

SPECIAL AUTO ISSUE

Slow Burn

A gallon of gas has never been more precious. Or provocative. Is it really possible to get 100—or 200 or even 500—mpg? Dan Neil puts a gallon in the tank and sees how far today's technology can take you.

Grilles That Bite

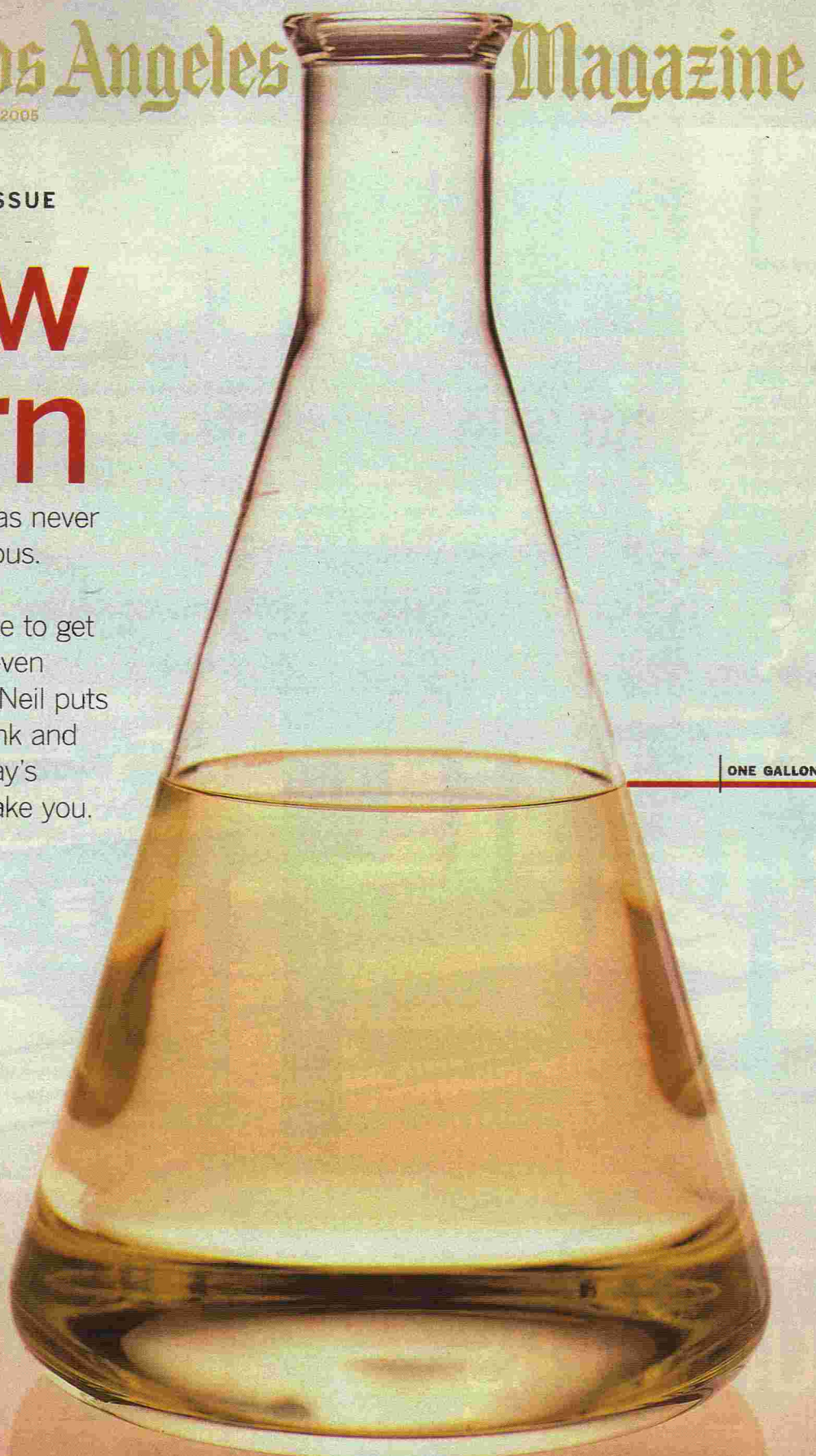
Where the Oil Change Comes With a Manicure and a Putting Green

Is Your Car Spying on You?

