by Robert L. Bradley, Jr.

November 2018

The Economic Fall & Political Rise of RENEWABLE ENERGY

TEXAS PUBLIC POLICY FOUNDATION

Novemer 2018

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"A grasp of a few hard facts, a little arithmetic, and some basic physics are necessary to avoid calamitous blunders in energy policy."

—Stephen Moore and Kathleen Hartnett White
Fueling Freedom: Exposing the Mad War on Energy, 78

Introduction

The history of renewable energy spans the history of man. From the Stone Age until recent times, the market share of renewables was virtually 100 percent. The pre-industrial inanimate energies were woody matter, falling water, and rudimentary capture of wind and solar.[1]

The modern energy era, dating from the Industrial Revolution, replaced renewables with vastly superior mineral energies. The age of coal began in the 18th century. Oil came of age in the second half of the 19th century with major U.S. discoveries. And natural gas joined in the 20th century as manufactured (coal) gas was replaced by piped methane. Bitumen (trademarked as Orimulsion), with reserves rivaling that of crude oil itself, became the fourth fossil fuel in the last half of the last century (Bradley 1999).[2]

Most recently, the "shale revolution" has redefined and expanded oil and gas with profound implications for a fossil-fueled 21st century (Moore and White, ch. 2). Among other things, natural-gas superabundance is creating a global market for liquified natural gas (LNG). And most recently, compressed gas liquid (CGL) is competing against LNG as a globally shipped fuel (Darbonne 2017).

Modern energy is the story of innovation and expansion within the fossil-fuel family, far less outside of it where government intervention has only made the uneconomic and unsuitable less so. The fossil-fuel revolution is the story of incremental improvement (Smil 2014) via human ingenuity, what Julian Simon called the ultimate resource (Simon 1981; 1996). Nowhere has this been more obvious than at the wellhead, where resourceship has continually expanded the supply of so-called nonrenewable minerals (Bradley 2012).

KEY POINTS

- Renewable energy has been used by men since the beginning of time.
- Fossil fuels raised living standards by replacing hitherto dominant renewable energies. Dense, storable, reliable energy powered the Industrial Revolution.
- Human ingenuity and innovation free of government intervention continue to enable the ever-expanding use and ever-decreasing cost of fossil fuels to support our daily energy needs.
- Massive government subsidies to solar and wind energies since the 1970s not only have failed to make these sources of energy nearly as competitive as fossil fuels, but also have cost ratepayers and taxpayers hundreds of billions of dollars.

Solar and wind power made a comeback in the energy-crisis 1970s. Politicians, experts, and leading oil and gas executives were convinced that mineral energies were inexorably depleting, leaving the U.S. with a national security problem of increasing oil imports (Bradley 2009, chapter 10).

Despite a four-decade effort, wind power, solar power, and ethanol are still not competitive against conventional carbon-based energy. Electric vehicles are also uneconomic on a stand-alone basis compared to the internal combustion engine. But government intervention via tax credits, ratepayer subsidies, and mandates has turned back the energy clock, as it

1 Fossil fuels fortuitously present at the surface provided energy, but the mining and use of subsurface coal, natural gas, and oil was largely absent until the late 18th century.

2 As unconventional petroleum, bitumen and bituminous sands (oil sands) point toward a very long (and still young) fossil-fuel era. Peat, which falls between biomass and fossil fuel, attracting such descriptors as *baby coal* and the *forgotten fossil fuel*, is another recognized energy category.

were.[3] A free-market, consumer-driven, taxpayer-neutral playing field will virtually eliminate the wind power industry, reduce solar power to its off-grid niche, and reduce ethanol's blend in motor fuel to its oxygenate-only level. Electric vehicles would be a specialty item rather than a mass-produced alternative.

The wealth transfer from taxpayers and consumers to favored corporations, the result of political work by the involved firms and supportive environmental pressure groups, has increased energy costs and compromised the reliability of the electricity grid. Corporate rent-seeking and Bootleggers-and-Baptists[4] lobbying for intervention is the subject of this paper.

The keep-it-in-the-ground anti-fossil-fuel crusade, a quarter-century old, has become a global affront to economic freedom, consumer welfare, and even modernity. Along the way, the depletion argument against fossil fuels was replaced by another: the human influence on climate, anthropogenic climate change, what was originally called global warming (Bradley 2009, 305–6).

Environmental regulation to mitigate greenhouse gas emissions, stated Al Gore (269), must be the "central organizing principle for civilization." Global government control of industry, agriculture, and land-use in the name of stabilizing climate is the new central planning, one never envisioned by earlier critics of the government planned economy.

"What textbooks call the Industrial Revolution," Stephen Moore and Kathleen Hartnett White have noted, "might be better described as mankind's Great Energy Enrichment—a massive increase in the availability of versatile energy" (5). Contemporary talk of renewables as new or futuristic reverses the historical record. "The notion that green energy is 'in its infancy' is laughable," these authors add (xiv).

The "Great Energy Enrichment" was market driven, not government created. Certain countries during certain periods subsidized one or more of their fossil-fuel industries (e.g., the U.S. subsidization of domestic oil production between 1917 and 1971 via the depletion allowance and other special tax provisions). But such political favor was superfluous to the establishment, viability, and dominance of the coal, oil, and natural gas industries—quite unlike what would occur with the solar and wind industries in the last decades of the 20th century.

Today, the market share of fossil fuels in the U.S. and the world is 82 percent and 84 percent, respectively (U.S. EIA 2017a; 2017b). This dominance will continue for the next decades—and will increase should political support for nuclear energy and renewables wane.

This essay surveys the rise of fossil fuels in light of the public policy choice between free-market energy abundance and statist energy scarcity, building upon Moore and White's *Fueling Freedom*. The modern history of solar and wind power in the United States is then presented, showing how in the 1970s and 1980s market commercialization failed and government intervention stepped in. The push for renewable energy mandates and subsidies was driven by corporate interests with crucial help from the burgeoning anti-fossil-fuel movement. In the 1990s, energy politicization went into overdrive with one hyperaggressive Texas company, Enron Corporation. Enron's renewable energy and global warming agenda, in fact, helped set the foundation for President Obama's war on fossil fuels (2009–17).

Timeless Energy Insight: Jevons, 1865

The great energy transformation radically upgraded the sun's flow to the sun's mineral stock. Energy went from dilute to dense, intermittent to ready, fleeting to storable. In economic terms, the transformation was from scarce to abundant, costly to affordable, unreliable to reliable.

In the very first book on energy economics, *The Coal Question* (1865), W. Stanley Jevons explained the nature and implications of what would become known as the *fossil-fuel revolution*.

