IT TAKES SEVERAL LIFETIMES TO PUT A NEW ENERGY SYSTEM INTO PLACE, AND WISHFUL THINKING CAN'T SPEED THINGS ALONG

A COMMENTARY BY VACLAV SMIL

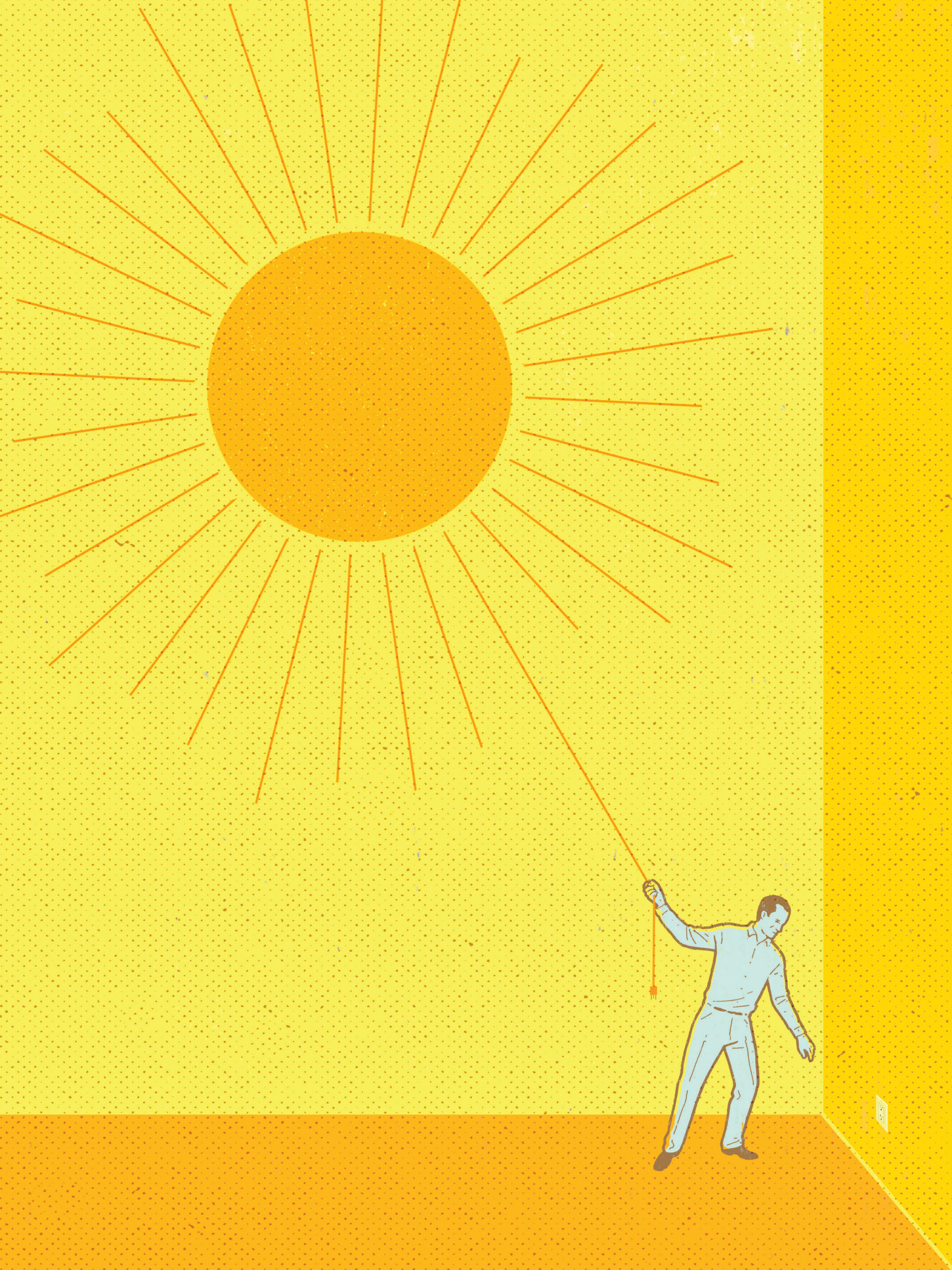
A Skeptic Looks at Alternative Energy

In June 2004 the editor of an energy journal called to ask me to comment on a just-announced plan to build the world's largest photovoltaic electric generating plant. Where would it be, I asked—Arizona? Spain? North Africa? No, it was to be spread among three locations in rural Bavaria, southeast of Nuremberg.

