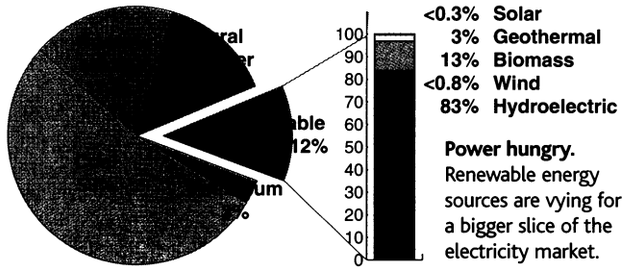
tor of project development.

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.

U.S. Electric Power Generation, 1997



Power hungry. Renewable energy sources are vying for a bigger slice of the electricity market.

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.

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION

PNGV rose from the ashes of that defeat. Changing tactics, White House officials the next year moved to enlist the industry's help in designing high-mileage cars that might do away with the need to joust over regulations. As an incentive, seven federal agencies promised to spend hundreds of millions of dollars on long-term R&D on technologies —from cheaper nickel-metal-hydride batteries to ceramic engines—that companies considered too risky to fund themselves.

While some lawmakers grumbled that the plan amounted to corporate welfare, the big three automakers—Chrysler, Ford, and General Motors—signed up, agreeing to share the results of "precompetitive" research, such as studies of how fuel burns or battery chemicals interact. The companies also agreed to match the federal investment and design one-of-a-kind concept vehicles by 2000, which they would aim to develop into production-ready models by 2004. The goal is a deceptively ordinary-looking supercar that consumers "shouldn't be able to tell apart from today's models," says Penney.

The PNGV cars may end up handling like a regular sedan, but an unfamiliar sight will await anyone who peers under the hood. Although the supercar guts are still being designed at dozens of academic, corporate, and government labs, the PNGV partners are converging on a similar approach. After sifting through hundreds of possible technologies—from gas-turbine engines to carbon-fiber frames—the partners agreed in 1997 to focus their efforts on developing a lightweight hybrid electric vehicle that uses both an electric motor and a combustion engine to turn the wheels. The program also committed to continuing promising research into fuel cells, which generate electricity directly from hydrogen (see p. 682), but concluded that hybrids were closer to fruition.

According to current hybrid schemes, a combustion engine that burns diesel fuel or gasoline will be used for highway cruising, while an electric motor will give an extra nudge up hills or when accelerating, improving fuel efficiency. The hybrid can also produce some of its own power, using braking friction to generate electricity that can be stored in a battery.

Building batteries that can withstand the rigors of life on the road, however, is one of the daunting challenges facing hybrid designers. At NREL, for instance, a team led by engineer Ahmad Pesaran is studying how the multibattery packs needed for hybrids behave under stress. Using their torture chamber, the researchers have measured how battery cells heat up and discharge electricity under various conditions. And in a kind of wind tunnel, they have discovered how subtle changes in air flow can alter the performance of battery packs, heating up some cells while cooling others. The hottest, weakest cell can reduce the entire battery pack's output.

Such research has revealed that PNGV batteries have a ways to go before they are ready for widespread use, according to a report (www.nap.edu/catalog/6485.html) released in April by a National Academy of Sciences panel. The panel, chaired by engineer Trevor Jones of Biomec Inc. in Cleveland, Ohio, says current designs are "unlikely" to meet PNGV's demanding life-span, power, cost, or safety targets.

Batteries aren't the only PNGV technology facing "extremely difficult challenges," the panel says. Perhaps the thorniest problem is getting the lightweight diesel engine that PNGV engineers want to put in the cars—called a Compression Ignition Direct Injection (CIDI) engine—to meet pollution standards. Although the CIDI engines get higher marks than gas engines for fuel economy, so

Toyota's Hybrid Hits the Streets First

TOKYO—Want to know what a U.S. supercar might look like when it debuts in 5 years? Stand on a street corner here and watch the traffic whiz by. You're likely to spot a Prius. As U.S. automakers struggle to draft blueprints for their future fuel-efficient cars (see main text), the Toyota Motor Co. has beaten them to the punch with a gas-electric hybrid that gets about double the gas mileage and spews half the carbon dioxide of similarly sized sedans.

