Bright Future—or Brief Flare—For Renewable Energy?

Solar, wind, and other forms of renewable energy are making surprising gains as some U.S. states open their power markets to competition. But with fossil fuel prices near all-time lows, experts are split on whether alternative energy can maintain its momentum

PALM SPRINGS, CALIFORNIA—It's a warm day in late May, and the steady gale in the hills above this desert oasis drowns out the shouts of construction workers and pelts them with sand. Penetrating the howl is a rhythmic whoosh from three huge blades atop a 50-meter-tall turbine. The propeller-like blades spin in sync with 3500 other turbines, casting playful somersaulting shadows on the sand. "You almost think they have a personality," says one worker.

Crews have added more than two dozen turbines so far this year to the wind farm straddling San Gorgonio Pass. The machines embody the hopes of an era in which renewable energy providers could —after decades of unfulfilled promise—gain a sizable slice of the power market. The new turbines run for Enron Wind Corp., Green Mountain Energy Resources, and other firms that have plugged into the power grid after California last year became the first state to open its electricity market to competition. These and other energy suppliers will serve roughly 125,000 families —and companies such as Patagonia Inc.—that have chosen to pay extra to go green.

Winds of change. Wind turbines have come a long way from milling grain, but they are struggling to compete with fossil fuels.

California customers aren't the only ones turning to renewable energy from the wind, sun, rivers, geothermal vents, and even corn stalks. In Pennsylvania earlier this year, 300,000 residents chose to dump their old electricity suppliers, often switching to renewable alternatives. And last month, Texas Governor George Bush Jr. signed a bill into law that will restructure the state's power market, mandating that electric companies add 2000 megawatts (MW)—the equivalent of two large coal-fired plants—of new renewable resources over the next decade, the largest provision of its kind in any state. At least 20 more states plan to deregulate their markets soon, giving renewable companies a chance to compete for the $250 billion a year in sales racked up by utilities. And although natural gas is cheap and abundant—conjuring fantasies of boundless reserves—surveys suggest that a growing number of people may pony up extra to go green, if it means avoiding pollution that may degrade health or cause climate change.

Most consumers, however, will let their wallets do the choosing, which gives natural gas a huge advantage. For renewable energy's road ahead to be paved with gold, or at least profits, it must become cheaper—and that will require better technologies. That's a troubling prospect for the United States, which trails other countries in the research arena: Japan spends three times as much as the United States on solar photovoltaic (PV) cells, for instance. And the disparities may grow. As *Science* went to press, a Senate panel had lopped about 20% off the Department of Energy's (DOE's) proposed $446 million budget for renewable energy R&D. Congress is now negotiating a final budget, as well as considering a pivotal tax credit for wind companies and bills that would mandate nationwide electricity deregulation. Some experts contend such federal handouts are the only way renewable energies can compete with fossil fuels.

Renewables do have one powerful force pulling in their favor: concerns about climate change. Power plants may have to cut greenhouse gas emissions substantially under the Kyoto climate change treaty. But if the Kyoto deal falters and global warming forecasts become less dire, "fossil fuels are out of the woods, so to speak, and we can look forward to the fossil fuel era extending for a long time to come," says Robert Bradley Jr., president of the Institute for Energy Research, a think tank in Houston, Texas.

Still, analysts say renewable energy is catching on in states that have opened their electricity markets, as energy providers move to tap customer desire for green power. "The federal government is not the leader in electric deregulation," says Thomas Corr, manager of regulatory relations at the Electric Power Research Institute in Palo Alto, California. With consumers suddenly going green, he adds, anything could happen.

Green Revolution

The stirrings of a U.S. market have been a long time coming for renewables advocates. Although Japan and European countries such as Germany and the Netherlands have for decades strived to wean themselves of oil dependence, the United States took its first baby steps only after the 1973 oil embargo led to gasoline shortages and skyrocketing fuel prices. Around that time, DOE announced an ambitious goal to produce 20% of the country's energy from renewable resources by the year 2000, beginning with a handful of well-publicized wind turbines and the establishment of what would become the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

