



# PLUG-IN HYBRIDS (PHEVs)

***30 pages of flyers, magazine & newspaper articles about the technology, campaigns & organizations promoting 100+ MPG Flexible-Fuel PHEVs***

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*For more info, see links from [calcars.org](http://calcars.org) to the [About/Kudos page](#) for media coverage, [Frequently Asked Questions](#) and the [CalCars-News Archive](#) for the latest developments.*

*The California Cars Initiative (CalCars) is a non-profit startup of engineers, entrepreneurs, environmentalists and consumers that combines advocacy and technology development.*

March 31, 2006

# 10 TALKING POINTS FOR PLUG-IN HYBRIDS

**1. Why plug-in hybrids?** Today's hybrids are efficient because they don't idle, they recapture braking energy into a battery, and they use smaller engines. They're a great step forward—but they're still 100% gas-fueled. **Use a larger, rechargeable battery and you add a second cleaner, cheaper, domestic energy source: electricity.**

**2. Spend less time—and money—at the pump.** A plug-in hybrid (PHEV) is like having a second fuel tank you always use first. Fill up at home from an ordinary socket, at a cost equivalent to less than \$1/gallon. [See box]

**3. Use no gas for short trips, still have unlimited range.** If your batteries have a longer range than your commute, you'll almost never need gas. But if you forget to plug in, or take a longer trip, you have the same range as always from a gas engine—but in a clean, efficient hybrid.

**4. Neo-cons and greens agree.** PHEVs have been endorsed by an alliance of environmentalists and conservatives who see it as **the best way to cut our foreign "oil addiction."** Republicans and Democrats, Senators Hatch, Lieberman and Obama, former cabinet members Shultz and Woolsey, and recently President Bush have endorsed PHEVs. Use E85 and 100+MPG PHEVs become "flex-fuel" PHEVs getting **500 MPG** of gasoline (+ electricity + ethanol).

**5. Keep the earth cool.** Even though coal powers half the nation's electricity, driving electrically produces **45% lower greenhouse gases** than a gas-only car. This will only improve as utilities use cleaner, renewable energy.

**6. Lead car-makers out of the wilderness.** US car-makers missed the boat on hybrids; now they're playing catch-up.

**PHEVs offer one company the chance to leapfrog its competitors.** Today's batteries are good enough; they will improve and get cheaper as production increases.

**7. Save money in the long run.** In high volumes, car-makers could sell PHEVs for under \$2,000-\$5,000 more than current hybrids. Just as car buyers pay for large engines or leather seats without expecting a return on investment, early adopters will pay extra for the PHEV "green feature." The bonus? Projections based on experience from electric car fleets show **PHEVs have a lower lifetime cost of ownership than any other vehicle.**

**8. Power your house with your car.** Hybrids and PHEVs can be used as mobile generators after disasters and outages, **providing low-emission 120-volt back-up power for days** to emergency centers and individual homes.

**9. PHEVs are already here.** For 10 years, Dr. Andy Frank at UC Davis has converted **Ford/GM** cars and SUVs. **DaimlerChrysler** is now testing PHEV versions of the **Mercedes Sprinter** 15-passenger commercial van. Last year, non-profit **CalCars.org** built the first **Prius** PHEV. This year **EDrive Systems, LLC** will sell **Prius** conversions.

**10. Deploy the fleet.** Fleet buyers are leading the way on many fronts. **Plug-In Partners** is a national campaign for a large fleet buy. To slash battlefield costs and get the no-heat "footprint" of electric vehicles, the military may be a big buyer. New tax credits and company benefits can help buy down extra costs. Other incentives are on their way from all levels of government. And **CalCars** **hopes to partner with a car company**, converting an existing hybrid to meet a fleet market demand we estimate at 10,000-100,000 vehicles.

## Assumptions for Point #2:

Here's another way to think about it: At \$3/gallon of gas, driving a non-hybrid car costs 8-20 cents/mile (depending on your miles/gallon). With a PHEV, local travel and commuting can drop to 2-4 cents/mile.