What's more, the Prius has made it to market without the benefit of taxpayer-sponsored research and without any looming domestic requirements for zero-emissions vehicles. Toyota officials say they needed no prodding—or cash—from the government to meet rising interest in cars that are environmentally friendly and fuel efficient. One reason for that interest: Gas sells here, on average, for $0.70 per liter ($2.70 per gallon)—more than twice the price in the United States. The Prius is a big step in the right direction, says Yuichi Moriguchi, who studies transportation energy and pollution issues at the National Institute for Environmental Studies in Tsukuba.

Hybrid milestone. The first electric-gas sedan to hit the market, Toyota's Prius, has spurred the competition to come out with their own.

The Prius is no shot in the dark: Toyota spends about $3.7 billion a year on R&D and sells an electric car. But electric cars are not yet truly practical, says Hiroyuki Watanabe, a Toyota board member who oversees electric and hybrid vehicles. Battery packs, which weigh more than 300 kilograms, cost too much, give electric cars sluggish acceleration and poor handling, and can carry a car only 215 kilometers on a single charge.

By melding old and new technology, says Watanabe, "the Prius solves those problems." Under the hood is a conventional 1.5-liter gasoline engine with an electric motor, and a battery pack—about one-sixth the weight of batteries in electric cars—designed to last a car's lifetime. The gas engine charges the batteries, so they don't have to be plugged into a socket. The combination boosts fuel efficiency: When accelerating from a standstill to about 32 kilometers per hour, the Prius relies on the battery-powered electric motor. The gas engine kicks in at higher speeds, where it can operate more efficiently. Any excess power gets shunted to a generator to charge the batteries.

The result is a car that gets 28 kilometers per liter (67 miles per gallon) in a standard mixed city-highway test. And besides halving carbon dioxide emissions, the Prius spews about 90% less carbon monoxide and nitrogen oxides than comparable sedans. Toyota is hoping to improve on those numbers with the second-generation Prius, a fine-tuned version to be launched in North America in mid-2000. By the end of next year, Honda, Nissan, and Mitsubishi plan to have hybrid cars on the market in Japan.

The modest success of the Prius—Toyota has sold more than 25,000 so far—shows that consumers will buy alternative vehicles if they perform well enough at a price close to the equivalent conventional car, says Daniel Roos, a founder of the Massachusetts Institute of Technology's International Motor Vehicle Program. Like Moriguchi, Roos sees hybrid cars as "a transition technology" to bridge the gap until fuel cell cars appear. He may not have long to wait. Both Toyota and Honda have announced they intend to have virtually pollution-free fuel cell vehicles ready for sale by 2003—a year before U.S. *hybrids* are slated to roll out of labs.

–DENNIS NORMILE

CREDIT: TOYOTA

far they have flunked a key emissions test: They produce more nitrogen oxides and soot particles than proposed standards allow.

Diesel-engine designers have always faced a perplexing Catch-22. Because of the way the engines burn fuel, techniques that reduce NO_x emissions—such as recirculating exhaust gases back into the engine to be burned again—increase soot production, while reducing soot ratchets up NO_x. To address the problem, PNGV-funded scientists are tinkering with fuel variations and a filter that can sop up twice as much NO_x before it leaves the tailpipe. It's a daunting challenge: To meet NO_x standards, for instance, sulfur may have to be virtually eliminated from fuel, cut from 500 to 50 parts per million.

Critics are skeptical that CIDI engines can clean up their act. Under proposed California low-emission standards that would take effect in 2004, for instance, even CIDI-based hybrids "might be virtually illegal to sell in California," the nation's largest car market, says Jason Mark of the Union of Concerned Scientists in San Francisco. He would rather see the $40 million a year spent on the diesel program go toward developing cleaner technologies such as fuel cells.

Other critics are calling for an end to PNGV. Taxpayers "should not be forced to help private companies," says Moore, who supports the efforts of some budget hawks in Congress to trim the program. The opponents got some new ammunition last year, after Chrysler merged with Daimler, Germany's car giant, prompting Kasich and others to question whether the United States was funding research that would benefit foreign competitors. PNGV skeptics also seized on Toyota's 1997 introduction of Prius, a hybrid gas-electric car, noting that the Japanese company built the car on its own dime (see sidebar).

