into simpler molecules) that oil in 1853 to see if it might be good for lighting lamps.

It's remarkable how tenuous those beginnings of oil now seem. In this story, Silliman looks like an archaeologist who almost didn't notice the tip of a brontosaurus bone just peeking out from the earth. Would the age of petroleum have ever happened if it wasn't for a few such contingent twists and turns of history? Even after oil started flowing, it was hardly a threat to any existing business or way of life. The petroleum was hard to sell—it smelled awful, it was costly to transport, the barrels leaked horribly (losing one-third of their volume in transport), and it was full of non-useful hydrocarbons that were just dumped into the soil and water. But the railroads and then the pipelines solved the transportation problem, helping to make petroleum the preferred feedstock for kerosene. Then along came Henry Ford.

Rhodes uses his concluding chapters to take a swipe at the neo-Malthusians and other misanthropes who worry about the coming ecological apocalypse and wonder if maybe all our energy treasures should have been left hidden away. He especially thinks that the bad reputation of nuclear power is ill-deserved. "So-called" nuclear waste is held to an unreasonable standard when we ask for assurances that it will be safe for thousands of years. Rhodes notes that we never hold any other technology to such exacting standards, because our children and grandchildren will invent smarter solutions than we can imagine.

Again, we don't have to design things with a long-range master plan. We only have to tinker and then leave the tinkering to the next generation: "Far from threatening civilization, science, technology, and the prosperity they create will sustain us as well in the centuries to come. They are the only institutions human beings have yet devised that consistently learn from their mistakes." Tellingly, he omits any mention of the political institutions needed to fund the science and coordinate the technology. It's as if his geniuses and inventors work in the vacuums of their own creation.

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The word 'snarge' (coined by Smithsonian Institute ornithologist Carla Dove, in studying bird strikes on airplanes) captures the mortal encounters between fossil-fueled vehicles and animals. In the U.S. alone, between one and two million deer are snarged annually. All total, automobiles kill 365 million vertebrates every year. This is why I often say that cars are assholes. The people driving them may be perfectly nice, but it doesn't matter because the medium is the message. And the message delivered by cars is a loud, land-paving, air-defiling recklessness all neatly outfitted with cup-holder, heated seats, and satellite radio. I bike to work daily and see the snarge they leave behind, mostly squirrels but also the occasional possum and cat.

I also often see the buzzards and the crows flocking to feast on the roadkill. This is the image that came to mind when reading Maya Rao's *Great American Outpost: Dreamers, Mavericks, and the Making of an Oil Frontier*. In the past ten years, the land above the Bakken Shale in western North Dakota has become a feeding frenzy. In 2008, the US Geological Survey estimated that the newly improved fracking technologies could economically unlock billions of barrels of oil from the Bakken. The men came like buzzards to the bloated carrion; they came with thousands of trucks and with drilling rigs that can literally walk from one site to the next, like something out of *The Empire Strikes Back*, sinking mile-long teeth into the treasures below.

To her credit, Rao courageously jumped into the fray, driving down desolate, frozen roads, working at a truck stop, and visiting fracking sites, bars, man camps, and industrial waste yards. She spent over a year interviewing the characters caught up in the melee, often at no small risk to her personal safety. She uses beautiful prose to paint an ugly scene dominated by greed, waste, and selfishness. Rao quotes an apt report from the 1849 gold rush, "Men of irreproachable character at home and elsewhere, have often here…given themselves up to the guidance of personal interest."

With his focus on major thinkers and inventors, Rhodes gives us an august history of energy fit for the textbooks; with her focus on the ruffians, ex-cons, and grifters of the oilfield, Rao gives us a people's history of energy. The contrast makes plain one rather dispiriting fact about capitalism and modern technology: when the ideas are being birthed and the machines are only prototypes, there is the occasion for great feats of intellectual virtue and creative enterprising. These are the lofty heights that Gates is cultivating in his search for the next Watt or Volta. But once the ideas are mature and the machines are mass-produced, the room for genuine human excellence gets squeezed out. The inventor gives way to the man on the assembly line. The genius casts his shadow over the laboring masses. Prometheus has uncorked the oily stomachs of the earth – all that is

left now is to feast. The characters that Rao interviews are the dim echoes of a destructive greatness.