> Coal, in truth, stands not beside but entirely above all other commodities. It is the material energy of the country—the universal aid—the factor in everything we do. With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times (Jevons, viii).

"Coal is everything to us," *The Times* of London editorialized the year after Jevons's book. "Without coal, our factories will become idle, our foundries and workshops be still as the grave; the locomotive will rust in the shed, and the rail be buried in the weeds." It continued:

> Our streets will be dark, our houses uninhabitable. Our rivers will forget the paddlewheel, and we shall again be separated by days from France, by months from the

3 Wind power's Production Tax Credit, currently at 2.4 cents per kWh, is examined below. A federal 30 percent investment tax credit provides a similar non-market advantage for solar power (SEIA). Additionally, 29 states have a Renewable Portfolio Standard, which mandates a certain percentage of qualifying renewables be sold by electricity sellers (Durkay).

4 This phrase takes its name from the observed lobbying partnership between business (the Bootleggers) and public-interest groups (the Baptists). Enron and environmental groups worked together in Bootleggers-and-Baptists fashion with natural gas and, later, with renewable energy.

> United States. The post will lengthen its periods and protract its dates. A thousand special arts and manufacturers, one by one, then in a crowd, will fly the empty soil, as boon companions are said to disappear when the cask is dry (Editorial).

This super energy was in stark contrast to what had come before. Considering them one by one, Jevons explained why renewables did not and could not energize the new industrial economy. With wind energy, Jevons identified three shortcomings that remain pertinent today.

1. **Windpower is intermittent, unsuitable for modern work.**

   The first great requisite of motive power is, that *it shall be wholly at our command, to be exerted when, and where, and in what degree we desire*. The wind, for instance, as a direct motive power, is wholly inapplicable to a system of machine labour, for during a calm season the whole business of the country would be thrown out of gear (Jevons, 122; italics in the original).

   Before the era of steam-engines, windmills were tried for draining mines, "but, though they were powerful machines, they were very irregular, so that in a long tract of calm weather the mines were drowned, and all the workmen thrown idle. From this cause, the contingent expenses of these machines were very great; besides, they were only applicable in open and elevated situations" (122–23; quoting loosely from Farey, 227).

2. **Wind energy is land constrained.**

   No possible concentration of windmills…would supply the force required in large factories or iron works. An ordinary windmill has the power of about thirty-four men, or at most, seven horses. Many ordinary factories would therefore require ten windmills to drive them, and the great Dowlais Ironworks, employing a total engine power of 7,308 horses, would require no less than 1,000 large windmills! (123)

3. **Wind energy for land transportation did not work.**

   Richard Lovell Edgeworth spent forty years' labour in trying to bring wind carriages into use. But no ingenuity could prevent [wind carriages] from being uncertain; and their rapidity with a strong breeze was such, that, as was said of [the sixteenth-century Dutch polymath Simon] Stevin's carriage, "they seemed to fly, rather than roll along the ground." Such rapidity not under full control must be in the highest degree dangerous (126; source of quotation is unidentified).

Other renewables could not substitute for coal either. "We cannot revert to timber fuel," explained Jevons, "for 'nearly the entire surface of our island would be required to grow timber sufficient for the consumption of the iron manufacture alone'" (140; quoting Taylor, 176).

What is now called geothermal was rare. "The internal heat of the earth," Jevons noted, "again, presents an immense store of force, but, being manifested only in the hot-spring, the volcano, or the warm mine, it is evidently not available" (120–21).

What is now called hydropower was chancy. "When an abundant natural fall of water is at hand," he explained, "nothing can be cheaper or better than water power." Jevons continued:

> But everything depends upon local circumstances. The occasional mountain torrent is simply destructive. Many streams and rivers only contain sufficient water half the year round, and costly reservoirs alone could keep up the summer supply. In flat countries no engineering art could procure any considerable supply of natural water power, and in very few places do we find water power free from occasional failure by drought (129).

There was no going back. Only coal—and by implication fossil fuels—escaped the energy poverty of before.

Recent Energy Insight

"By providing energy flows of high power density," explained Vaclav Smil, "fossil fuels and electricity made it possible to embark on a large-scale industrialization creating a predominantly urban civilization with unprecedented levels of economic growth reflected in better health, greater social opportunities, higher disposable incomes, expanded transportation and an overwhelming flow of information" (Smil 1999, 134). Electricity, enabling the second Industrial Revolution, was fossil-fueled as much as the first Industrial Revolution. Coal, joined by so-called *white coal* (meaning *hydropower*), dominated electrical generation from the inception of the second Industrial Revolution through the first third of the 20th century, with natural gas and then nuclear power joining in (Bradley 2011, x, 481, 487).

Basic physics has changed little from what Jevons first explicated 153 years ago. "America's $18 trillion industrial economy cannot be powered with windmills and solar paneling unless we can transcend the four laws of thermodynamics," Moore and White write (169–70). Tens of billions of dollars of renewable energy subsidies, proportionately far greater than those of fossil fuels, have allowed non-hydro renewables to reach a 3 percent market share of the U.S. energy market, from virtually zero (169).

Still, government intervention can make the uneconomic viable by subsidies and mandates—a tax, as it were, on consumers and taxpayers. Wind power, on-grid solar power, and ethanol have required government largesse to grow rapidly, with the U.S. and global share increasing from virtually nothing.

The aforementioned *Fueling Freedom*, a 300-page primer, has distilled the energy wisdom of the ages in four broad points:

- Fossil fuels—market driven, consumer friendly, and taxpayer neutral—are poised to affordably and reliably supply the world's economies for many decades to come (66, 135).
- The United States, the fossil-fuel center of the world, is poised to turn mineral potential into wealth, prosperity, and public-sector fiscal reform (x, 3, 245).
- Dilute, intermittent, inefficient *political* energies are anti-consumer, anti-taxpayer, pro-crony, and environmentally burdensome (xiv, 8, 82–84, 123, 146, 191, 232, 237).
- The climate-change alarm is yet another Malthusian exaggeration reflecting extreme hypothecated scenarios (14–17, 21, 23, 29, 94). Carbon dioxide, the *green* greenhouse gas, has notable benefits for the ecosphere and the economy (95, 155–56, 211–12).

Consumer preference for petroleum, natural gas, and coal is not a negative externality or market failure requiring government intervention, the authors show. These super fuels are a blessing to mankind, a *positive* externality in the jargon of economics, and the gift that keeps on giving under the institutions of freedom: private property rights, voluntary exchange, and the rule of law.