I said there must be some mistake. I grew up not far from that place, just across the border with the Czech Republic, and I will never forget those seemingly endless days of summer spent inside while it rained incessantly. Bavaria is like Seattle in the United States or Sichuan province in China. You don't want to put a solar plant in Bavaria, but that is exactly where the Germans put it. The plant, with a peak output of 10 megawatts, went into operation in June 2005.

It happened for the best reason there is in politics: money. Welcome to the world of new renewable energies, where the subsidies rule—and consumers pay.

ILLUSTRATION: DAN PAGE



Without these subsidies, renewable energy plants other than hydroelectric and geothermal ones can't yet compete with conventional generators. There are several reasons, starting with relatively low capacity factors—the most electricity a plant can actually produce divided by what it would produce if it could be run full time. The capacity factor of a typical nuclear power plant is more than 90 percent; for a coal-fired generating plant it's about 65 to 70 percent. A photovoltaic installation can get close to 20 percent—in sunny Spain—and a wind turbine, well placed on dry land, from 25 to 30 percent. Put it offshore and it may even reach 40 percent. To convert to either of the latter two technologies, you must also figure in the need to string entirely new transmission lines to places where sun and wind abound, as well as the need to manage a more variable system load, due to the intermittent nature of the power.

All of these complications are well known, and all of them have been too lightly dismissed by alternative energy backers and the media. Most egregious of all is the boosters' failure to recognize the time it takes to convert to any new source of energy, no matter how compelling the arguments for it may be.

An example is the 2008 plan promoted by former vice president Al Gore, which called for replacing all fossil-fueled generation in the United States in just a decade. Another is Google's plan, announced in 2008 and abandoned in 2011, which envisaged cutting out coal generation by 2030. Trumping them all was a 2009 article in *Scientific American* by Mark Jacobson, a professor of civil engineering at Stanford University, and Mark Delucchi, a researcher in transportation studies at the University of California, Davis. They proposed converting the energy economy of the *entire world* to renewable sources by 2030.

History and a consideration of the technical requirements show that the problem is much greater than these advocates have supposed.

WHAT WAS THE GERMAN GOVERNMENT thinking in 2004, when it offered a subsidy, known as a feed-in tariff, that guaranteed investors as much as €0.57 per kilowatt-hour for the next two decades of photovoltaic generation? At the time, the average price for electricity from other sources was about €0.20/kWh; by comparison, the average U.S. electricity price in 2004 was 7.6 cents, or about €0.06/kWh. With subsidies like that, it was no wonder that Bavaria Solarpark was just the beginning of a rush to build photovoltaic plants in Germany. By the end of 2011, Germany's PV installations had a capacity of nearly 25 gigawatts, which was more than a third of the global total. If you subsidize something enough, at first it can seem almost reasonable; only later does reality intervene. This past March, stung by the news that Germans were paying the second highest electricity rates in Europe, the German parliament voted to cut the various solar subsidies by up to 29 percent.

Such generous subsidies are by no means a German peculiarity. They have been the norm in the new world of renewable energies; only their targets differ. Spain also subsidized wind and PV generation before cutting its feed-in tariff for large installations by nearly 50 percent in 2010. China's benefits to its wind-turbine makers were so generous that the United States complained about them to the World Trade Organization in December 2010. In the United States the greatest beneficiary so far has been neither solar nor wind but biomass—specifically, corn used to produce ethanol.

According to the U.S. Government Accountability Office, the excise tax credit for ethanol production cost taxpayers US $6.1 billion in 2011. On top of that direct cost are three indirect ones: those related to soil erosion, the runoff of excess nitrate from fertilizers (which ends up in the Gulf of Mexico, where it creates dead zones in coastal waters), and the increased food costs that accrue when the world's largest exporter of grain diverts 40 percent of its corn to make ethanol. And topping all those off, the resulting fuel is used mostly in energy-inefficient vehicles.

