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Changing Direction

The worldwide transition from fossil fuels to renewable sources of energy is under way. As fossil fuel resources shrink, as air pollution worsens, and as concerns about climate instability cast a shadow over the future of coal, oil, and natural gas, a new world energy economy is emerging. The old economy, fueled largely by coal and oil, is being replaced with one powered by solar and wind energy.

We can now see this new economy starting to take shape. We saw it in 2013, when Denmark generated 34 percent of its electricity from the wind. In January 2014, wind supplied a whopping 62 percent of that country's electricity. Portugal and Spain each got over 20 percent from wind in 2013, and Ireland, 17 percent. Indeed, on some days wind power supplies half of Ireland's electricity. In Spain, wind is challenging nuclear power to become the country's leading source of electricity. And for several days in August 2014, electricity generated from wind in the United Kingdom eclipsed that from coal.

We also see the new economy surfacing in the state of South Australia, where wind farms now supply more electricity than coal plants do. On September 30, 2014,

power generation from the wind and the sun exceeded the state's electricity demand. In China, electricity from wind farms has surpassed that from nuclear power plants. And water for 170 million Chinese households is heated by rooftop solar water heaters.

In the United States, the start of the energy transition is on display in the hundreds of utility-scale solar power plants under development or construction in the Southwest. And Iowa and South Dakota are each generating at least 26 percent of their electricity from wind farms. The wind share in Iowa could reach half by 2018. Texas, which now gets nearly 10 percent of its electricity from wind power, is building huge wind farms and the long-distance transmission lines that will facilitate the sale of low-cost wind-generated power in Louisiana and Mississippi.

Solar and wind costs are falling fast, undercutting fossil fuels in a growing number of electricity markets. A July 2014 study by the Danish government projects that new wind farms coming online there in 2016 will supply electricity at half the cost of that from new coal and natural gas plants. In parts of Australia, which is experiencing a solar boom, the cost of producing electricity from the sun has fallen well below that from coal. In fact, a 2014 analysis citing government data reported that high electricity delivery costs mean that coal-fired power still could not compete with solar, even if the coal itself were free.

The energy transition is advancing rapidly in some unexpected places. Falling costs for solar and wind energy are opening the door for massive investments in Africa. Bloomberg New Energy Finance reported in August 2014 that there would be more renewable energy installations in Africa in 2014 than during the preceding 14 years. Wind and solar projects in Latin America are advancing even faster.

Several concerns are driving the great transition from fossil fuels to renewables. One of these is climate change and its effect on our future. Another is the health impact of breathing air polluted by burning fossil fuels, as seen in the 3 million people who die each year because of outdoor air pollution. A third is the desire for local control over energy production and overall energy security.

In response to these broad-based public concerns, government policies—including emissions controls, renewable energy targets, and financial incentives—are encouraging the shift to renewables, principally solar and wind. And as the need for clean alternatives to coal and oil is becoming apparent, there is growing interest in solar and wind energy within the investment community. This includes not only investment banks but also several billionaires who are plowing vast sums of money into renewable energy. The influx of “smart money” into this relatively new segment of the energy economy suggests that much more investment will likely follow.

As scientists have been pointing out for decades, carbon dioxide (CO₂) emissions from burning coal, oil, and natural gas are altering the climate. Increasing levels of CO₂ and other greenhouse gases in the atmosphere are raising the earth’s temperature. The consequences include melting ice sheets and glaciers, rising sea level, worsened drought in some areas, more intense rainfall in others, and more-destructive storms. If the world continues to rely heavily on fossil fuels, the global average temperature could rise by nearly 11 degrees Fahrenheit (up to 6 degrees Celsius) by the year 2100. Melting ice and the thermal expansion of the oceans could raise sea level by some 6 feet during this century.

The stakes are high, and there is no need to look beyond food security to see why. A Stanford University study analyzed the historical relationship between temperature and

corn yields from some 600 U.S. counties. It concluded that each 1 degree Celsius rise in temperature above the growing-season norm dropped yields 17 percent. Wheat and rice, the world's food staples, are similarly vulnerable to higher temperatures. Viewed against the projected 6 degree rise in temperature during this century, which would bring more crop-withering heat waves, shrinking harvests could drive food prices up to unprecedented levels, resulting in chaos in the world food economy.

The rise in sea level threatens to inundate Asia's highly productive rice-growing river deltas, including the vast Ganges Delta in India and Bangladesh and the Mekong Delta in Viet Nam. Because so much rice is grown in low-lying river deltas, this world food staple is uniquely vulnerable to the rising global temperature.