Grid Solar Power: Tried, Failed

The photovoltaic (PV) effect, discovered in 1839, converts photons (natural sunlight) to electrons. In 1954, Bell Telephone Laboratories introduced the PV method using silicon, which enabled a niche market for (remote) electricity away from a power grid. PV panels in space were the opening application, followed by panels for offshore oil and gas platforms, offering an energy alternative to huge batteries that were transported to sea, used up, and tossed overboard.[5]

Other uses emerged as PV solar costs dropped: navigation aids (buoys, call stations), remote military applications, and off-the-grid living where propane gas was unavailable. The major on-grid use for solar was water heating, which became common after World War II in California, Florida, and other sunny regions.

While very expensive, this alternative to available plug-in power was and is a sustainable business proposition. But compared to grid electricity (fossil-fueled for the most part), solar panels are not competitive either in price or reliability. Free (nonpriced), dilute, intermittent sunlight requires vast amounts of infrastructure to perform the services that mineral energies provide at far lower cost and at scale. Stock (stored and storable) energy is the sun's work over the ages, after all, versus the momentary work of the sun.

In the 1970s, the U.S. experienced an energy crisis of price spikes and retail shortages of oil and natural gas. The cause was federal price controls on natural gas, crude oil, and oil products, worsened by government allocation regulation. But the conventional wisdom was that oil and natural gas were rapidly depleting, portending still higher prices in the future (Bradley and Fulmer, 95–98). President Carter's statement, "No one can ever embargo the sun," applied to both solar panels and wind turbines, if not other renewables (quoted in Yergin, 523).

Leading oil executives fell prey to such pessimism. Renewable energy, and none greater than solar, was seen as a viable energy source for the future, if for no other reason than government policy. An executive of Amoco (formerly Standard Oil Company of Indiana, an offshoot of John D. Rockefeller's Standard Oil Trust) told investment analysts in 1976: "We believe a prudent management should seek out and develop alternative investments outside of the oil and gas business to hedge against proliferating government interference and controls which will inhibit our ability to operate profitably in the petroleum business" (quoted in Pratt, 33).

In 1979, President Jimmy Carter told the world: "There is no longer any question that solar energy is both feasible and also cost-effective" (Carter, 1095). And in that year, Amoco purchased 30 percent of a leading manufacturer and distributor of solar cells, Solarex, located in Rockville, Maryland, and bought the rest of the company four years later.

Formed in 1973, Solarex introduced the use of polycrystalline silicon in solar cells in 1976 and marketed thin-film amorphous silicon modules three years later. Still, a large cost premium remained for distributed solar, limiting its niche applications and obviating any role in a power grid.

Despite federal grants, more than 90 percent of which "ended up in the coffers of the largest corporations in the United States" (Jensen, 103), a graveyard of private efforts resulted from President Carter's solar vision. In the 1970s and 1980s,

5 This section is based on Bradley 2018, ch. 13.

failed solar investments were made by Texas Instruments, General Electric, IBM, Polaroid, RCA, and Westinghouse; Sanyo, Kyocera, and Sharp of Japan; and the energy majors Arco, Exxon, Mobil, and British Petroleum.

Exxon began researching solar in 1969 and formed Solar Power Corporation in 1973. In 1984, losses and limited prospects led the world's largest energy company to shut the division. Losses of $30 million were recorded over 15 years.

ARCO Solar, formed in 1977 with a goal of becoming "the General Motors of solar energy" (Nieh; quoting ARCO Solar vice-president Peter Zambas), was sold to Siemens A.G. of West Germany in 1989. Losses of $200 million were recorded over 12 years. Mobil Solar Energy Corporation, launched in 1981, also unprofitable, sold out to German-based Applied Solar Energy (ASE) in 1994.

That left one major domestic player: Amoco's Solarex, the largest U.S.-owned manufacturer and distributor of PV modules and systems. In 1987, Solarex was placed within Amoco Technology Company with a mission to reduce costs in order to increase sales, and thus increase production economies. Its largest facility was increased to 5 MW (annual capacity of produced solar panels).

Despite federal grants, a graveyard of private efforts resulted from President Carter's solar vision.

Inadequate earnings and a need to fund new-generation technology led Solarex to seek a partner for fresh capital, better marketing, and a new business plan. Short of a savvy savior, it seemed as if the U.S. on-grid solar industry was through, a victim of a return to free-market energy policies—and an energy surplus—under Ronald Reagan.

Enron Corporation, located in Houston, Texas, was in search of new businesses to support an annual-earnings growth narrative of 15 percent, in order to double the size and earnings of the company in five years. (This plan for 1996–2000, called *Enron 2000*, was set in 1995.) Ken Lay, sounding the global warming alarm to advantage Enron's natural gas divisions against coal and fuel oil, saw renewables as the new frontier.[6] He knew there would be government support and liked the applause from environmentalists and favorable media. With retail marketing of electricity scheduled to be the company's next big thing, Enron also imagined itself as the green provider for environmentally conscious consumers in a carbon dioxide (CO_2)-constrained world.

"Solar Power for Earthly Prices," a November 15, 1994, headline in the *New York Times* read (Myerson). Subtitled "Enron Plans to Make the Sun Affordable," the business feature described the company's proposal to deliver electricity to the federal government in two years at $0.055 per kWh, an initial rate that would escalate 3 percent annually for 20 years. This price was unheard of, with prior estimates having been closer to $0.20 per kWh.

"Grand promises in the late 1970's about the potential of virtually pollution-free, endlessly renewable energy sources like solar energy faded into an embarrassed hush," the article allowed, but Enron's optimistic goal was described as "probably reachable." Unit costs had "quietly" declined by two-thirds, it was explained. What Enron was proposing—a $150 million, 100 MW manufacturing plant—would provide the scale economies that were hitherto missing. U.S Department of Energy (DOE) Deputy Secretary Bill White was quoted in the article. "I'm confident we can make some commitment for a Federal entity to purchase or at least broker some purchase of solar power" (Myerson).

Enron was not even in the solar business—yet. A series of contracts with consultants and outside suppliers led to the above offer and public relations coup. But the highly speculative, government-dependent project would be scaled back and then forgotten amid the next year's bigger news: Enron's 50 percent purchase of Amoco's Solarex for $20 million, plus a $15 million contribution from each partner to complete construction of a new generation thin-film manufacturing plant capable of annual production "in excess of 10 MW of large area, multijunction amorphous silicon modules" (Amoco). This new technology, the press release noted, was developed in conjunction with the Department of Energy.[7]

Enron's grand strategy was to build large grid-connected solar farms, creating scale economies for (cheaper) panels to capture the rooftop market.