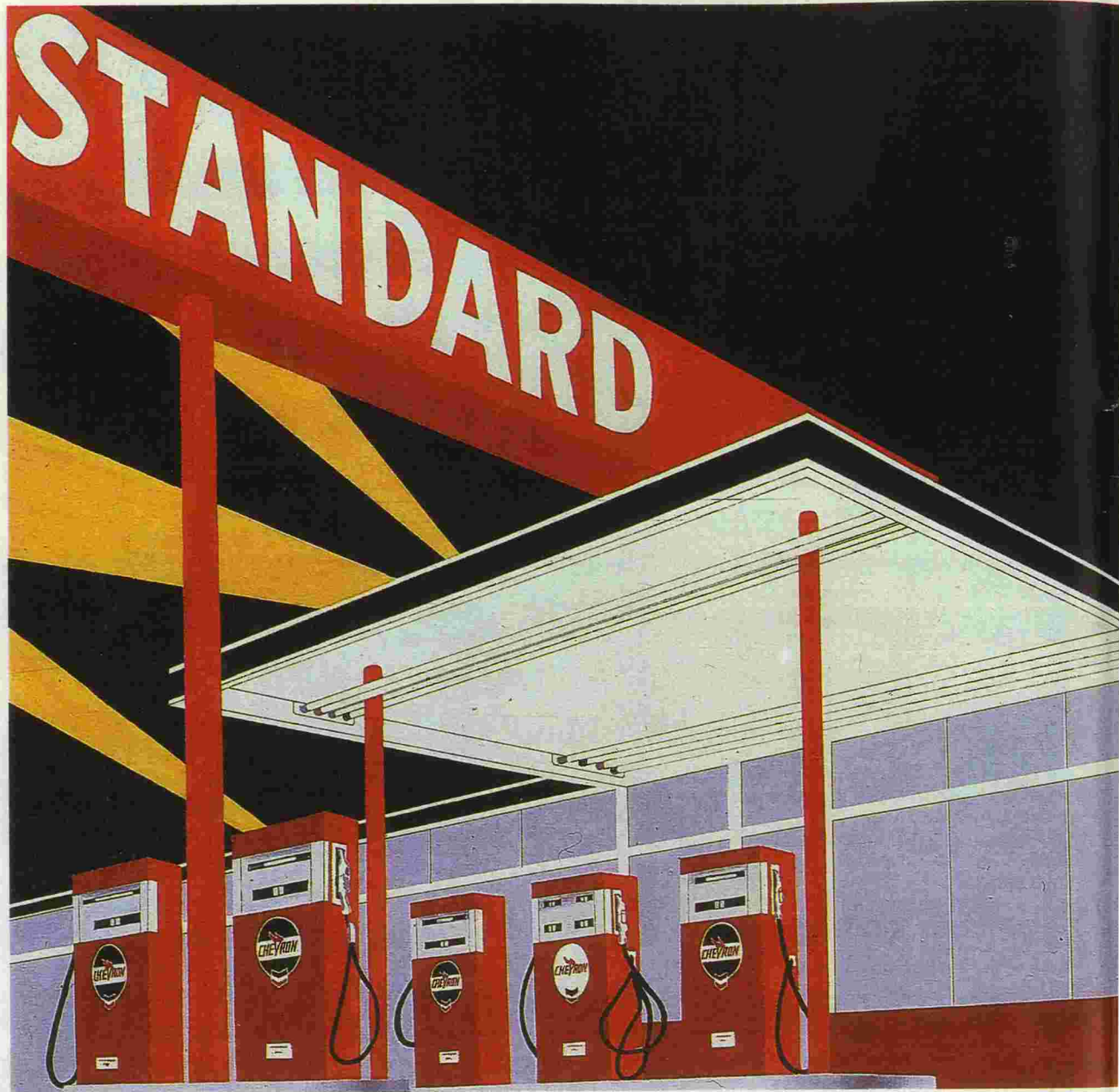
If Bettie Page Drove a Red Rocket 88...