In the 1980s, however, the Reagan Administration slashed funding for renewables R&D, and the technologies have since hobbled along on subsidies and tax breaks. Low natural gas and coal prices have also turned alternative energy sources into underachievers in the United States. In 1997, renewable energy accounted for just 8% of total U.S. energy consumption, compared to 24% for natural gas, according to DOE's Energy Information Administration. The renewable energy that makes the largest contribution to U.S. energy production is hydroelectricity (see pie chart, p. 680), but the future of hydropower is uncertain. Environmental concerns have sparked a plan to remove four dams on the Snake River in Washington state (*Science*, 23 April, p. 574), as well as a dam on the Kennebec River in Maine. Meanwhile, geothermal energy, culled from steam trapped in Earth's crust, at best can contribute about 5% of North America's needs, according to the Geothermal Energy Association, a Washington, D.C.–based

CREDITS: (LEFT TO RIGHT) WOLFGANG KAEHLER; SEAWEST

Solar Homes for the Masses

For the sun to compete with fossil fuels (see main text), solar engineers will have to think bigger. Success is "about making square miles of [solar panels], not onesies-twosies," says Ken Zweibel of the Department of Energy's National Renewable Energy Laboratory in Golden, Colorado. "We have to make modules like carpet."

A novel Dutch effort is setting out to do just that. Near Amersfoort, the Netherlands, the NV REMU power company is leading a $13 million project to build 500 houses with roofs covered with photovoltaic (PV) panels. By the time the homes are finished next year, they should be drawing 1.3 megawatts of energy from the sun, enough to supply about 60% of the community's energy needs, with the rest coming from the power grid. The development, called Nieuwland, is the world's largest attempt at "building-integrated photovoltaics" (BIPV). "We want to demonstrate the construction of a solar energy system at the level of a precinct," says project co-leader Frans Vlek, manager of REMU's energy conversion division. "Everything has been designed from scratch."

Amersfoort gets much less sunshine than the world average of 1700 watts per square meter: Nieuwland's homes should be bathed in about 1050 watts worth of energy per square meter. From this Vlek expects they should glean as much as 128 watts per square meter, thanks to nifty PV cells that respond best to light reflected by clouds. Each kilowatt-hour from the solar panels will cost about four times more than electricity supplied by the grid, says Nieuwland co-leader Ingmar Gros, an engineer at REMU. His company and local authorities will subsidize the difference. The cost could come down with refinements in manufacturing PV cells: "We are now still at the level of the blacksmith," says Vlek.

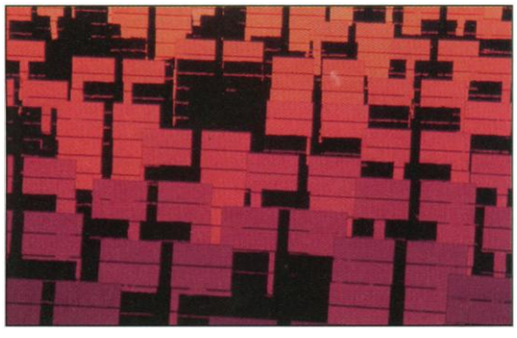
Sunshine on a cloudy day. Nieuwland is the largest effort yet to use solar energy to wean a community from the fossil fuel–fed electrical grid.

Getting more BIPV projects off the ground should help drive technical advances and perhaps make solar energy a commercial winner sometime in the next 5 or 10 years, predicts Zweibel, who heads DOE's Thin Film Photovoltaics Partnership, in which federal and corporate scientists are collaborating to develop better solar cells. One of the partnership's products, PV shingles, could spur BIPV projects in the United States, he says. For an energy source now better known, perhaps, for its failures—satellites losing contact after not having their solar panels oriented toward the sun, for instance—the rise of BIPV communities could be a much-needed success story. **–ALEXANDER HELLEMANS**

Alexander Hellemans is a writer in Naples, Italy. With reporting by Kathryn Brown.

trade association. Incinerating biomass has carved a market niche but gets low grades from environmentalists because of its contributions to air pollution.

For now the spotlight is shining brightest on wind and solar power, which contribute less than 2% of the nation's total energy. Although inching along in the United States, these energy sources are leaping ahead worldwide: Global wind and solar power capacities, in megawatts, have been growing by roughly 22% and 16% a year, respectively, since 1990, according to the Worldwatch Institute, a nonprofit public policy research organization in Washington, D.C. In 1998, for the first time in recent memory, the world's consumption of coal—a stalwart source of energy for electricity—fell 2%, partly because China cut subsidies to its coal producers.