"Our joint venture with Amoco builds on Enron's strategy of providing clean energy to the world economy," an Enron vice-chairman stated (Amoco). "This is the technology that will allow us to provide solar electric power at competitive prices, both in the United States and in other areas around the world." Amoco, meanwhile, hailed the joint venture as providing "the missing link in PV—lower costs through high-volume production enabled by sales into grid-connected markets" (Amoco).

6 Enron, led by Ken Lay, a Ph.D. economist with grand business ambitions, was "the company most responsible for sparking off the greenhouse civil war in the hydrocarbon business" (Leggett, 204).

7 This third-generation technology, in the experimental stage, came after silicon wafers and thin-film amorphous silicon.

Exciting press releases about project negotiations followed. There was "the world's largest solar electric generating plant in northern India" (Hurst). There was a major solar farm in Greece, the centerpiece of the Greenpeace Solar Crete campaign. Domestic projects were announced for southern California, West Texas, and Hawaii.

But none of these projects were finalized or built. On-grid solar was much more expensive than other generation options—and unsuitable without very costly storage appendages to overcome intermittency. Mass production of panels for solar farms in order to lower the cost of rooftop solar did not take hold. Still, Amoco/Enron Solar was the world's second-largest panel manufacturer (and largest U.S. maker), with plants in Frederick, Maryland; near Newport News, Virginia; and in Australia, Hong Kong, and Japan.

Sales in 70 countries were a mix of "solar farms, rooftops, village electrification, water pumping, telecommunications, and other industrial and consumer products" (Enron Corp. 1997a). One venture in Japan, enabled by $25,000 government grants, offered residents a "zero-energy house," where monthly oil, gas, and electric bills were eliminated (Solarex).

Rooftop solar, marginally profitable, was tugged under by futile efforts to commercialize solar farms. Not even the Clinton administration's Million Solar Roofs Initiative, which Solarex head Harvey Forest predicted would help "stimulate a domestic market here in the United States," would prove enough to stem the red ink (quoted in Crawford).[8] Meanwhile, Enron/Amoco's Virginia thin-film plant was behind schedule and over budget, leading to a management shakeup. More losses were coming, but a fortuitous exit for Enron and Amoco was just ahead.

Effective January 1, 1999, British Petroleum (BP), purchased Amoco for $48 billion to form BP Amoco. Enron's half-ownership in Solarex created a conflict of interest for Amoco's new owner, given that BP Solar (established 1981) was bigger than the unit it was buying. Redundancies could be eliminated, and BP's new branding was to be the world's green petroleum marketer, not unlike Amoco's aspiration a decade before. Thus BP (now standing for "beyond petroleum") became the world's largest solar-panel manufacturer by purchasing Enron's half of Solarex for $45 million, creating an after-tax gain for Enron of $6.5 million in 1999.

But Enron's exit came with a discouraging report card. "None of the proposed solar farms ever got built," Sarah Howell of Solarex told the press, referring to a dozen projects touted by Enron (quoted in De Rouffignac). "We are concentrating on the more viable grid-tied [that is, urban rooftop] systems." This was the business that everyone else was after too.

Hyperbole marked solar power pre- and post-Enron. "All the world's energy could be achieved by solar many thousands of times over," said Roger Booth, Shell's renewable-energy chief in 1995 (quoted in Greenpeace). "Amoco/Enron Solar aims to power the earth by harnessing the energy of the sun—at a price that is competitive with fossil fuels," *Enron Business* stated in 1996 (Hurst). And Greenpeace: "1997 is being viewed as a turning point in the fortunes of solar photovoltaics as global demand is 'poised to soar'" (Greenpeace; quoting the research firm Strategies Unlimited, 3).

Reality told another story. In the mid-1990s, Solar Two, a $55 million, 10 MW solar thermal demonstration project in the Mojave Desert, led by Southern California Edison, began producing (intermittent) power at between $0.18 and $0.22 per kWh. (Solar One, a 10 MW project built in 1981, had been destroyed by fire in 1986.)

"Solar Two looks good on paper, and it is expected to provide steady baseload electricity as well as late afternoon peaking capacity, but the future of all the central solar generators is in doubt," opined Christopher Flavin and Nicolas Lenssen in 1994. "They are expensive to build, their very scale escalates financial risks—as with nuclear power—and their massive height (in excess of 200 meters) may attract opposition" (Flavin and Lenssen, 143). They were right. Solar Two's 130-acre computer-controlled mirrors, reflecting sunlight to a central tower, ceased operation in 1999 and was demolished a decade later.

Solar Two was "a technological success, but not economically ready for prime time," the editors of the *Electricity Journal* concluded ("SCE's Solar Two," 6). The same can be said for more recent, failed or failing government-enabled projects.

Solyndra, a "venture socialism" experiment intended to "jump start" unprofitable solar projects (Moore and White, 47), swallowed a $535 million loan from the U.S. Department of Energy in 2009, declared bankruptcy in 2011, and was subsequently liquidated (Stephens and Leonnig).

The 377-MW Ivanpah Solar Electric Generating System in the Mojave Desert in southern California, the world's largest, has produced very expensive electricity since 2013 at disappointingly low capacity factors. "A Huge Solar Plant Caught on Fire, and That's the Least of Its Problems," one summary of the project's early operation read (Zhang).

8 The $600 million federal loan program, as proposed by the Solar Energy Industry Association, involving a constellation of government agencies, would provide "buy-down" subsidies for one million installations of solar water heaters and PV equipment by 2007 (Crawford).

Still, the hyperbole continues. "Before maybe the end of the decade," stated DOE Secretary Stephen Chu in 2011, "I see wind and solar being cost-competitive without subsidy with new fossil fuel" (quoted in "Wind, Solar"). And more recently (2017): "One can argue that PV is growing at such a rate that it's on its way to becoming mankind's largest enterprise," stated Greg Wilson, an official with DOE's National Renewable Energy Laboratory (quoted in Fialka). "Forget coal, solar will soon be cheaper than natural gas power," proclaims Joe Romm at the Center for American Progress, drawing upon a study from Bloomberg New Energy Finance (Romm).

Today, solar's rooftop market is buoyed by a set of complementary government interventions to make the uneconomic economic. State and federal tax credits are crucial; without them the rooftop solar market would evaporate except in the wilds. And a number of states have set "net metering" requirements for utilities to buy solar-generated power from the homeowner or business at high prices, whether or not the utility and non-solar ratepayers want or need that power. A federal law, the Energy Policy Act of 2005, has federalized the requirement as well (Moore and White, 180–81).