But they are not without their own color and, at least at times, their own convictions and character. The protagonist of her story is Danny, a former surfer from North Carolina who followed the stench of money north to the badlands and prairie. The oil wells quickly outpaced the pipeline infrastructure in North Dakota, so the crude had to be hauled by trucks. Danny learned on the fly how to jake-brake his way down the winding hills and navigate an eighteen-wheeler across ribbons of black ice. It is a dangerous job. At one point, a tank of oil explodes near his truck, catching a man on fire. Later, exhausted, Danny dozes off while he was waiting for an enormous tank full of crude to fill his truck. He awoke to a fountain of oil shooting out of the vent pipe. Everywhere he went, he wore his monitor that sniffed for poisonous sulfur dioxide gas.

Danny's truck could haul nearly 300 barrels of oil. At the height of the boom in 2014, the Bakken was bleeding upward at a rate of one million barrels daily. On top of that, each frack job requires millions of gallons of water, which often had to arrive by truck. In fact, Danny started out hauling water before he switched to oil. Many of his days were spent reading books in his idling truck, waiting in line for his own 6,000 gallon offering of water to be injected down the syringe into the veins underground. Then, he was back on the road to fill up again and again. That's a whole lot of trucks. And it caused a significant uptick in snarge, human and otherwise.

This is hardly a *Bildungsroman*, but we do see in Danny something of a moral pilgrimage. The lonesome road and long hours seem to discipline him. He always had potential—he wasn't one of the many men who blew their super-sized paychecks during a weekend in Vegas to come back being forced to live on ramen noodles only to do it all again next month. He wasn't a womanizer or a huckster. He was just a drifter, maybe a little too rough around the edges. By the end, Rao says that Danny had transformed from the "freewheeling southerner" despised by the locals into "a disciplined professional."

In 1886, Theodore Roosevelt gave an Independence Day address near the water depot where Danny would fill his trucks. He said, "We must keep steadfastly in mind that no people were ever yet benefited by riches if their prosperity corrupted their virtue." Rao keenly notes this speech, because hers is a book that is ultimately about virtue—about what it means to be a good person and what kind of society is required to cultivate good people. The question it should get us asking is this: What is the relationship between oil and morality? Obviously, oil can unlock the worst in us leading to avarice, violence, decadence, and distraction. In short, it can make us spoiled brats. It is also true, though, that it has humanized us by giving us a dense store of energy from which to draw out more of our potential.

Roosevelt went on to say, "Here we are not ruled by others, as in Europe; here we rule ourselves." Self-rule—how should we interpret that? There is the nationalist reading of it, as in Rao's discussion of the North Dakota speech given by then-Presidential nominee Donald Trump: "We will accomplish complete American energy independence ...American first, folks! America first!" The speech itself rings like a faint echo of Roosevelt and a former greatness, perhaps from a time before prosperity had ruined us.

I don't think Roosevelt's audience of Norwegian-American farmers would have understood self-rule simply in this way. There is more to it. Self-rule, or autonomy, also means self-discipline or the control of one's desires. Insofar as it is a communal self, Roosevelt's listeners probably also imagined something much smaller—a community of neighbors at least as much as a nation of millions of strangers.

This was the ethos that reigned in western North Dakota until the fracking boom. Rao arrived just in time to see it ripped to shreds—that quiet and unassuming demeanor, the slow pace, the trust in human decency, patience for weather and seasons, and the grace of the land and its maker. Illich called this way of life outside of commodities, wage work, and disabling industrial technology "the vernacular." Seen from this perspective, "energy independence" is a contradiction in terms. A high-energy life is necessarily a life made more dependent on inscrutable systems, runaway desires, faceless bureaucracies, and merciless markets. That we consider all of this the very stuff of freedom and independence is the great irony and myth of our civilization. A