How to Push a Lowrider's Buttons

Your House to Smokehouse: Food That's Worth a Road Trip



ONE GALLON



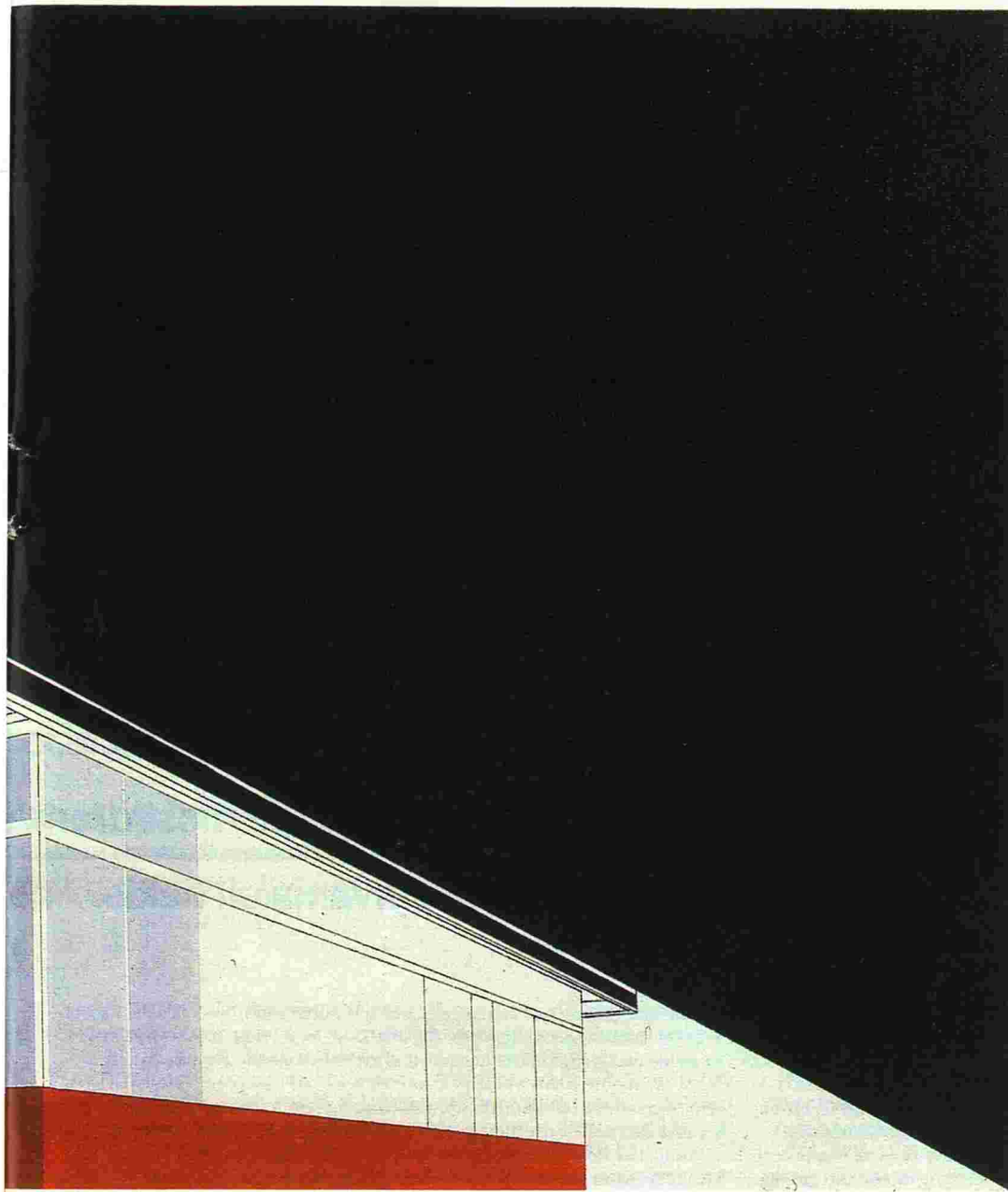
Running on Empty

A hot-rodded Prius hybrid can get extraordinary mileage from a gallon of gas—even in stop-and-go L.A. Is triple-digit mileage just around the bend?

BY DAN NEIL



CalCars
THE CALIFORNIA
CARS INITIATIVE



"Standard Station,
Amarillo, Texas,"
by Ed Ruscha, 1963.

hOW FAR CAN WE STRETCH A GALLON OF GASOLINE? OK, MAYBE it isn't a question for the ages. But with oil setting new records at more than \$60 per barrel, it seems like a good time to ask. And considering that the U.S. economy is hooked on oil imported from political nightmares such as Nigeria and Saudi Arabia, and that our petrodollars support regimes that indulge Islamic radicalism, and that global warming threatens to turn Orlando into beachfront property . . . well, maybe it is a question for the ages.