Ascent of (Political) Wind Power

Windmills, an early use of mechanical energy, predated the fossil fuel era by centuries. "The role of wind energy has historically been a major factor in the development of human civilization," noted one historian, "with wind powering the early sailing ship as well as the first major source of mechanical power, the windmill" (W. Clark, 513).

Turning wind into electricity had an 1887 beginning in Thomas Edison's neighborhood and as far away as Denmark a decade later.[9] American companies picked up the pace in the 1920s. During World War II, the 1.25 MW Grandpa's Knob wind turbine distributed electricity to Central Vermont Public Service Corporation, an experiment that led the Federal Power Commission to estimate the potential of domestic wind power in 1945.

Free energy spun the turbines, but electricity conversion was material- and capital-intensive—and intermittent. An 1883 article in *Scientific American* noted wind's unpredictable, unsteady flow and asked how the output could be stored from "gathering it at the time we do not need it and preserving it till we do" ("Storage of Wind Power"). W. Stanley Jevons had documented the same thing almost two decades before.

In contrast to solar power, wind power had virtually no industry in the United States through the 1960s. Wind-generated electricity was not for the rooftop or yard, although windmills on the farm had different uses. At scale, wind was hardly distributed energy, as was a solar panel away from a utility grid.

The energy crisis, which began with natural gas shortages in the winter of 1971–72 and oil shortages two years later, revitalized interest in wind power in the United States. The American Wind Energy Association (AWEA) was formed in 1974; six years later the nation's first wind farm was constructed in Vermont, consisting of 20 turbines generating 600 kilowatts (0.6 megawatts) at its peak. Still, the industry's embryonic status was evident in President Jimmy Carter's 1977 National Energy Plan, which emphasized solar-panel energy, nuclear fusion, synthetic fuels (from coal), and municipal waste—not wind power.

"Wind power may be a breath of fresh air on the world energy scene during the eighties," wrote Christopher Flavin in *Wind Power: A Turning Point* (Flavin, 5). "Pacific Gas & Electric and Southern California Edison seem to be playing a game of leapfrog as each attempts to one-up the other in a fight for leadership and public recognition in wind-energy development" (30). In fact, the federal Public Utility Regulatory Policies Act of 1978 (PURPA) opened the door for uneconomic power generation via PURPA-qualifying sales contracts. Captive (utility) ratepayers, not only unwitting taxpayers, would soon subsidize the launch of a major new domestic industry.

The birth of wind power as commercial energy began in California in the early 1980s. The winds were no stronger than before, but government largesse kicked in as a response to the energy crisis, a time when oil and gas shortages turned attention to renewables as the energy future.

On the demand side—very important since wind electricity was expensive, intermittent, and unproven—California's "most cooperative utilities in the nation" (Gipe, 30) entered into long-term purchase contracts pursuant to PURPA, as interpreted by state commissions under the eye of the Federal Energy Regulatory Commission (FERC). On the supply side, the Golden State—a "nation within a nation" (30) by size and philosophy—"offered lucrative incentives to match those of the federal government" (30), virtually doubling the federal 25 percent tax credit.[10]

9 To compete against coal-fired power in lighting his home, Charles Brush, a rival to Thomas Edison, erected a 60-foot windmill, a dynamo, and batteries to capture the current. But Brush soon connected to cheaper, more reliable central station electricity, Edison's model (Righter, ch. 2).

10 Christopher Flavin was moved to say: "Southern California is doing more to challenge the world energy economy than any single national government is" (quoted in Jennrich).

This confluence resulted in "an avalanche" (31) of capital into California, "including wind and solar power plants as well as solar water heaters" (31). Eclipsing Denmark's 30 percent tax credit, California "almost overnight" (31) became the center of the world wind industry, with 50,000 investors pouring $2 billion into projects (31). Amid this government-created Spindletop (the 1901 oil gusher that launched the Texas oil industry), quick money was made. But a boom-bust cycle resulted from the end of tax subsidies in the mid-1980s, when a surplus of oil and gas dimmed the energy-crisis rationale for renewables. (The global-warming issue was not yet in play.)

Major federal laws commercialized solar- and wind-generated electricity for the grid. Significant government research and development aid under President Carter, diminished under Reagan but resurrected by George H. W. Bush, was not enough. As intermittent resources with concentrated up-front capital costs, solar and wind needed contractually secure long-term sales and a known investor payback. The aforementioned PURPA (1978), enacted when the prevailing wisdom was that oil and natural gas were running out, as well as the Energy Policy Act of 1992 (EPAct), created that certainty as a reward to the renewable-energy lobby, consisting of involved businesses and environmental groups in the Bootleggers-and-Baptists tradition.

Section 210 of PURPA, which made a market for independents to compete against hitherto monopolistic utility generators, was crucially shaped by a waste-to-energy firm, Wheelabrator-Frye Corporation, as well as its trade association, the 48,000-member Solar Lobby, representing not only solar-panel companies but also biomass, hydro, and wind enterprises. Electric utilities were required to buy power from "qualifying facilities" (Public L. No. 95-617, 92 Stat. 3117, at 3145 (1978)) at a rate up to "the incremental cost to the electric utility of alternative electric energy" (at 3144). Importantly, incremental cost was not the marginal cost of operations; nor was it to be determined in a competitive least-cost bid process by the purchasing utility. Intended to promote renewables (and cogeneration), "total avoided cost" was determined by the state utility commission with blessing from FERC (Yergin, 530, 599). The resulting avoided-cost determinations, at least in the gravy-train 1980s, were a bonanza for independent (nonutility) generators but a burden for ratepayers.

The second law, EPAct of 1992, introduced the Renewable Electricity Production Tax Credit (PTC) of 1.5 cents per kWh, representing a good half of the going price of electricity at the power plant (busbar). The 10-year provision was inflation-adjusted. Nine extensions of the expiring PTC would keep the subsidy alive as of 2018, with its current inflation-adjusted amount at 2.4 cents per kWh.[11]

Zond Systems, founded in 1981 in Tehachapi, California, would become the most enduring wind power company in America (via Enron and, today, GE). Reaping early state tax credits, Zond imported its turbines from the Danish wind company Vestas, itself helped by a government-funded research institute near Copenhagen.

Zond would prove to be the major survivor of "California's extraordinary wind rush" (Yergin, 595), which produced "an eyesore of broken and twisted blades" (Yergin, 596; quoting Richards), "PURPA machines" (530) and "tax farms" (Yergin, 599; quoting oft-reported remarks by California Congressman Pete Stark) in return for little electricity. To break out of the pack, Zond in 1993 hired a Danish turbine designer to remake its technology, aided by a million-dollar grant from the U.S. Department of Energy. Major projects, such as the 342-turbine Sky River Project in California, made Zond a U.S. leader.

