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Is a Rapid Green-Energy Switch Prohibitively Costly?

Dear Dr. Dollar:
Virtually everyone now recognizes the reality of climate change. However, there is still opposition to making a major, rapid switch to green energy, based on the argument that there are substantial limits to green technology and that these limits could only be overcome at a prohibitively high cost. Is there validity to this argument? —Chip Carey, North Hampton, N.H.

BY ARTHUR MACEWAN

A switch to green energy could be costly. But a failure to switch would be far more costly, perhaps even catastrophic. In fact, the damage that is occurring because of our use of fossil fuels is already imposing substantial costs, as witness, for example, the severe fires and hurricanes of recent years. Worse yet, global warming and its impacts will only become more extreme in the coming years because greenhouse gases (carbon dioxide, especially) remain in the atmosphere for many decades. Nonetheless, it is still possible to take actions that will not only improve the situation in the long run, but will have immediate positive impacts on health and general well-being. (See the sidebar on the "hidden costs" of energy production.)

The switch to green energy does face some substantial cost barriers. Although these barriers have been exaggerated by opponents, some will have substantial—but by no means prohibitive—costs. Also, the switch could negatively affect many people who work in fossil fuel industries. Failure to mitigate this social impact would greatly inhibit the move to green energy, as well as being ethically offensive. Yet, there are programs (beyond the scope of this article, but see the Green New Deal's "just transition" provisions) that could ensure that this group of people does not suffer the burden of energy transformation.

There are various forms of green energy, including hydropower and geothermal power. Here, however, I will focus on solar and wind power, which are potentially the most important.

The Good News

It used to be argued that wind- and solar-powered generation of electricity was excessively expensive, a good deal more expensive than generation using fossil fuels. Leaving aside the fact that this cost comparison did not include the very high social costs of generation by fossil fuels—climate change and damage to people's health—the argument is no longer valid. (See the sidebar regarding the environmental costs of wind and solar energy generation.)

Great increases in reliance on green energy are both necessary and possible, and the sharp decline in the costs of solar and wind power are major steps in the right direction.

The best estimates indicate that between 2009 and 2019, the cost of producing electricity by solar photovoltaic cells (in large-scale facilities, not rooftops) fell 89%, and the cost of producing electricity by wind power fell 70%. In this same period, the cost of electricity generation by coal fell 2% and the cost of producing electricity by natural gas fell 32%. In 2019, the costs of generation by solar or by wind were about the same and far cheaper than generation from fossil fuels, just 36% of the cost of generation by coal and about 70% of the cost of generation by gas. The actual cost estimates are shown in the table on the next page. (These are estimates of unsubsidized costs and include capital costs; again, they do not include social and environmental costs, what economists call "externalities" or "spillover effects," which are, of course, much higher for fossil fuel generation than green energy generation.)

The cost reductions have come as the demand for green energy has grown and governments around the world have provided support for expansion. According to a November 2019 article in the *Financial Times*, the advance "has been driven by solar expansion in the EU [European Union],

$160 BILLION AND COUNTING

A 2009 report from the National Research Council (a part of the U.S. National Academy of Sciences and U.S. National Academy of Engineering) made estimates of many of the "hidden costs" of energy production and use—in particular, the damage to human health from air pollution—that are not reflected in market prices of fossil fuels. The report's estimate of these "hidden costs" was $120 billion in the United States in 2005—which would be about $160 billion in 2020 prices. The figure primarily reflected the health damages from air pollution associated with electricity generation and vehicle transportation.

The actual "hidden costs" are much higher, as the Research Council notes that its estimate did not include damages from climate change, harm to ecosystems, effects of some additional air pollutants (e.g., mercury), or risks to national security.

SOURCE: The National Academies of Sciences, Engineering, and Medicine, "Report Examines Hidden Costs of Energy Production and Use," October 19, 2009 (nationalacademies.org).

India, and Vietnam as well as growth in onshore wind in the EU, US, and China." Increases in production have allowed economies of scale to lower costs. Also, new manufacturing techniques and new materials in solar photovoltaic panels have contributed to the cost reductions, as have taller towers, longer blades, and improved control systems in wind power.

The data suggest that new electrical generation capacity would use wind or solar instead of coal or natural gas, as the profit-maximizing firms that dominate the market would want to minimize costs; and the much smaller number of publicly owned utilities would also want to minimize costs. There is some move in the direction of these green sources of energy. In the United States between 2008 and 2018, in generation by utility firms, wind and solar photovoltaic generation together rose six-fold while total generation increased by only 1% (as the increase of green generation was roughly offset by a decline in other forms of generation). Yet, in 2018, these two sources accounted for only 8% of utility scale-generation.