Beyond the rice fields of Asia, rising sea level also poses a serious threat to some of the world's most populous cities, including New York, Tokyo, London, Shanghai, and Mumbai. Residents in these cities will have to decide whether to "stay and fight"—by building dams, levees, and other protective structures—or move to higher ground. The costs to society of the combined effect of rising food prices and urban inundation could bring the world economy to its knees.

Time is everything. We cannot turn back the clock and prevent the earth's temperature from rising. That is already happening. But if we move to dramatically cut carbon emissions with a wartime sense of urgency, we may be able to slow the rise and prevent climate change from spiraling out of control. This means restructuring the world energy economy: saying farewell to fossil fuels, embracing efficiency, and quickly expanding the use of renewable forms of energy.

Encouragingly, the energy transition is progressing much faster than most people realize. And it will accel-

erate. We are looking at the prospect of a half-century's worth of change within the next decade. Whereas the cost of energy from fossil fuels is largely commodity-dependent and will increase over time as the fuels become more scarce, producing power from the wind and the sun is largely technology-dependent, with costs falling as the science improves. Every country has its own supply of renewable energy. Both solar and wind energy are widely distributed and also inexhaustible. In contrast to coal and oil, the amount of solar and wind energy consumed today does not reduce the amount available tomorrow.

The worldwide use of solar cells to convert sunlight into electricity is expanding by over 50 percent a year. Early photovoltaic (PV) installations were typically small-scale—mostly on residential rooftops. Now, in addition to millions of rooftop installations, thousands of utility-scale solar projects are under development or construction.

At peak power, the solar systems installed worldwide by the start of 2014 could match the output of at least 100 nuclear reactors. As technology progresses and as PV system costs fall, the accelerating spread of rooftop installations—both residential and commercial—is reducing the market for utility-generated electricity in many communities. With their market shrinking, utilities are forced to adapt or raise prices. Yet higher prices encourage the installation of even more solar panels. Once under way, this cycle can reinforce itself, leading to what is commonly described as a “death spiral” for electric utilities.

This scenario has recently played out in Germany, where leading utilities including the giants RWE and E.ON found themselves at risk of bankruptcy, in part because rooftop solar installations were satisfying a growing share of residential needs and driving down wholesale power prices. Now these utilities are retooling their business

models to better accommodate renewables in order to survive in the new energy landscape. A similar situation could unfold in the sun-rich U.S. Southwest, where the number of rooftop installations is growing exponentially.

With solar panel costs continuing to fall and with the number of installations multiplying, installing solar panels on residential rooftops in villages in developing countries is now often cheaper than building a central power plant and the grid to supply electricity. Just as cell phones took off in the developing world and bypassed reliance on the traditional network of landline telephones, rooftop solar generators are bypassing the electric grid.

Numerous other trends are signaling the fast-moving shift from fossil fuels to renewable sources of energy. The burning of coal, for example, is declining in many European countries. In the United States, the number two coal consumer after China, coal use dropped 18 percent from 2007 to 2013 as scores of coal-fired power plants closed.

Of the 500-plus U.S. coal plants that were generating electricity at the beginning of 2010, fully 180 have closed or are scheduled to do so, leaving 343 plants in operation. Among the reasons for this drop are local opposition to coal (often for health and environmental reasons), the adoption of stricter air quality regulations that raise the price of coal-fired power, the growing use of solar and wind energy, and the rapidly expanding availability of low-cost natural gas. A strong force in the U.S. anti-coal movement is the Sierra Club's Beyond Coal campaign. Its goal is to close all the coal plants in the country by 2030, replacing them with a combination of efficiency gains and clean energy.

Thus far, an increased reliance on natural gas has helped the United States begin to wean itself from coal. The burgeoning use of horizontal drilling and hydraulic fracturing or "fracking" techniques to coax trapped oil

and natural gas out of shale rock formations reversed a decline in U.S. natural gas production, boosting it 32 percent between 2006 and 2014. Yet while it has been touted as a “bridge fuel” to a clean energy economy, natural gas is losing its luster. In producing energy, burning natural gas emits only half as much CO₂ as coal. However, recent studies have found that in many cases natural gas can actually be worse for the climate because of the extensive leakage of methane—a much more potent greenhouse gas—from wells, pipelines, and tanks.