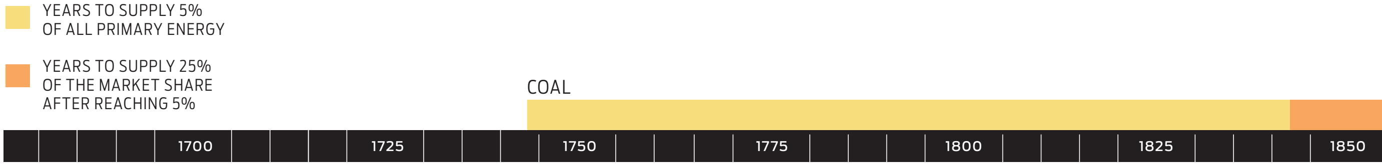
YOU MIGHT ARGUE THAT subsidies aren't bad in themselves; indeed, there is a long history of using them to encourage new energy sources. The oil and gas industries have benefited from decades of tax relief designed to stimulate exploration. The nuclear industry has grown on the back of direct and enormous R&D support. In the United States it received almost 54 percent of all federal research funds between 1948 and 2007. In France it got the all-out support of the state electricity-generating company. Without that subsidy, the industry would never have managed to get its recent share of more than 75 percent of the French electricity market. We must therefore ask whether the subsidies for alternative energy can deliver what their promoters promise.

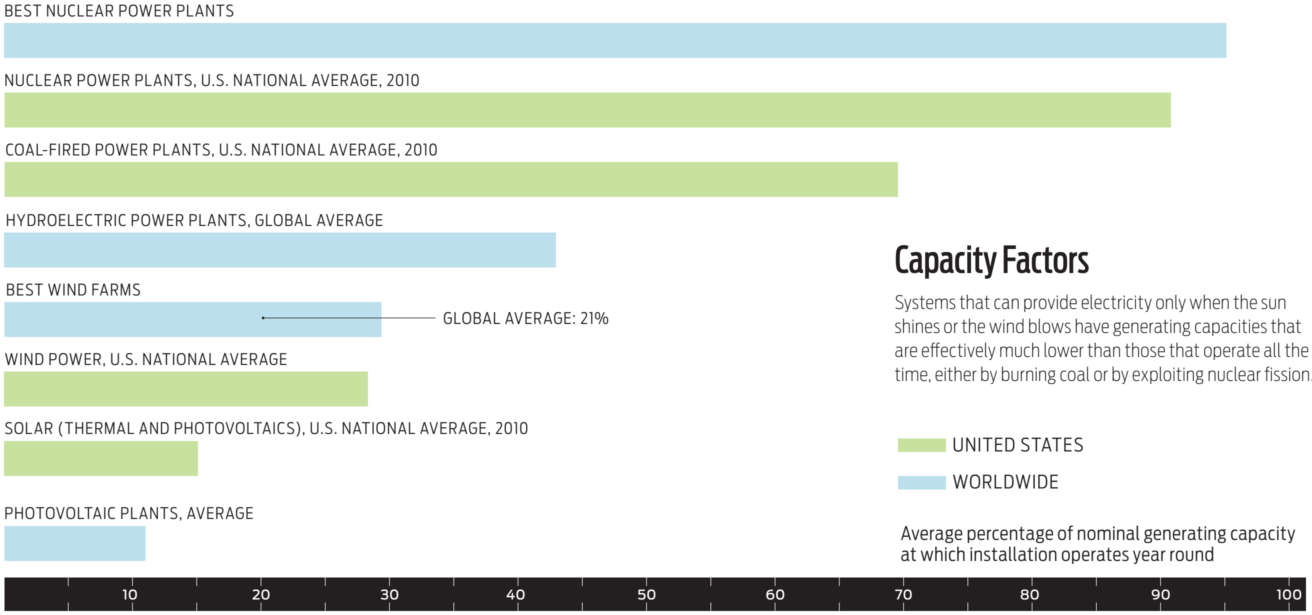
Make no mistake—they promise much. The most ardent supporters of solar, wind, and biomass argue that these sources can replace fossil fuels and create highly reliable, nonpolluting, carbon-free systems priced no higher than today's cheapest coal-fired electricity generation, all in just a few decades. That would be soon enough to prevent the rise of atmospheric carbon dioxide from its current level of 394 parts per million to more than 450 ppm—at which point, climatologists estimate, the average global

DATA SOURCE: VACLAV SMIL

Energy Sources: They Grow Up So...Slowly

An energy technology takes a lifetime to mature. In the United States, for instance, it took coal 103 years to account for just 5 percent of the total energy consumed and an additional 26 years to reach 25 percent. Succeeding technologies hit the first benchmark sooner but the second one as late or even later: In the United States, nuclear power still hasn't gotten there.





temperature will rise by 2 °C. I wish all these promises would come true, but I think instead I'll put my faith in clear-eyed technical assessments.