Times toughened by mid-decade. Lower gas prices dropped the avoided-cost assignment from regulators pursuant to PURPA. In-state subsidies expired. A revenue stream from a small ownership interest in each project proved just enough for Zond to "survive until the next stage" (Yergin, 600; quoting Zond's James Dehlsen).

Power from large wind turbines was far cheaper than power from an array of solar panels, but neither could compete against on-grid electricity. Further, the huge turbines with blades larger than a 747's wing were a hazard to avian wildlife and a nuisance to neighbors. Long transmission lines were also needed to get wind power from the wilds to urban areas—and none greater than the $7 billion, 3,600-mile Competitive Renewable Energy Zone (CREZ) line, paid for by every electricity customer in the state of Texas, like it or not (Moore and White, 56).[12] But these drawbacks did not prove decisive to the industry as a whole. The environmental community, having little supply-side strategy otherwise, accepted wind power's shortcomings.

"Enron Forms Enron Renewable Energy Corp.; Acquires Zond Corporation, Leading Developer of Wind Energy Power," read a January 1997 news release (Enron Corp. 1997b). With its one-half interest in Solarex, Enron Renewable Energy Corp was formed.

11 The original EPAct credit expired at year-end 1999. Legislative extensions followed in 2000, 2002, 2004, 2005, 2007, 2009, 2012, 2014, and 2015.

12 Texas became the "Reddest State Covered with Wind Turbines" (Moore and White, 56), thanks to an Enron-sponsored renewables mandate in the (Texas) Electric Restructuring Act of 1999 (Senate Bill 7), federal production tax credit, and the CREZ line, completed in 2013.

"Renewable energy will capture a significant share of the world energy market over the next 20 years, and Enron intends to be a world leader in this very important market," Ken Lay stated. "We believe wind energy is one of the most competitive renewable energy resources, and we believe this acquisition clearly positions Enron as a leader in this business," Lay added (Enron Corp. 1997b).

The press release described 15-year-old Zond as "developing, building, and operating wind power stations," with its Z-class turbines being "among the world's most competitively priced" and "capable of producing electricity at competitive prices" (Enron Corp. 1997b). With 2,400 sited turbines rated at 260 megawatts, Zond's 1995 output of 600 million kWh earned a federal tax credit approaching $10 million. Unused tax credits, or so-called carry-forwards, were valued in Enron's purchase price of $80 million: $60 million in cash and the rest in debt.

Environmentalists and the American Wind Energy Association were elated. "This action by Enron underscores the enormous worldwide potential for wind energy," stated Randall Swisher, head of AWEA, adding: "Clearly, Enron sees renewable energy as a necessary component of their operations—a component that will give them a competitive advantage in tomorrow's electricity market where consumers will be able to choose their power suppliers" (quoted in "Enron Casts").

The rationale for government intervention was to forestall mineral depletion, improve air quality, and increase energy security. With all three now demoted, the new rationale is to address climate change.

"We believe that utility restructuring holds tremendous promise for companies with 'green' energy sources, like renewables," stated Norm Terreri of Green Mountain Power Company, "because environmentally-conscious customers will prefer to buy their power from a clean source" (quoted in AWEA). Terreri mentioned opinion polling research from New Hampshire where households were choosing their electricity provider in a pilot program led by Enron. *Enron Business* magazine explained how a projected 50 percent increase in energy demand in the next 20 years "will put considerable pressure on conventional fuel supplies, like oil, coal, and natural gas" (M. Clark, 4).

Zond had a backlog of projects well beyond California that Enron would continue. Purchase-power agreements had been signed with Minnesota's Northern States Power (100 MW) and Iowa's MidAmerican Energy Company (112.5 MW). Both projects were part of state legislative mandates requiring these utilities to buy wind in return for storing part of their nuclear waste. A 5 MW Zond project in Vermont for Green Mountain Power was nearly complete. Still, none of this was making enough money for Zond despite receiving government subsidies.

"We brought Zond back from the brink," recalled Enron's Robert Kelly (quoted in Yergin, 601). Zond was running low on cash and unable to monetize its huge tax credits. "We were hanging by a thread," Zond's James Dehlsen remembered. "It was a really grim story" (quoted in Yergin, 600). The domestic wind industry was in even worse shape. Kenetech Windpower, experiencing technical difficulties with its turbines, among other problems, had entered bankruptcy in June 1996, six months prior to Enron's January 1997 purchase of Zond.[13]

The company to be renamed Enron Wind Corporation would struggle to help Enron's bottom line in its first years. Technological lessons were learned on the fly to dodge the blade problems experienced by Kenetech. Zond had done the proper testing and worked with a world-leading turbine manufacturer, Vestas, to address life-cycle blade integrity.

The extra work paid off. Enron Wind, which the parent put up for sale in 1998 in order to deploy capital in other areas, would fetch top dollar when it was sold to GE in 2002, the year after Enron's bankruptcy.

Enron, primarily a natural gas company, entered into solar power (1995) and wind power (1997) in an industry-leading way. In fact, Enron rescued both fledging, government-dependent industries. "The company that actually put wind back in business in the United States was Enron, the high-flying natural gas and electric power company, which at the time was an innovator in the power sector," noted Daniel Yergin (601). The same can be said for solar via Solarex.

But irony of ironies: In 1997, quietly, Enron entered the coal business, which would be the most profitable of the three ventures. Enron's 35-employee coal unit earned $35 million in 1999, a true profit center with $300 million invested in coal reserves to back Enron Capital & Trade Resource's physical trading. This created image problems for Ken Lay.

13 *CQ Weekly* cited Kenetech Corp.'s "horrible mechanical problems with its newest wind turbine, overly aggressive expansion, even environmental concerns arising from the mulching of federally protected birds by the company's windmills" (Weisman).

"Our position as a 'green' company is getting thin," stated Enron's head of European affairs, Mark Schroeder. "We will find it increasingly difficult to even maintain the John Browne imitation, having sold solar (to BP), and sometime next year becoming the largest trader of coal in the world" (Schroeder).

Conclusion

"The agenda of the so-called green movement, one of the most influential political forces in America today, does not end with carbon-based energy," Stephen Moore and Kathleen Hartnett White noted. "It is a war on free-market economics" (2). Wind power and grid-connected solar power—intended to displace fossil-fuel-generated electricity—are wholly dependent on special government favor. Ethanol, too, derives much of its market share from government mandate. The rationale for government intervention was to forestall mineral depletion, improve air quality, and increase energy security. With all three now demoted, the new rationale is to address the amorphous issue of the human influence on climate (*climate change*, what was originally called *global warming*).