Ultimately, since gas reserves are limited and new wells are depleted so rapidly, it makes little sense for society to invest in expanding the gas infrastructure and then have to abandon it. This would simply become another dead-end street, a diversion from building a lasting energy economy. While natural gas and oil prices are volatile, dependent on an unpredictable supply from exhaustible reserves, there is no fuel cost for wind and solar installations. Zero.

When looking at the decline in coal burning in the United States and many other industrial countries, the question that inevitably arises is, But what about China, which uses more coal than all other countries combined? The good news is that coal use in China started to fall in 2014. “Peak coal” is nigh. Two deeply held concerns in Beijing will bolster China’s nascent energy transition. One is the effect of coal burning on the health of the Chinese people and the resulting political unrest that it brings. The other is the scarcity of water, which is needed in large quantities to mine coal, to wash it, and to cool coal-fired power plants.

As for oil, the other major source of global CO₂ emissions, its use is fading in many industrial countries—including in the leading consumer, the United States. American oil consumption dropped 9 percent from 2005 to 2013. Part

of this is due to people driving less and part is due to the development of ever more fuel-efficient cars. Oil use can be reduced even further by increasing mass transit options and by electrifying the transport system and then powering it with solar- and wind-generated electricity. Plug-in hybrid and all-electric cars can run largely on carbon-free electricity. And since powering cars with wind-generated electricity costs roughly the equivalent of \$1-per-gallon gasoline, the market will help drive the transition to electric cars.

Oil companies are facing growth constraints on both the supply and the demand sides of the energy equation. Demand is weakening as vehicles become more efficient and as motorists look to alternatives to driving. Meanwhile, on the supply side, remaining oil reserves are less accessible than the large gushers found in decades past, making it more costly to bring new oil to market.

Among those losing out in the energy transition are the big independent oil and gas companies, including Chevron, ExxonMobil, and Shell—three of the giants in the field. These three firms combined spent a half-trillion dollars between 2009 and 2013 to expand oil and gas production, but even with this hefty investment, their production declined in 2013. Each company suffered a drop in profits that year.

The stock market has not been kind to Big Oil. While the Standard & Poor's (S&P) 500 Index rose 54 percent from the beginning of 2012 through the third quarter of 2014, shares of Chevron and ExxonMobil rose only 12 and 11 percent, respectively, and those of Shell rose just 4 percent.

The financial and logistical risks of expanding oil production are substantial. As conventional fields are depleted and the new finds are smaller or more dispersed, such as oil trapped deep beneath the ocean floor or in tar sands or shale, extracting and processing oil uses

more energy than ever before. Tapping it requires costly equipment and experienced engineers, who are becoming harder to find. In late 2013 and early 2014, Chevron, Shell, and ExxonMobil each announced cuts in capital spending. These firms may soon have to do something that large corporations are not accustomed to doing—namely, start shrinking their operations.

Oil companies are faced with soaring production costs in many situations. After spending more than \$6 billion trying to develop oil resources off of Alaska without a drop of oil to show for its efforts, Shell announced in January 2014 that it was suspending efforts to drill there. Accompanying the announcement was the release of data showing that the company's profits for the fourth quarter of 2013 had fallen by 71 percent. Its new chief executive officer, Ben van Beurden, also announced that Shell was cutting its capital expenditures from \$46 billion in 2013 to \$37 billion for 2014, a reduction of 20 percent. Then in August 2014, Shell—seemingly determined to throw good money after bad—again submitted plans to the U.S. government to drill off the coast of Alaska.

Another prime example of escalating costs is the Kashagan field below the Caspian Sea, where a consortium that includes ExxonMobil, Shell, Total, and Eni is drilling for oil. Kashagan was found in 2000—the world's largest oil discovery in 30 years, though still a far cry from the giant deposits in the Middle East. It also has become the costliest. As difficult conditions have forced a series of delays, the cost of bringing oil to market has soared from the early estimate of \$10 billion to \$50 billion spent as of late 2014. The cost is likely to climb further, illustrating yet again that the low-hanging fruit in the oil sector has already been picked.

The oil industry is much more dependent on government handouts than is generally realized. In 2013, gov-

ernments worldwide subsidized the fossil fuel industry with over \$600 billion, giving this aging industry over five times the \$120 billion that went to renewables. About half of the fossil fuel subsidies went to boost oil consumption. In effect, taxpayers' money is being used to subsidize climate change.