The matter of affordable costs is the hardest promise to assess, given the many assorted subsidies and the creative accounting techniques that have for years propped up alternative and renewable generation technologies. Both the European Wind Energy Association and the American Wind Energy Association claim that wind turbines already produce cheaper electricity than coal-fired power plants do, while the solar enthusiasts love to take the history of impressively declining prices for photovoltaic cells and project them forward to imply that we'll soon see installed costs that are amazingly low.

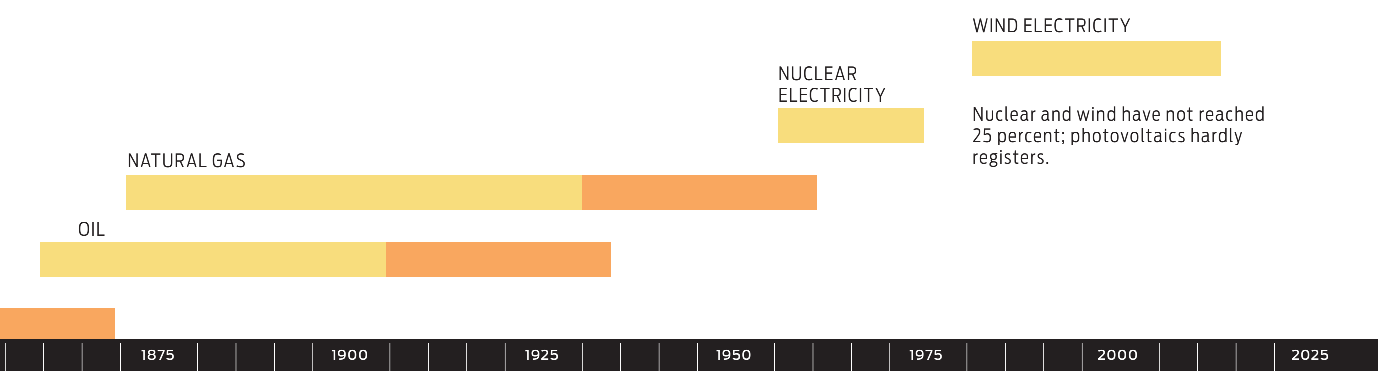
But other analyses refute the claims of cheap wind electricity, and still others take into account the fact that photovoltaic installations require not just cells but also frames, inverters, batteries, and labor. These associated expenses are not plummeting at all, and that is why the cost of electricity generated by residential solar systems in the United States has not changed dramatically since 2000. At that time the national mean was close to 40 U.S. cents per kilowatt-hour, while the latest Solarbuzz data for 2012 show 28.91 cents per kilowatt-hour in sunny climates and 63.60 cents per kilowatt-hour in cloudy ones. That's still far more expensive than using fossil fuels, which in the United States cost between 11 and 12 cents per kilowatt-hour in 2011. The age of mass-scale, decentralized photovoltaic generation is not here yet.