Estimates of Cost Per Kilowatt Hour of Various Methods of Electricity Generation, and Percent Decline, 2009 and 2019

	2009	2019	Percent Decline
Solar photovoltaic	38.9 cents	4.0 cents	89%
Wind	13.5 cents	4.1 cents	70%
Coal	11.1 cents	10.9 cents	2%
Gas	8.3 cents	5.6 cents	32%
Gas Peaker	27.5 cents	17.5 cents	37%

NOTE: Social costs (i.e., externalities or spill-over effects) are not included.
SOURCE: Lazard, "Lazard's Levelized Cost of Energy Analysis—Version 13.0," November 7, 2019 (lazard.com).

The Bad News

There is a catch, however. The sun does not shine all the time and the wind does not blow all the time. If there were a way to store electricity when the natural environment (sun and wind) isn't cooperating, the problem of weather intermittency could be mitigated. But at present there is no way to do this on a large scale. Still, the problem could be significantly reduced if the electricity could be transmitted from those places where the sun is shining and the wind is blowing. In particular, the best place in the United States to produce solar energy is in the Southwest, and the best place for wind power is on the Great Plains.

Both of these regions, however, are far from the country's population centers (with the exception of southern California). In our present electric energy grid, it would be highly costly to transmit electricity over long distances. The wires heat up and much of the energy is thus lost in long-distance transmission.

So within the confines of the existing grid, the sites of generation must be close to the sites of use. This generally means that, for example, along the East Coast, a major reliance on wind and solar would have to be substantially supplemented with fossil fuel generation or other sources of green energy (e.g., hydropower) when the sun isn't shining and when the wind isn't blowing.

And it gets worse. Currently, this supplementary role is often played by gas "peaker" generation—that is, generation of electricity at peak demand times. Gas peaker generation is quite costly, about four times as costly as solar or wind generation. (See table above.) Currently, where low-cost green energy generation has become a significant part of generation, the price to consumers has not dropped, in part because some electricity generation still comes from costly peaker plants. Generation by

ENVIRONMENTAL IMPACTS OF WIND AND SOLAR

It seems there is no such thing as completely "clean" energy, in that even electricity generation by wind and solar has some negative impacts. The Union of Concerned Scientists (UCS) reports: "Despite its vast potential, there are a variety of environmental impacts associated with wind power generation … They include land use issues and challenges to wildlife and habitat." And: "The environmental impacts associated with solar power can include land use and habitat loss, water use, and the use of hazardous materials in manufacturing, though the types of impacts vary greatly depending on the scale of the system and the technology used—photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP)."

However, the UCS prefaces these statements with, "Fossil fuels—coal, oil, and natural gas—do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions." And, of course, by the measure of climate change.

The negative environmental impacts of green energy need to be recognized so they can be diminished as much as possible, but they provide no reason to inhibit the switch from fossil fuels to wind and solar.

SOURCE: Union of Concerned Scientists, "Environmental Impacts of Renewable Energy Technologies," March 5, 2013 (ucsusa.org).

these plants is so expensive because it requires that an entire facility be constructed but only used intermittently—so the fixed costs are spread over a relatively limited amount of output.

Gas peakers might be replaced with some kind of green energy generation—hydro or geothermal, for example. But these sources are not available at all sites, and the construction of large-scale hydropower facilities has its own environmentally destructive aspects—and is unlikely to occur anywhere in the United States. While nuclear power is sometimes advocated as a green option, it has its own well-known safety concerns, and efforts to deal with those concerns have made the cost of nuclear generation almost as high as gas peaker generation.

Solutions to the Problems?

One potential solution to some of these problems is rebuilding our energy grids (of which there are four for the United States and Canada) and connecting those grids more fully to one another. Currently, transmission within each grid is by alternating current (AC). Electricity can also be transmitted in the form of direct current (DC). DC can be economically transmitted over long distances. For example, on a DC-based grid, energy could be economically transmitted from the Southwest or the Great Plains to the East Coast. The DC could be transmitted at a much higher voltage without loss, as compared to AC. Thus the new system is called high-voltage direct-current transmission, or HVDC. In addition to replacing the existing long-distance transmission lines, DC transmission would require building converter stations at both ends of the lines, to convert generated AC to DC for transmission and then back to AC for use. (See sidebar, "AC and DC.")