Vehicle electrification, also dependent on government intervention, is Part II of the government's energy plan to displace fossil fuels. The *deep decarbonization* movement goes from power generation via politically correct renewables (wind and solar) to electrifying the transportation market, all in violation of free consumer choice under natural market economics.

A return to a displaced, obsolete energy past is a recipe for energy poverty—and wholly unnecessary. "Fossil fuels are wonder fuels," Moore and White remind us. "If we want a just, prosperous, healthy, and safe world that respects the rights and dignity of the individual, we have a moral imperative to use them in a responsible and productive way" (122).

The choice between two energy futures is clear. They state:

> Fossil fuels have been one of the greatest anti-poverty programs in history, improving the human condition more than all of the trillions of dollars of government welfare programs and foreign aid programs combined. By contrast, most forms of green energy aren't green at all. They're a prescription to make the poor poorer. (166)

May the lessons of history be relearned, and freedom reign for energy as in other sectors of the economy. ☆

Appendix

Key Energy Dates

1839: The photovoltaic (PV) effect is discovered whereby photons from the sun are converted to electrons.

1865: W. S. Jevons publishes The Coal Question. The first treatise on energy explains how mineral energy has made prior (renewable) energies obsolete for the machine age.

1881: Thomas Edison and Samuel Insull form the company now known as GE (General Electric) to construct central-station "jumbo" generators in place of on-site "isolated plants." (Coal-fired generation will be joined a half-century or more later with oil-fired and gas-fired turbines.)

1887: A wind turbine produces electricity in Thomas Edison's neighborhood.

1890s: Solar water heaters are commercialized in the U.S. (and would remain competitive until the 1950s).

1891: The first electric automobile is built in the U.S., five years before Henry Ford introduces his first internal-combustion-engine model.

1896: Thomas Edison advises Henry Ford to not build electric cars ("Electric cars must keep near to power stations. The storage battery is too heavy").

1941: The first megawatt-sized wind turbine becomes operational, delivering power to Central Vermont Public Service Corporation. The 1.25 MW Grandpa Knob project is dismantled in 1946 due to operational failures.

1945: The Federal Power Commission (now FERC) estimates the potential of U.S. wind power to produce electricity as a result of the above Grandpa Knob project.

1954: Bell Labs introduces silicon for PV usage, opening up a niche market for remote electricity applications.

1960: Geothermal steam produces commercial electricity for the first time in the U.S. (the Geysers in California).

1970s: Oil and gas shortages in the U.S. (from federal price and allocation regulation) give rise to fears about mineral resource exhaustion, leading to private and governmental efforts to commercialize wind power and solar power.

1973: Exxon forms Solar Power Corporation. After losses of $30 million, the unit is dissolved in 1984.

1976: Solarex, founded in 1973, introduces the use of polycrystalline silicon in solar cells.

1977: Arco Solar is formed. After losses of $200 million, the division is sold to Siemens A.G. of West Germany

1979: Solarex markets thin-film amorphous silicon modules.

1980: Kenetech Corp., which will become the world's largest wind company, is founded in northern California. It would cease operation sixteen years later (see below).

1981: Solar One, a 10 MW demonstration project in California's Mojave Desert, begins generating electricity from 1,818 sun-tracking mirrors (heliostats). The nation's first thermal solar project, designed by the US Department of Energy, is disabled five years later and later converted to Solar Two (see below).

1981: Mobil Solar Energy Corporation is formed. After steady losses, the unit is sold to Applied Solar Energy of Germany in 1994.

1981: Zond Systems is founded in Tehachapi, California. Zond would prove to be the most viable of US-based wind companies (see below).

1983: Solarex, the largest remaining U.S. solar firm, merges with Amoco Solar Company.

1980s: The wind power industry takes root in California from state and federal subsidies. The boom turns to bust at mid-decade with the scale-back of subsidies and from the fall in energy prices in 1986.

1991: LUZ International, which built nine solar plants in southern California since 1984, declares bankruptcy and is liquidated.

1994: The New York Times business section features a proposed 100 MW Nevada solar plant by Enron that is competitive with retail electricity prices. The heavily subsidized project does not eventualize.

1995: Enron purchases one-half of Amoco's Solarex in order to develop the central-station (versus rooftop) solar market. Despite numerous negotiations, no solar farms are built.

1995: Solar Two becomes operational. An expanded/rebuilt version of Solar One (see above), the central-station thermal solar project, was decommissioned in 1999.

1996: Kenetech Corp., experiencing technical failures and low sales with its wind turbines, declares bankruptcy and is then liquidated.

1997: Enron purchases Zond Corporation, the largest US wind company with properties and planned projects of several hundred megawatts. The renamed Enron Wind Corporation is sold after Enron's bankruptcy (see below).

1999: Enron sells its interest in Solarex to BP after the Amoco/BP merger. BP integrates Solarex into BP Solar to form BP Solarex, which eventually is renamed BP Solar.

2002: Enron's estate sells Enron Wind Corporation to GE to form GE Wind Energy.

2011: Solyndra, founded in 2005, a thin-film solar cell manufacturer in California, declares bankruptcy is liquidated the next year.

2013: The 377 MW Ivanpah Solar Electric Generating System, the world's largest, begins operation in the Mojave Desert on the strength of a $1.6 billion government loan guarantee.

2016: Stephen Moore and Kathleen Hartnett White publish Fueling Freedom: Exposing the Mad War on Energy, a primer on the moral, economic, and environmental case for market-based mineral energies.

Reference List

American Wind Energy Association (AWEA). 1997. "Enron Acquires Zond, Launches Enron Renewable Energy Corp." Press release, January 6.

Amoco Corp. 1994. "Amoco Corporation and Enron Corp. Form Joint Venture to Provide Missing Link in Solar Energy Industry." Press release, December 19.

Bradley, Robert, Jr. 1999. "The Growing Abundance of Fossil Fuels." Foundation for Economic Education, November 1.

Bradley, Robert, Jr. 2009. *Capitalism at Work: Business, Government, and Energy*. Salem, MA: M & M Scrivener Press.

Bradley, Robert, Jr. 2011. *Edison to Enron: Energy Markets and Political Strategies*. Salem, MA: Scrivener Press, and Hoboken, NJ: Wiley & Sons.