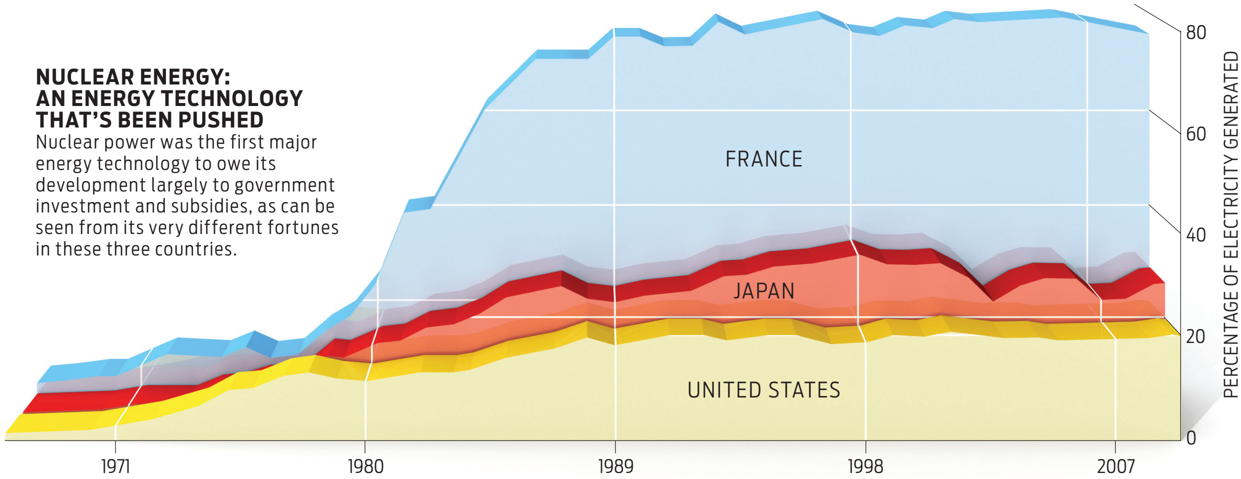
Then consider the question of scale. Wind power is more advanced commercially than solar power, but with about 47 gigawatts in the United States at the end of 2011 it still accounted for less than 4 percent of the net installed summer generating capacity in that country. And because the capacity factors of U.S. wind turbines are so low, wind supplied less than 3 percent of all the electricity generated there in 2011.

It took 30 years—since the launch of small, modern wind turbines in 1980—to reach even that modest percentage. By comparison, nuclear power had accounted for 20 percent of all U.S. generation within 30 years of its launch in 1957, and gas turbines achieved 10 percent three decades after they went into operation in the early 1960s.

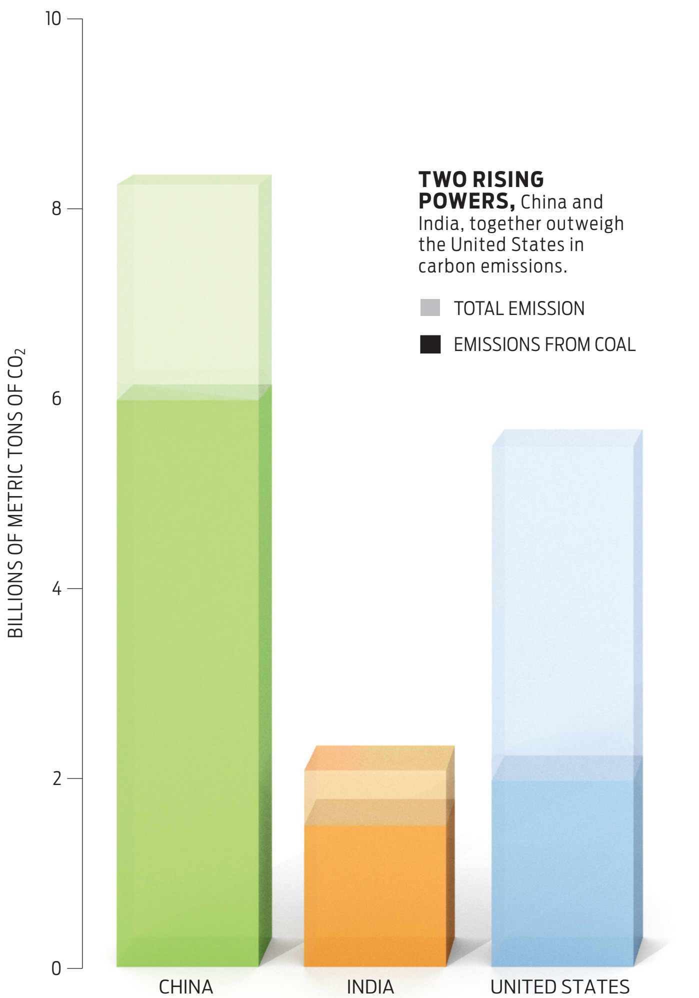
Projections of wind-power generation into the future have been misleadingly optimistic, because they are all based on initial increases from a minuscule base. So what if total global wind turbine capacity rose sixfold between 2001 and 2011? Such high growth rates are typical of systems in early stages of development, particularly when—as in this case—the growth has been driven primarily by subsidies.