Changing the long-distance transmission from AC to DC would be a large and costly undertaking. However, over time the project would pay for itself through the lower-cost provision of electrical energy. Indeed, research by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) found that this could be "the cheapest way to cut emissions," and that the new grid could be established within 15 years. The Department of Energy says that the creation of the HVDC grid would cost only $80 billion, but it could run much higher. For example, Senator Bernie Sanders' presidential campaign advocates putting the new grid underground and estimates a cost of $500 billion. However, NOAA says that consumers would save almost $50 billion per year (to say nothing of the greatly reduced social costs of climate change and health impacts).

There are possible other means by which the limits of green energy could be overcome. For example, when there is extra capacity (lots of sun and wind), water can be pumped up to a high-level reservoir and then released when the bases of green energy go down (a windless night), thus generating electricity by hydropower; the use of this pumping-up process could be expanded. Also, while there are no effective means for storing large amounts of energy, technological advances, including battery systems, are being pursued and could ease, if not eliminate, the intermittency problem of solar and wind power.

One of Many Steps

Great increases in reliance on green energy are both necessary and possible, and the sharp decline in the costs of solar and wind power are major steps in the right direction. The problems of green energy generation—in particular, the intermittency of supply and the details of HVDC—are still to be solved in practice, but solutions appear both technically and economically feasible, with HVDC transmission a likely basis for progress.

Of course, beyond the green generation of electricity, there are additional steps that are needed to combat climate change. One of those additional steps is connected to green electric energy—namely shifting the basis of our transportation system from oil and gas to electricity. Another is energy conservation, by, for example, extensive programs to improve building insulation. And there is an important role for carbon dioxide sequestration, which would remove large amounts of this main greenhouse gas from the atmosphere through increasing forestation and other means.

(Continued on back cover...)

AC/DC

Electricity can be transmitted and used as either alternating current (AC) or direct current (DC). An alternating current reverses its direction many times per second. A direct current flows in only one direction. Most machinery, lights, and household equipment run on AC, while items that run on batteries (e.g., cell phones) run on DC. AC can be transformed to DC and vice versa.

In any transmission of electricity—AC or DC—heat is generated and thus some of the electricity is lost in transmission. The current (the flow of electricity) affects the extent of heat generation and thus the loss of electricity in transmission. However, sending electricity with high force—that is, high voltage—allows electricity to be sent at a lower current. Thus, there is less heat generated per unit of electricity, which is to say less loss of electrical power in transmission.

Engineers have been able to develop DC transmission lines that can handle very high voltages, higher than can be handled by AC transmission. Thus, DC at high voltage can be transmitted over long distances with less loss than AC. Transmission over long distances, which would be inefficient (i.e., large losses) with AC, is thus efficient with DC.

Ask Dr. Dollar *(...continued from p. 23)*

A Basis for Optimism

The costs of establishing green energy as the basis of our lives are not prohibitive. The technology for much of the change is known, and the costs, while large, are not outlandish—especially compared to the costs of no action. It would have been better if we had started to adopt green technology 40 years ago when the major oil companies knew, but hid, that continuing to rely on fossil fuels would cause climate change. But there is still time to take action that could save us from the worst disasters.

There are technical problems that remain to be solved. The lack of sufficient electricity storage capacity is an example. Also, shifting to green energy is not just a matter of replacing existing fossil fuel generation with green sources; there is also the need to provide for major growth in electricity demand, as transportation and heating systems move to electricity. Yet, the progress that has been made in surmounting technical problems in recent years provides a basis for optimism.

Optimism, however, cannot be fully justified unless there is a very large increase in governments' support for the switch to green energy.

Unsolved technical problems and costs are real, but the main barrier to change is political. It is necessary to overcome the great political power of those forces that have an interest in maintaining our energy system as it is—the fossil fuel companies and the many companies, including the financial institutions, tied to the fossil fuel industry. Also, it is essential to ensure that the many people whose jobs are tied to fossil fuels do not bear the brunt of the transition to green energy; placing the burden on them would not only be unfair, but would lead them to resist the necessary changes. D&S

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SOURCES: Herman K. Trabish, "Is a national high voltage transmission system the cheapest way to cut emissions?," UtilityDive, Feb. 19, 2016 (utilitydive.com); NOAA Research News, "Rapid, affordable energy transformation possible," Jan. 26, 2016 (research.noaa.gov); Alexander E. MacDonald *et al*., "Future cost-competitive electricity systems and their impact on U.S. CO_2 emissions," *Nature Climate Change*, May 6, 2016 (doi.org); Brian Murray, "The Paradox of Declining Renewable Costs and Rising Electricity Prices," *Forbes*, June 17, 2019 (forbes.com); U.S. Energy Information Administration (eia.gov); Aleksandra Wisniewska, "Prices are down and capacity is up as solar and wind take hold," *Financial Times*, Nov. 7, 2019 (ft.com).

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