Such complaints have done little to erode PNGV support, however. In recent testimony before Congress, Administration officials dismissed concerns about foreign companies siphoning intellectual property from the project, and they hold up Toyota's supercar as a reminder that PNGV is necessary to keep U.S. automakers competitive. Supporters also note that low gas prices provide little incentive to invest in developing high-mileage cars. "This field would be asleep without federal funds," says a Senate aide.

But with low gas prices and no requirement to market cars based on the PNGV prototypes, observers express skepticism that supercars—at least those made by U.S. firms—will roll into showrooms anytime soon. Jokes one industry official: "You've probably got about a decade to save up for a downpayment." **–DAVID MALAKOFF**

NEWS

Bringing Fuel Cells Down to Earth

Automakers are banking on fuel cells, used to run equipment aboard spacecraft, to power the first zero-emission vehicles; the type of fuel that supplies the cells could determine how deeply these cars penetrate the market

Hydrogen has long been touted as the fuel of the future. Combine it with oxygen in a fuel cell, and it will give you electricity and a little heat, with one byproduct: water. Trouble is, the future never quite seems to arrive. Although fuel cells helped the Apollo astronauts make it to the moon, they have never made much of an impact on Earth. But if you listen to automakers these days, you may think they've seen the future—and that the future is on its way to a showroom near you.

Electricity generation gap. Fuel cells powered the Gemini spacecraft; now they are ready to hit the road, in DaimlerChrysler's NECAR 4.

In a bid to keep up with ever tighter air pollution standards, automakers are pushing hard to introduce fuel cells to mundane family sedans and pickup trucks. Virtually every major car company is now working on the technology. Early demonstration vehicles running on hydrogen and methanol are already on the road. The California Fuel Cell Partnership, a new collaboration between car- and fuel cell–makers, oil companies, and government agencies, plans to put some 50 demo cars and buses through their paces in the next 4 years. And DaimlerChrysler is so confident the partnership will like one of the early designs that it has promised to roll out 40,000 fuel cell vehicles by 2004. If fuel cells, as expected, become cheaper and can match the performance of traditional car engines, they "will be the most prominent power source in the next century," predicts Ron Sims of Ford's research lab in Dearborn, Michigan.

Those are brave words, considering that the internal combustion engine—thanks to a stream of technological advances since Henry Ford's day—has managed to beat back challenges from every upstart alternative for powering automobiles. And the fuel cell's challenge could be blunted by a bruising battle over which fuel should provide the hydrogen the cells will consume. It's a battle that could undermine the technology before it ever gets up to speed.

Engineers and clean-air experts say the simplest and cleanest option is hydrogen gas itself. But it would cost tens of billions of dollars to outfit all the filling stations in the United States to supply hydrogen—not to mention an intense marketing campaign to convince the public of the safety of a fuel still associated with the fiery demise of the Hindenburg, a hydrogen-filled zeppelin, in 1937. Car and oil companies would prefer to equip vehicles with miniature chemical factories to convert liquid fuels, such as gasoline or methanol, into hydrogen gas that can be fed into fuel cells. Critics, meanwhile, argue that the converters likely will be expensive and prone to breaking down. "Everybody is pushing their own version of the technology," says Reinhold Wurster, a fuel cell expert at LB Sustain Technique in Ottobunn, Germany.

The outcome of this battle will set the course for fuel cell technology—and perhaps alter the world's energy map—well into the next century. Because the United States uses over 40% of the gasoline produced globally, "it's the gorilla that drives the rest of the world," says John Turner, a fuel cell expert at the U.S. Department of Energy's (DOE's) National Renewable Energy Lab in Golden, Colorado. "What we do here will have a lot of influence on future energy use."

Space-to-Earth odyssey. Fuel cells didn't start nipping at the heels of traditional car

CREDITS: (LEFT TO RIGHT) NASA; DAIMLERCHRYSLER