The answer: It depends. Last month at the Society of Automotive Engineers' Supermileage competition in Marshall, Mich., a team from Mater Dei High School in Evansville, Ind., got 1,836 miles per gallon. However, the winning vehicle carried only one passenger—a skinny kid—at just over 15 mph, and it looked like a body bag on wheels.

Slightly more practical, DaimlerChrysler last month unveiled a concept vehicle called the Mercedes-Benz Bionic Car, a lightweight, streamlined four-seater whose biomorphic design is based on the tropical boxfish. Powered by

a small diesel engine, the bait-shaped runabout gets 70 mpg (diesel fuel, it should be noted, has more energy content than gasoline and some emissions issues that gasoline doesn't have).

Among street-legal cars, the Honda Insight—another aerodynamic guppy and the first (1999) hybrid gas-electric vehicle sold in the United States—is the gas mileage champion, getting 60 mpg in the city and 66 mpg on the highway.

And then there's the car I'm driving: a Toyota Prius jury-rigged by a couple of wildcatting engineers in Monrovia. Equipped with an oversized battery, a home-built battery controller (and lots of home-built computer code) and a battery charger, it's a plug-in hybrid electric vehicle, or PHEV, a technology that might just represent one of the most dramatic advances in fuel stretching since the Pennsylvania oil fields. And not a minute too soon.

The idea is that owners charge up the car overnight, plugging into their garage outlet for cheap, off-peak electricity, and the stored energy covers their short-range daily driving—on average, less than 30 miles. Except that, unlike electric-only vehicles, which can range only as far as a charge allows, PHEVs can fall back

on a gas engine. Within its electrically boosted range, this car can get 100 mpg.

Or more. A lot more, if you believe a growing chorus of PHEV partisans, some of whom are famously hard-nosed conservatives born again as energy evangelists. PHEV technology has earned a rousing endorsement from the bipartisan Commission on National Energy Policy. Former Secretary of State George Shultz and former CIA director R. James Woolsey, co-chairs of a dire-sounding organization called The Committee on the Present Danger, wrote in a policy paper last year: "A plug-in hybrid averaging 125 mpg, if its fuel tank contains 85 per cent cellulosic ethanol, would be obtaining about 500 mpg [of gasoline]. If it were constructed from carbon composites the mileage could double. . . . What are we waiting for?"

Setting aside the mysteries of cellulosic ethanol and carbon composites for the moment, the idea that PHEVs can be built from off-the-shelf parts has become something of an orthodoxy. "The solution is already with us," wrote Newsweek International columnist Fareed Zakaria in March. "We don't need to reinvent the wheel or wait for sci-fi hydrogen fuel cells," New York Times columnist Thomas Friedman wrote in late June. "The technologies we need for a stronger, more energy independent America are already here."

Not so fast, says Dave Hermance, an executive engineer of Toyota and the company's guru of all things Prius. Somewhat ruefully—he isn't very happy about people hacking his beloved and delicately engineered Prius—Hermance says that while the PHEV concept has merit, it won't work with the current generation of lithium-ion batteries, which, while powerful, are both too expensive and temperamental for use in mass-production cars. Depending on their chemistry, lithium-ion batteries tend to get really hot—thermal runaway, it's called—and, as the military well knows, to ignite. "The betting line of developers is that a lithium-ion battery of sufficient cost, durability and safety is three to five years away."

Hermance isn't alone. Dr. Dan Doughty, an expert in battery technology at the Department of Energy's Sandia National Laboratory in Albuquerque, N.M., thinks high-performance lithium-ion batteries are still too buggy to warrant exuberance. Doughty also notes that electric vehicle backers' claims of super-high mileage often do not include the cost of electricity as well as gasoline. "What chaps my hide is when people know better and hold back some of that information," he says.

And so I've come to a battery-strewn laboratory and workshop in Monrovia. Greg Hanssen and Pete Nortman of the engineering firm EnergyCS are loaning me their electrically hot-rodded Prius, the kind of vehicle upon which so many angels have alighted. On the dash of their plug-in car is an LCD gauge that measures gas use to the thousandth of a gallon—"milli-gals"—and as they pass me the key I'm aware that the car embodies a lot of painstaking engineering and handiwork, hopes and dreams. I'll be careful. How far, actually, can I go on a single gallon of gas? How far can we all go?