And a new factor has been changing the prospects for wind and solar: the arrival of abundant supplies of natural gas extracted by hydraulic fracturing, or fracking, from shales. Fracking is uncommon outside the United States and Canada at the moment,

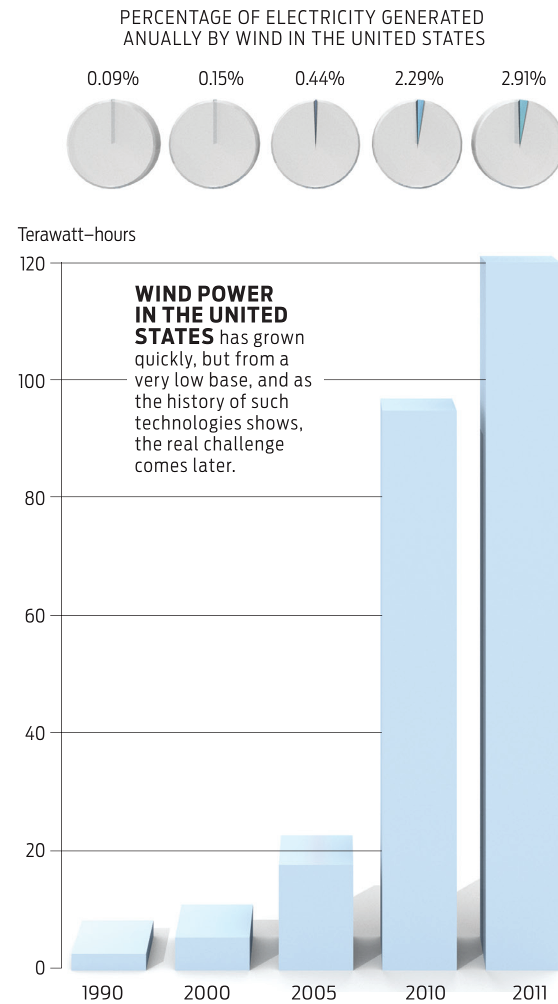




NUCLEAR ENERGY: AN ENERGY TECHNOLOGY THAT'S BEEN PUSHED Nuclear power was the first major energy technology to owe its development largely to government investment and subsidies, as can be seen from its very different fortunes in these three countries.



TWO RISING POWERS, China and India, together outweigh the United States in carbon emissions.



WIND POWER IN THE UNITED STATES has grown quickly, but from a very low base, and as the history of such technologies shows, the real challenge comes later.

but it could be used in many countries in Europe, Asia, and Latin America, which also have large shale deposits. Some countries, such as France and Germany, have banned the technology for fear of possible environmental effects, but such concerns accompany all new energy technologies, even those touted for their environmental virtues. And natural gas can be used to generate electricity in particularly efficient ways. For example, combined-cycle gas plants exploit the heat leaving the gas turbine to produce steam and generate additional electricity using a steam turbine. What's more, gas turbine modules with up to 60 megawatts of capacity can be up and running within a month of delivery, and they can be conveniently sited so as to feed their output into existing transmission lines.

THE SITING OF MASSIVE WIND FARMS is also becoming increasingly contentious—many people don't like their look, object to their noise, or worry about their effect on migrating birds and bats [see "Fixing Wind Power's Bat Problem," in this issue].

INFOGRAPHICS: BRYAN CHRISTIE DESIGN; DATA SOURCE: VACLAV SMIL

This has become a problem even for some offshore projects. For example, a vast project off Martha's Vineyard island, in Massachusetts, which was supposed to be the first offshore wind farm in the United States, has been stalled for years because of local opposition. The intermittence of the wind makes it hard to estimate how much electricity can be generated in a few days' time, and the shortage of operating experience with large turbines introduces even greater uncertainty over the long term. We'll just have to wait to see how reliable they'll be over their supposed lifetimes of 20 to 30 years and how much repair and maintenance they will require.

And, of course, you can't use wind turbines unless you're prepared to hook them to the grid by building lots of additional high-voltage transmission lines, an expensive and typically legally challenging undertaking.

Assuming that any major wind farms in the United States would be built on the Great Plains, where there is sufficient wind and land, developers would need to construct many thousands of kilometers of transmission lines to connect those farms to the main markets for electricity on the coasts. Of course, the connection challenge is easier for small countries (particularly if they can rely on their neighbors), which is one reason why Denmark became a leader in wind power.