Bradley, Robert, Jr. 2012. "Resourceship: Expanding 'Depletable' Resources." Library of Economics and Liberty, May 7.

Bradley, Robert, Jr. 2018. *Enron Ascending: The Forgotten Years, 1984–1996*. Salem, MA: Scrivener Press, and Hoboken, NJ: Wiley & Sons.

Bradley, Robert, Jr., and Richard Fulmer. 2004. *Energy: The Master Resource*. Dubuque, IA: Kendall-Hunt.

Carter, Jimmy. 1979. "Solar Energy: Remarks Announcing Administration Proposals." Public Papers of the Presidents of the United States, Jimmy Carter, June 20, 1979, 1095.

Clark, Mary. 1997. "Enron Adds Wind Power to Its Energy Portfolio." *Enron Business*, March 1997, 4–5.

Clark, Wilson. 1974. *Energy for Survival: The Alternative to Extinction*. Garden City, NY: Anchor Books.

Crawford, Mark. 1997. "White House Takes a Shine to Solar Power." *Energy Daily*, July 2, 1997, 3.

Darbonne, Nissa. "To the Caribbean with Gas." *Oil and Gas Investor*. July 2017, 45–46.

De Rouffignac, Anne. 1999. "Enron Pulls the Plug on Solar Power Operation." *Houston Business Journal*, Week of April 16–22.

Durkay, Jocelyn. "State Renewable Portfolio Standards and Goals." National Conference of State Legislatures. August 1, 2017.

Editorial. 1866. "A busy and prosperous age forgets the past and is blind to the future." *The Times* (London), April 19, 1866, 10.

"Enron Casts Its Energy Reach to Wind with Purchase of Zond." 1997. *Energy Reports*, January 13.

Enron Corp. 1997a. "Amoco/Enron Solar Granted Funding for 5-Megawatt Solar Facility in Greece." Press release, June 12.

Enron Corp. 1997b. "Enron Forms Enron Renewable Energy Corp.; Acquires Zond Corporation, Leading Developer of Wind Energy Power." Press release, January 6, 1997.

Farey, John. 1827. *A Treatise on the Steam Engine: Historical, Practical, and Descriptive*. London: Longman, Rees, Orme, Brown, and Green.

Fialka, John. 2017. "From 'Hippie Thing" to Hundreds of Mirrors and 1,000 Degrees." E&E News website, September 26.

Flavin, Christopher. 1981. "Wind Power: A Turning Point." *Worldwatch Paper 45*, Worldwatch Institute, Washington, D.C., July.

Flavin, Christopher, and Nicholas Lenssen. 1994. *Power Surge: Guide to the Coming Energy Revolution*. New York: W. W. Norton.

Gipe, Paul. 1995. *Wind Energy Comes of Age*. New York: John Wiley & Sons.

Gore, Al. *Earth in the Balance: Ecology and the Human Spirit*. New York: Houghton Mifflin Company, 1992.

Greenpeace International. 1997 "Plugging into the Sun—Kickstarting the Solar Age in Crete." June.

Hurst, Teresa. 1996. "Amoco/Enron Solar Brings Solar Power Down to Earth." *Enron Business*, March 1996, 2–3.

Jennrich, John. 1992. "Gas Wins Debate on 'Sustainable Development.'" *Natural Gas Week*, October 12, 1992, 2.

Jensen, Carl. 1997. *20 Years of Censored News*. New York: Seven Stories Press.

Jevons, William Stanley. 1865. *The Coal Question*. London: Macmillan and Company.

Leggett, Jeremy. 1999. *The Carbon War*. London, Penguin Books.

Moore, Stephen, and Kathleen Hartnett White. 2016. *Fueling Freedom: Exposing the Mad War on Energy*. Washington, DC: Regnery.

Myerson, Allen. 1994. "Solar Power, for Earthly Prices." *New York Times*, November 15, sec. D.

Nieh, Doris. 1978. "The General Motors of Solar Energy." *The Executive of Los Angeles*, February.

Pratt, Joseph. 2000. *Prelude to Merger: A History of Amoco Corporation, 1973–1998*. Houston, TX: Hart Publications.

Richards, Anne. 1986. "Wind Firm Short of Cash, Power, Long on Lawsuits." *Press-Enterprise* (Palm Beach, CA), May 18.

Righter, Robert. 1996. *Wind Energy in America: A History*. Norman: University of Oklahoma Press.

Romm, Joe. 2017. "Forget Coal, Solar Will Soon Be Cheaper Than Natural Gas Power." ThinkProgress website, June 15.

"SCE's Solar Two Deemed Workable, but Not Economical." 1999. *Electricity Journal*. November, 6–7.

Schroeder, Mark. 1999. "Climate Change Levy." Enron memorandum to Rob Bradley, November 3.

SEIA (Solar Energy Industries Association). "Solar Investment Tax Credit (ITS).

Simon, Julian. 1981. *The Ultimate Resource*. Princeton, NJ: Princeton University Press.

Simon, Julian. 1996. *The Ultimate Resource 2*. Princeton, NJ: Princeton University Press.

Smil, Vaclav. 1998. *Energies: An Illustrated Guide to the Biosphere and Civilization*. Cambridge, MA: The MIT Press.

Smil, Vaclav. 2014. "The Slow Rise of Solar and Wind." *Scientific American*. January, 52–57.

Solarex. "Solarex/Japanese Partners Complete World's First 'Zero-Energy House.'" Press release, December 7, 1998.

Stephens, Joe, and Carol Leonnig. 2011. "Solyndra: Politics Infused Obama Energy Programs." *Washington Post*, December 25.

"The Storage of Wind Power." 1883. *Scientific American*, n.s., 49, no. 2 (July 14), 17.

Strategies Unlimited. Solar Flare Executive Report Series, 96-4.

Taylor, Thomas John. 1858. *Archaeology of the Coal Trade*. London: Archaeological Institute of Great Britain and Ireland.

U.S. Energy Information Administration (U.S. EIA). 2017a. *Annual Energy Outlook* 2017.

U.S. Energy Information Administration (U.S. EIA). 2017b. *International Energy Outlook 2017*.

Weisman, Jonathan. 1996. "An Energy Star Flames Out." *CQ Weekly*, October 12, 1996, 2916.

"Wind, Solar Becoming Cost Competitive: Chu." 2011. Phys.org website, March 23.

Yergin, Daniel. 2011. *The Quest: Energy, Security, and the Remaking of the Modern World*. New York: Penguin Press.

Zhang, Sarah. 2016. "A Huge Solar Plant Caught on Fire, and That's the Least of Its Problems." *Wired*, May 23.

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