GREG HANSEN HAS NOTHING BUT RESPECT FOR THE TOYOTA PRIUS. "NOT A day goes by that I don't think what an amazing machine this is," he says from the right seat during our orientation drive (and, yes, the meter is running).

From an engineering perspective, the Prius' neatest trick is its computer-orchestrated integration, the fluid interplay of the electric motor and gas engine. The Prius is a "strong" parallel hybrid, which means that both electric motor and gas engine act on the driveshaft through a power-splitting gearset. At low speed, the electric motor drives the car. When higher speeds or heavy acceleration are required, the gas engine and electric motor work together. Some of the engine's power is diverted to a generator that charges the battery. Also, like other hybrids, the Prius captures kinetic energy otherwise lost during coasting and braking and converts it into electricity, a technology called regenerative braking.

The result of all these dancing electrons is that the Prius extracts about twice the energy from a gallon of gasoline as a conventional car—a measure called tank-to-wheel efficiency. A lot of Prius owners have been disappointed that they couldn't get the mileage claimed by the Environmental Protection Agency—60 mpg city and 51 mpg highway—but that has more to do with the testing cycle of the EPA than with the Prius, which reliably returns 45 mpg in mixed city-highway driving.

Hanssen and Nortman want more. Given its lightweight, aerodynamic shape and state-of-the-art engineering, "the Prius is an ideal platform for a plug-in," says Hanssen.

Dan Neil is The Times' auto critic and writer of 800 Words, a weekly column for the magazine.

But it's not simply a matter of adding an extension cord. The Prius' stock nickel metal-hydride battery is relatively small—holding about 1.3 kilowatt hours of energy, enough to run a powerful hair dryer for an hour. It is also lightly taxed. The car's computers limit the battery workload in order to reduce wear and tear. To meet the California Air Resources Board requirements for advanced technology partial zero-emission vehicles—AT-PZEV, a green-car badge of honor—an advanced powertrain vehicle has to be virtually maintenance-free for 150,000 miles.

Hanssen and Nortman removed the stock battery (as well as the spare tire) from below the cargo floor and installed a 9 kWh lithium-ion battery, a King Kong version of the battery running your laptop. It's about twice as energy dense (energy-to-weight ratio) as the stock battery, but on the downside adds about 180 pounds.

Also, they hacked the car's software to let the system tap the battery (up to 21kW of instantaneous energy) to within about 20% of its capacity.

The other significant bit of hacking involved rewriting the software to allow full-electric operation at speeds up to 34 mph. In other words, at traffic jam speeds, the plug-in Prius operates as an electric vehicle.

Does it work? In the time it takes for Hanssen to explain the car's operation, we have traveled 9.09 miles around Monrovia on highway and surface streets and have used only .067 of a gallon of gas. According to the computer, that's 134.8 mpg with the same humming effortlessness as the stock Prius. So far, so amazing.

NOW CAN WE OPEN THE CHAMPAGNE AND CELEBRATE THE END OF FOREIGN oil? Not quite yet. The biggest problem, Hanssen acknowledges, is cost. The battery pack, made by Valence Technology in Austin, Texas, costs about \$1,000 per kWh. EnergyCS wants to market a Prius retrofit kit next year through its partners, EDrive

A plug-in hybrid electric vehicle, or might just represent one of the most drama the Pennsylvania oil fields. And

Systems and Cleantech of Los Angeles, which Hanssen anticipates will sell for about \$12,000, maybe less. On top of the \$25,000 or so for a Prius, that's a lot of money for all but the clingiest of tree huggers, and the work voids the Toyota warranty.

"At the moment this will appeal only to very early adopters," Hanssen says. "Not thousands, but hundreds, but they are going to be the most important because they will be the most passionate." Ed Begley Jr.'s name comes up.

Municipal fleet customers also may want the kit. EnergyCS recently got \$130,000 from the South Coast Air Quality Management District to build four more plug-in Priuses for testing.

Another issue: Deeply exercising the battery from a maximum to minimum state of charge hastens its decline. The death spiral could begin in less than six years of real-world ownership, which means the plug-in Priuses would fail the state's AT-PZEV regulation.