For the first time in their careers, oil company CEOs are being forced to lower their production goals and expectations simply because the earth has been carefully picked over during a century of intense international oil exploration and production. New oil finds are now barely sufficient to offset depletion. Failing to see the transition coming, CEOs are now behind the curve and without a game plan. They could have decided to broaden their portfolios and become energy companies, becoming part of the transition instead of being overrun by it.

Why did they adopt an ostrich-like head-in-the-sand approach by denying that an energy transition was under way? Indeed, companies like ExxonMobil and Shell have recently argued that the world will continue to remain heavily dependent on oil and that anyone who thinks otherwise is dreaming. Their solution to whatever problems that a restructuring of the energy economy poses for them has been to vociferously deny its existence while simultaneously using their financial and political muscle to fight it and maintain their relevance.

It now seems apparent that if the world takes climate change seriously, much of the oil still underground will never be used. As journalist Kieran Cooke wrote for the Climate News Network, "if any meaningful action is to be taken on climate change in the years ahead, the activities of the fossil fuel industry will have to be severely curtailed and the bulk of assets frozen, inevitably leading to a sharp decrease in corporate valuations—what some analysts refer to as a bursting of the 'carbon bubble.'"

Much of the remaining coal, oil, and natural gas will become what are called “stranded assets.”

Public attention was drawn to the concept of stranded assets in the context of climate change by Carbon Tracker, a U.K.-based nonprofit, in a 2011 report entitled *Unburnable Carbon*. Drawing on research by the Potsdam Institute, the group observed that for the world to have a chance of constraining the global average rise in temperature to 2 degrees Celsius, as the international community has agreed to do, it will need to dramatically reduce fossil fuel use. According to the latest scientific estimates, to have decent odds of staying within that 2 degree Celsius limit, the world will need to limit the CO₂ emitted from the remaining underground fossil fuels in the first half of this century to 1,400 gigatons (1 gigaton equals 1 billion tons). And since we had already released 400 gigatons of CO₂ by 2013, only 1,000 gigatons can be released between 2013 and 2050.

The CO₂ embodied in the world’s remaining proven fossil fuel reserves total 2,860 gigatons in the form of coal (roughly 65 percent), oil (22 percent), and natural gas (13 percent). If only 1,000 gigatons can be burned under the 2 degree warming scenario, that means 1,860 gigatons worth of carbon reserves, mostly in coal and oil, must be left in the ground. In this case, the reserves lose value and become stranded assets. This requires recalculation of the worth of energy companies that have included these assets in their valuations. Stockholders want to know what their energy stocks are worth.

Throughout history, economic transitions have left stranded assets in their wake. Think of the shift from whale oil to kerosene. Or from the horse and buggy to the automobile. This energy transition is no exception. It will leave behind a wealth of stranded assets. Coal companies are among the most obvious losers. As U.S. coal

consumption dropped from 1,023 million tons in 2007 to 839 million tons in 2013, scores of coal mines were idled and coal power plants were closed. In addition to unusable coal reserves, power plants, and mines, stranded assets related to the coal industry will include special railroads that once linked mines to the market as well as coal handling and storage facilities at rail depots and ports.

Coal is not alone. The giant French energy firm Total announced in May 2014 that it and its partners were putting on hold a tar sands mining operation in Alberta, Canada, one in which they had already invested \$11 billion. The cost of producing the oil was too high to warrant additional investment. This huge project could very well become a stranded asset.

Fossil fuels are not the only bastions of the old energy economy that are losing in the competition with low-cost renewables. World nuclear electricity generation, which was seen as the power source of the future a half-century ago, is declining as costs climb. Electricity from new nuclear power plants can cost twice as much as solar- and wind-generated electricity. Nuclear power will continue to fade into the past as aging plants, many too costly to maintain and operate, are closed.

The worldwide decline of nuclear electricity generation that began in 2006, then driven primarily by economics, is now also driven by fear of accidents. The 2011 Fukushima nuclear meltdown in Japan is helping to lower the curtain on the nuclear era. Immediately after Fukushima, German Chancellor Angela Merkel ordered seven of the country's oldest nuclear power plants to shut down. Two months later the government announced a complete nuclear phaseout by 2022. Germany plans to replace nuclear plants largely with wind- and solar-generated electricity. Other countries in Europe and elsewhere also reassessed their nuclear plans.

