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

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