"If you don't have battery life, the sales price doesn't matter much," says Doughty of Sandia National Laboratory.

ROAD TEST UPDATE: I'M DRIVING WEST ON THE 210 AT 70 MPH, ON MY WAY back to my home just north of Los Angeles. The instantaneous mileage read-out in the plug-in Prius tells me I'm flirting with 100 mpg. There's a little blue light on the dashboard controller box that indicates when the gas engine kicks in. Every time the light comes on it feels like a moral failing.

BATTERIES WERE ALMOST THE DEATH OF PURE ELECTRIC VEHICLES (EVs), AND batteries may yet be their salvation. In the 1990s, automakers, trying to meet the California requirement for zero-emission vehicles, delivered thousands of EVs in the state, cars such as General Motors' EV1 and Toyota's RAV4-EV. But automakers complained that there was little demand for the vehicles, which were range limited (usually 100 miles or so) and expensive. A replace-

ment battery pack for the RAV4-EV, for example, cost \$30,000.

Also, critics contended that the zero-emissions standard was erroneous, because while electric cars themselves don't pollute, the power plants that make electricity do—a fair point. Outside the green-car circle, the zero-emissions saga was often caricatured as top-down, bureaucratic fiddling with market forces.

In 2003, the state relaxed its zero-emissions requirements, and automakers bugged out of the all-electric business. GM, Ford and Toyota gathered as many of the mostly leased EVs as they could and scrapped them, which outraged EV zealots begging to buy the cars. In April, EVERS held vigils outside GM's offices in Burbank to protest the company's crushing of EVs. A similar protest broke out on Toyota's lawn in Torrance. There is bad blood on all sides.

Plug-in hybrids give the EV movement a second life. "My goal is the vindication of the EV," says Hanssen. "A lot of people were left out in the cold with EVs. They are eager to jump on this technology."

The reason: PHEVs capitalize on the same logic as EVs. Most people on most days don't need a 300-mile range.

"Since most vehicle use is for relatively short trips," wrote Joseph J. Romm in a report for the Federation of American Scientists, "even a relatively modest all-electric range of 20 or 30 miles could allow these vehicles to replace a substantial portion of gasoline consumption and tailpipe emissions."

The second-generation Prius went on sale in 2003. Through online news groups, Prius owners soon learned that cars sold in Japan and Europe had an electric-only "stealth" mode activated by a button that was omitted in U.S.-market cars. Within weeks, technically savvy Prius owners were installing their own EV buttons to access the stealth mode.

The Prius hackers drew on the experience of Andy Frank, a professor of engineering at UC Davis, who has been working on PHEVs since about 1990.

arena," says Kramer. Mission accomplished. In late June, Illinois Sen. Barack Obama offered an amendment to the Senate energy bill that would encourage PHEV development.

Kramer was an early advocate of fuel cells—the high-tech chemical devices that make electricity from hydrogen and oxygen—and when he heard about the PHEV work by Frank, he was "enchanted." He got his own Prius in October 2003 and, like other owners, considered converting it to a plug-in.

"At that time I was listening to [Toyota's] Dave Hermance, who was telling people the Prius could not be turned into PHEV," Kramer says. "Finally I thought, to hell with it, let's do it."

In July 2004, Kramer started the Prius+ discussion group on yahoo.com, soliciting technical advice. He teamed up with Ron Gremban, another Bay Area PHEV enthusiast and engineer who was about to take delivery of his own Prius. "As soon as the Prius came out I started wondering what you could do with it as a plug-in," Gremban says. Kramer and Gremban announced they would do a pilot project in Gremban's garage, using conventional lead-acid batteries.

Kramer says that dozens of people from around the globe, including a few engineers from major car companies who preferred to remain anonymous, chipped in with ideas. Among the contributors was Greg Hanssen, who offered to build the electronics and software at a deep discount. Gremban's team completed the first prototype in November. By January, EnergyCS had built its own plug-in Prius with advanced batteries.

The car shows that the real thing is out there, says Kramer. "Nothing has to be invented."

ROAD TEST UPDATE: I'VE DRIVEN MY DAILY ROUTE TO THE OFFICE AND BACK: 11.8 miles round trip on mostly surface streets. I don't baby the throttle particularly, and the gas engine kicks in several times as I accelerate with traffic and motor up hills. Mileage: 122 mpg. So, if I were to use the Prius PHEV as my sole commuting vehicle, I would have to fill up once every 22 weeks, or once every 5 1/2 months.