The two countries most often cited as nuclear power successes are France, which gets 75 percent of its electricity from nuclear plants, and China, the leader in building new plants. But that story is about to change. While France is completing construction of its last nuclear plant, it is in the process of developing 25,000 megawatts of wind generating capacity, of which 8,300 megawatts were already online in 2013. It is aiming to drop its nuclear share of power to 50 percent by 2025. China, which has 16,000 megawatts of nuclear generating capacity, has developed a world-leading 91,000 megawatts of wind generating capacity. Wind is leaving nuclear power in the dust.

One reason for wind's explosive growth in China is that wind farms scale up to a size not seen with coal-fired units or nuclear reactors. China is building several wind mega-complexes as part of its Wind Base program, each of which will have up to 6,800 megawatts of generating capacity. These projects are part of an effort to develop a path-breaking 200,000 megawatts of wind capacity by 2020.

While nuclear plants can take a decade to get up and running, wind farms typically go up within a year. (And a simple rooftop solar array can go up in one day.) In some parts of the world, wind is emerging as a leading component of the new energy economy. At the start of 2014, wind farms—now producing electricity in some 90 countries—had a generating capacity of 318,000 megawatts. China and the United States are currently the world leaders, with Germany, Spain, and India rounding out the top five.

These are some of the countries where the transition is under way, countries where stranded assets will become highly visible. They include coal mines, uranium mines, oil fields, oil refineries, deep water drilling rigs, oil pipelines, and gasoline service stations. In 1994, there were nearly 203,000 gas stations in the

United States, either free-standing or associated with convenience stores. As of 2013, fewer than 153,000 of these outlets remained, marking a decline of one fourth over the 19-year span. With electric or plug-in hybrid electric cars now starting to replace gasoline-powered cars, this shrinkage in the number of gas stations seems certain to continue.

One of the key questions is how fast plug-in hybrids and all-electric cars will take over the market. Chairman of the advisory board for Bloomberg New Energy Finance Michael Liebreich projected worldwide electric car sales would hit 300,000 in 2014. While this is less than 1 percent of total auto sales, he believes they are “in the process of passing through the credibility barrier.” If so, the low fuel and overall operating costs of electric cars could drive their future sales steadily upward at the expense of gasoline-powered cars, further weakening the demand for oil.

Today the United States has more than 3,000 electric utilities, but a decade from now the electricity landscape will likely look very different. Some utilities will be forced to merge; others will be dismantled as rooftop panels take over more and more of the electricity market. Coal companies in the United States will become few and far between. Eventually, deep-water drilling firms will disappear simply because oil from beneath the ocean floor will be too costly to compete.

A combination of geological, economic, and social trends is speeding up the energy transition. One social movement aiming to accelerate it further is the fossil fuel divestment campaign. Student and community groups are pressuring university endowments and pension funds to restructure their investment portfolios to eliminate fossil fuel holdings. The idea is to publicly disavow support for climate-disrupting sources of energy. Stanford Univer-

sity was among the first schools with a large endowment to announce that it would get rid of all its coal industry stocks. The Rockefeller Brothers Fund, whose original resources ironically came from John D. Rockefeller, an early oil tycoon, announced in September 2014 that it was ditching all the fossil fuel stocks in its portfolio.

As more and more investors realize that investing in coal, oil, and natural gas companies is neither consistent with their philosophy nor economically promising, the current wave of divestment is likely to continue. The Smith School of Enterprise and the Environment at Oxford University looked at the potential “stigmatization” effect the divestment campaign could have on the images and reputations of corporations. At some point, the public resistance to coal and other fossil fuels could reach a point where anyone owning, managing, or lending to a coal company would risk damage to their public image and reputation.

The divestment movement is responding to the stark reality that climate change has begun. As each new extreme weather event reminds us, avoiding a major disruption to life as we know it depends on dramatically reducing carbon emissions to keep global warming in check. This requires a total restructuring of the global energy economy. It must be done quickly. Previous energy transitions—like that from wood to coal—took decades, but the bulk of this new energy transition must be condensed into the next 10 years. The shift from coal, oil, and natural gas to solar and wind energy will be the defining event of our era.

The bottom line is that solar and wind, which are abundant and increasingly cheap, will be the foundation of the new energy economy. During the fossil fuel era, investments were short term, yielding energy only until the oil wells went dry or the coal deposits were depleted.

The discovery-development-depletion cycle was repeated over and over again. Now, for the first time since the Industrial Revolution began, we are investing in sources of energy that can last as long as the earth itself.

Data, endnotes, and additional resources can be found at Earth Policy Institute, www.earth-policy.org.