Rising sun. Japan is expected next year to edge out the United States as the leading exporter of photovoltaic cells.

CREDITS: (BOTTOM) PETER MENZEL

Fueling the global gains of wind and solar power are impressive technical achievements. Thanks to more efficient turbine design, wind power costs about 5 cents per kilowatt-hour (kWh), less than a tenth of the 1980 price, and PV power averages less than 20 cents per kWh. (A kilowatt-hour can light a 100-watt bulb all night or run a typical hair dryer for 1 hour. In California, homeowners use about 16 kWh a day and 6000 kWh a year.) These renewable energy costs have met—or beaten—projections made by economists in the early 1980s, according to an April report from Resources for the Future (RFF), a Washington, D.C., think tank.

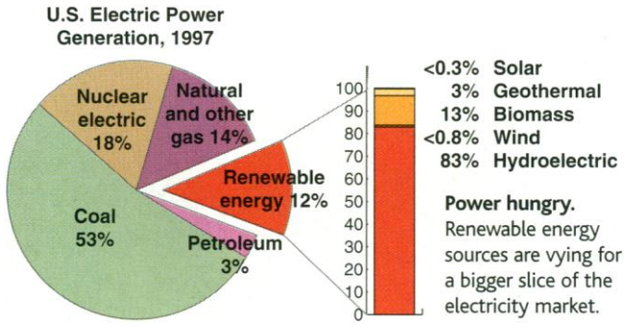
The advances allow renewables to compete with gas or coal in niche markets: mountains in the southwestern United States, for example, with lots of sun and few connections to the power grid. Mainstream markets are tougher to penetrate, largely because fossil fuel prices have also fallen since the 1970s. "The world has not stood still," says RFF economist Dallas Burtraw. Low costs for shipping coal and a surge in natural gas discoveries have helped drive these sources of electricity down to about 3 cents per kWh.

But thanks to the deregulation revolution now under way, renewables may at last have a chance to compete with fossil fuels. Renewables entered the energy market in 1978, when the Carter Administration—seeking to boost the country's energy independence—won passage of the National Energy Act, which included a bill ordering utilities to buy power from renewable energy producers at favorable rates. In an unrelated trend, big companies, eager to get electricity cheaply, began lobbying states for a competitive market that might lower power prices. On 31 March 1998, California's $20 billion power market opened, giving consumers served by three investor-owned utilities a chance to choose among eight firms, six of which offered alternative energy sources. By February 1999, some 125,000 homes and businesses had switched providers—and analysts suggest that at least half the small customers opted for some mix of renewable energy, either sold by independent power producers like Green Mountain Energy Resources or by standard utilities offering new programs. Santa Monica became the first U.S. city to switch all its public buildings to renewable power.

The new market spurred Enron to build a 22-turbine, 16.5-MW project outside Palm Springs. Installed last month, the turbines will supply enough electricity to light up 5000 California homes. The company is considering wind farms in other states that plan to deregulate, according to Albert Davies, direc-

tor of project development.

If California offered renewable energy companies a taste of success, Pennsylvania, which deregulated its market in January, is serving up a full plate. In just 2 months, 378,000 electricity consumers switched suppliers, a quarter for green power specifically. One reason for the deluge is a state law that set a default price—the electric price offered to consumers who do not switch—high enough that new companies can meet or beat it. Other states will likely follow this pricing model, offering competitive markets, says Ryan Wiser, a policy analyst at Lawrence Berkeley National Laboratory in California.



SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION

Energy rush

A boost in the U.S. market can't come too soon for renewables advocates. "We're in a technology war—and we're losing," says Scott Sklar, executive director of the Solar Energy Industries Association in Washington, D.C. Although sales of solar cells for items like highway signs, roofs, and radios jumped 21% last year, most of that growth came overseas. Over 70% of solar cells made in the United States are sent abroad, often to remote spots, like rural India, that are not connected to the grid. Since 1996, the U.S. share of the global market for solar cell products has dropped from 44% to 35%. Next year, DOE predicts, Japan—where electricity is relatively expensive—will edge ahead to lead solar PV sales worldwide. Not coincidentally, Japan will spend $240 million on solar power this year, more than triple DOE's $72 million PV research budget.