KRAMER MAY WELL UNDERESTIMATE THE PHEV'S TECHNICAL CHALLENGES, but all sides agree that advances in battery technology are much closer than fuel-cell cars. It is against a backdrop of thwarted hydrogen hopes that PHEVs emerge as a more likely savior.

"We are willing to spend billions of dollars on hydrogen, something that it's not clear will ever materialize," says Gal Luft, head of the Institute for the Analysis of Global Security, another man-the-ramparts think tank focusing on energy. "It's mind-boggling that a solution far more promising [PHEV] does not get any more government support than a solution that is so iffy."

Perhaps it's a symptom of our time that energy and environmentalism were marginalized in public debate until security hawks provided political cover, as it were. With the prospect of \$4- and \$5-a-gallon gas on the horizon, the public seems freshly receptive.

"Every component of the problem is going to get worse over time," says Luft. "People are beginning to understand that the solution is already in hand. We already have technical solutions to move beyond oil in the transportation sector."

That brings the debate back around to electricity. "A lot of politicians talk about oil independence," says Luft, "and therefore we need to do nuclear, coal, solar, renewables. All of these are means to generate electricity. We don't use oil to generate electricity anymore."

"Once you start to use electricity as fuel, then all of these energy sources come back into the future of transportation," he says. "If you want all these you need to use electricity as fuel, whether as an all-electric or as a plug-in."

Nothing is simple: Using the power grid to charge automobiles strikes many as bad public policy, since coal, the dirtiest fuel, generates about 60% of America's electricity. And yet, in terms of greenhouse-gas emissions, grid-charged cars are still cleaner than their gasoline-powered counterparts, and that's particularly true in California, where we rely largely on natural gas to make electricity.

ROAD TEST UPDATE: MY WIFE AND I HAVE BEEN DRIVING AROUND LOS ANGELES for hours, desperately trying to use up 1 gallon of gasoline. Downtown. Santa Monica. Burbank. Glendale. We finally cross the 1-gallon mark near our home in Eagle Rock. I start daubing buttons on the dashboard controller. Total mileage is 73.98 miles. For the first 44.6 miles—the electrically boosted range—I got 144 mpg and used 7.092 kWh. That's about 68 cents worth of electricity and \$2.50 worth of gasoline.

I can't be sure if plug-in hybrids will work for everybody, but 4 cents a mile works for me.

PHEV, is a technology that tic advances in fuel stretching since not a minute too soon.

As the battery-related problems of pure EVs became manifest, the plug-in solution got a lot more interesting, especially to the electric utilities. Backed by the Electric Power Research Institute, private interests and government air-quality agencies, including the California Air Resources Board, Frank built a small fleet of research PHEVs using conventional vehicles such as the Ford Taurus and Explorer. He made presentations to Toyota, Renault and Detroit automakers, but so far, none have committed to building a PHEV.

Quietly, though, and in increasing numbers, automakers are experimenting. DaimlerChrysler will test a small batch of PHEVs based on the company's Sprinter van this summer. And insiders suspect that other car makers, including Toyota, secretly operate a PHEV skunkworks. "There's no question in my mind that Toyota has plans for a plug-in hybrid right now," Frank recently told the Christian Science Monitor, "but they aren't talking about it."

The guerrilla interest in PHEVs puts Toyota in an unfamiliar posture: on the defensive. "We're getting a lot of pressure from the public," says Cindy Knight, a company spokesperson. "We've shown that we have the energy chops to do it, so people say, 'Why don't we do it?'"

MILEAGE UPDATE: I'VE PULLED INTO MY DRIVEWAY AFTER A 25-MINUTE DRIVE at speeds up to 75 mph. I've traversed 18.7 highway miles (total 27.79 miles) and used .239 of a gallon of gas. According to the computer, that drops my 1-gallon average to 116.1 mpg. I feel like such a gas hog.

FELIX KRAMER IS A WASTE-NOT KIND OF GUY. "AS A KID I HATED IDLING CARS," says the founder of CalCars.org. "It seemed so inefficient." Based in Palo Alto, CalCars is a nonprofit PHEV advocacy group that acts as a networking hub for engineers, investors and entrepreneurs.

"Our first goal is to make PHEVs a contender in the national policy debate