In the United States, the problem goes beyond building new lines; it is also necessary to add them to an existing grid that is already stressed and inadequate. The most recent *Report Card for American Infrastructure,* prepared with 2009 data by the American Society of Civil Engineers, gives the country's energy system a D+, largely because the grid is relatively old and its operations are repeatedly challenged by spikes of high summer demand. Raising that grade is more than a technical challenge, because improvements in infrastructure often face entrenched political opposition—the not-in-my-backyard syndrome.

As for Europe, there may be better interconnections, but it faces other problems in converting to wind and solar power. Its economic prospects are bleak, and that will limit its ability to invest massively in new technologies. Even Germany, the strongest European Union economy and a great proponent of new energies, has a difficult road ahead; it must find a replacement for its nuclear plants after having decided, following Japan's nuclear disaster in Fukushima, to phase them out. This is no small challenge at a time when Germany is cutting its subsidies for wind and solar power and its economy is close to recession.

Government intervention is needed because the odds are poor that any private program will be massive enough to speed the conversion to new sources of energy. But even governments in the rich countries are having trouble shoring up essential infrastructure, mainly because of mounting debts. Their causes include uncontained health-care costs, trade deficits, uncompetitive manufacturing, and tax-revenue shortfalls. At the same time, government subsidies to new energy technologies haven't delivered on an often-made promise: They haven't created many new, permanent, well-paid jobs either in the EU or the United States.

THE ULTIMATE JUSTIFICATION for alternative energy centers on its mitigation of global warming: Using wind, solar, and biomass sources of energy adds less greenhouse gas to the atmosphere. But because greenhouse gases have global effects, the efficacy of this substitution must be judged on a global scale. And then we have to face the fact that the Western world's wind and solar contributions to the reduction of carbon-dioxide emissions are being utterly swamped by the increased burning of coal in China and India.

The numbers are sobering. Between 2004 and 2009 the United States added about 28 GW of wind turbines. That's the equivalent of fewer than 10 GW of coal-fired capacity, given the very different load factors. During the same period China installed more than *30 times* as much new coal-fired capacity in large central plants, facilities that have an expected life of at least 30 years. In 2010 alone China's carbon-dioxide emissions increased by nearly 800 million metric tons, an equivalent of close to 15 percent of the U.S. total. In the same year the United States generated almost 95 terawatt-hours of electricity from wind, thus theoretically preventing the emission of only some 65 million tons of carbon dioxide. Furthermore, China is adding 200 GW of coal-fired plants by 2015, during which time the United States will add only about 30 GW of new wind capacity, equivalent to less than 15 GW of coal-fired generation. Of course, the rapid increase in the burning of Asian coal will eventually moderate, but even so, the concentration of carbon dioxide in the atmosphere cannot possibly stay below 450 ppm.

PERHAPS the most misunderstood aspect of energy transitions is their speed. Substituting one form of energy for another takes a long time. U.S. nuclear generation began to deliver 10 percent of all electricity after 23 years of operation, and it took 38 years to reach a 20 percent share, which occurred in 1995. It has stayed around that mark ever since. Electricity generation by natural gas turbines took 45 years to reach 20 percent.

In 2025 modern wind turbines will have been around for some 30 years, and if by then they supply just 15 percent of the electricity in the United States, it will be a stunning success. And even the most optimistic projects for solar generation don't promise half that much. The quest for noncarbon sources of electricity is highly desirable, and eventually such sources will predominate. But this can happen only if planners have realistic expectations. The comparison to a giant oil tanker, uncomfortable as it is, fits perfectly: Turning it around takes lots of time.

And turning around the world's fossil-fuel-based energy system is a truly gargantuan task. That system now has an annual throughput of more than 7 billion metric tons of hard coal and lignite, about 4 billion metric tons of crude oil, and more than 3 trillion cubic meters of natural gas. This adds up to 14 trillion watts of power. And its infrastructure—coal mines, oil and gas fields, refineries, pipelines, trains, trucks, tankers, filling stations, power plants, transformers, transmission and distribution lines, and hundreds of millions of gasoline, kerosene, diesel, and fuel oil engines—constitutes the costliest and most extensive set of installations, networks, and machines that the world has ever built, one that has taken generations and tens of trillions of dollars to put in place.

It is impossible to displace this supersystem in a decade or two—or five, for that matter. Replacing it with an equally extensive and reliable alternative based on renewable energy flows is a task that will require decades of expensive commitment. It is the work of generations of engineers. ❑

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