Wind sales are also booming, with Germany in the lead. Since 1998, the world's wind energy capacity has grown more than 35%, topping 10,000 MW this spring—double the amount of 3 years ago. Germany contributed a third of last year's wind gains, largely by guaranteeing wind farms access to the grid at a competitive price for the power they generate. And as U.S. companies begin building 1- or 2-MW wind turbines, European firms are exploring 5-MW machines. "In the technology race, they're at least half a step ahead of us," says Robert Thresher, director of NREL's wind technology center.

Despite lagging behind, the U.S. wind market is enjoying its own heyday. Scrambling to seize an expiring wind energy–production tax credit, companies added roughly 1000 MW of new capacity in the past year, bringing the country's total to about 900 MW. DOE hopes to sustain the momentum. Last month, Energy Secretary Bill Richardson announced a new initiative, "Wind Powering America," that aims to quadruple U.S. wind energy capacity by the year 2010, so that wind would provide enough energy to power 3 million households a year. To kick off the project, DOE will spend $1.2 million on wind turbines in 10 states. There are plenty of choices—although California hosts 90% of the country's wind turbines, 16 other states have even greater wind energy potential, according to the American Wind Energy Association in Washington, D.C.

With the energy market shake-up, even firms selling electricity from conventional sources are taking a closer look at tapping renewables. Just last month, Central and South West Corp. (CSW), a Dallas-based utility, broke ground on the largest wind facility in Texas—a 107-turbine, 75-MW farm that will generate enough power for 30,000 homes. The utility began building it after a survey suggested customers were willing to pay, on average, $5 more a month for electricity from renewable energy. "That really opened our eyes," says CSW's Ward Marshall. "Competition is coming, and we suddenly realized how out of touch we've been." **–KATHRYN S. BROWN**

Kathryn S. Brown is a free-lance writer in Columbia, Missouri.

NEWS

U.S. Supercars: Around the Corner, or Running on Empty?

A collaboration between automakers and the federal government to develop high-mileage, low-emission cars is set to unveil its first prototypes next year; observers don't expect to see consumers cruising in them anytime soon

GOLDEN, COLORADO—In a government complex nestled against the Rocky Mountains sits a torture chamber so brutal it could crack the Energizer bunny. Technicians lower their victims into a pit and repeatedly broil, freeze, or zap them with electricity—taking careful notes as life slowly drains away. But researchers here at the Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) show no remorse. They are, after all, only torturing batteries, as part of a program to create energy-efficient automobiles.

Such "supercars" are the ultimate goal of the Partnership for a New Generation of Vehicles (PNGV), an ambitious, government-industry R&D collaboration begun in 1993 by the Clinton Administration. By 2004, the effort aims to produce vehicles that travel three times farther on a liter of gas and spew far less pollutants than do current family sedans, without costing more or being less safe. Halfway into a 10-year program that has spent $2 billion on research, the three major U.S. automakers are on schedule to unveil demonstration supercars—probably diesel-electric hybrids—next year. PNGV has "provided a push to getting these cars ready for the road," says Terrey Penney, who manages NREL's hybrid-car research program.

But critics charge that PNGV is headed down the wrong road. Some claim that the program is betting on the wrong technologies by emphasizing polluting diesel engines instead of potentially cleaner technologies, such as hydrogen fuel cells. Others view the entire enterprise with distaste, asserting that carmakers and the government make unsavory bedfellows. "I don't see why industry can't build these cars themselves; this is not an appropriate area for government subsidies," says Stephen Moore of the Cato Institute, a libertarian think tank in Washington, D.C.

The ultimate goal of the effort is to reduce energy use and pollution. Some 200 million U.S. cars and trucks consume more than a third of the nation's 18 million barrel per day oil supply. Vehicles emit smog-forming hydrocarbons and nitrogen oxides and, according to DOE, release about 15% of annual U.S. emissions of carbon dioxide, a greenhouse gas. Such statistics have long motivated environmentalists to push for tougher federal fuel-efficiency standards, which currently require passenger cars sold in the United States to get at least 12 kilometers per liter (26 miles per gallon) of gas, and light trucks—including minivans and sport utility vehicles—to travel at least 9 kilometers on a liter. In 1992, however, Congress rejected a White House bid to boost the standards—calling stiffer controls costly and unnecessary—and has since barred any tinkering with the regulations.