**Toyota Prius:** 260 Watt-hours/electric mile at "off-peak" (overnight) electricity rate (8.8 cents/kilowatt hour) equals a cost of 2.3 cents/mile. Multiply this by the 45 MPG of a typical Prius to get the equivalent of \$1.03/gallon.

**Typical Non-Hybrid SUV:** 400 Watt-hours/electric-mile at the off-peak rate equals a cost of 3.5 cents/mile. Multiply this by the less efficient SUV's average of 18 miles/gallon to get an even better \$0.63/gallon. (SUVs get low mileage, so they improve even more!)

**The California Cars Initiative is a non-profit startup of entrepreneurs, engineers, environmentalists and consumers that combines technology development and advocacy. Our goal? To get car companies to build PHEVs. [More at www.calcars.org](http://www.calcars.org).**

## ADDING AN ELECTRIC FUEL TANK TO A HYBRID

*by Felix Kramer*

VOICES



This year, batteries and electric motors are back in the news, spurred by the popularity of gas-electric hybrids and the recognition that fuel cell cars are electric vehicles. The plug-in hybrid (PHEV), long consigned to a footnote as an interesting but unrealistic idea, may soon enter the mainstream as an automotive option.

Our organization, CalCars, took years to come up with a metaphor that drove home the PHEV concept to drivers: "It's like having a second small fuel tank that you always use first. You fill it at home with electricity, at an equivalent cost of under \$1 per gallon. Your energy is cleaner, cheaper, and not imported."

Now, support for PHEVs is coming from unexpected places: Neo-conservatives seeking rapid reductions in oil dependency. Engineers immersed in online communities. Futurists concerned about a vulnerable, centralized power grid. Ethanol advocates discovering feedstock alternatives to corn. They've joined forces with long-time supporters like renewable energy advocates, utilities with cheap off-peak power, fleet owners eager for green cars, and component suppliers seeking new markets.

One by one, objections have fallen away. One points to the complexity of using two systems, but today's hybrids use advanced technology to remove components and engineer some of our highest quality and customer-value cars. Another is that the national power grid is too dirty. But Argonne National Laboratory studies show that electric vehicles beat out gasoline vehicles on well-to-wheel greenhouse gases. It's argued that nobody is interested. Yet, journalists have jumped on CalCars' and EDrive's high-mpg conversion stories. They understand how flexible-fuel PHEVs would use almost no gasoline, although admittedly, some reporters have not factored in electricity and biofuel costs. But when the bipartisan National Commission on Energy Policy dug into the emissions numbers and looked for achievable strategies, they gave PHEVs the highest grades. Then Orrin Hatch, Barack Obama, and other Senators, along with George Schultz, James Woolsey, and other former Cabinet members, hailed the 2 to 4 cents-per-mile cost for local travel as a breakthrough this country needs.

It's been said that car companies won't build plug-in hybrids. However, DaimlerChrysler is now completing the first original equipment manufacturer PHEVs. Recent statements from Toyota and Ford indicate they are weighing the concept as well. Battery costs are claimed to be too high with their useful life too short. This remains a subject of debate. Even discounting promising materials science advances, batteries are competitive through incremental but substantial technology, production, and cost improvements, and rising gasoline prices. Plus, a new Electric Power Research Institute (EPRI) study finds no technology impediments and sees affordable batteries when produced in volume.

An overly long payback has been claimed, but this topic is fading as many auto buyers demonstrate their willingness to pay more up front for green cars. They recognize that energy security and global warming are not simply issues of "dollars and cents at the pump." Meanwhile, EPRI studies project lower lifetime costs for PHEVs than for any other type of car. PHEVs are an extendable platform that welcomes other solutions like engine efficiencies. They can be designed for any fuel type, starting with gasoline and evolving to biodiesel, cellulosic ethanol, and even hydrogen. This way, PHEVs solve both the "chicken and the egg" infrastructure dilemma and the uncertainty of predicting future technologies.

CalCars.org and our allies plan to partner with OEMs on demonstration programs. We know the auto industry can deliver. After Pearl Harbor, Detroit switched from cars and trucks to planes and tanks in a year. With PHEVs, we have the opportunity to find out how clean and efficient cars can be right now.

— *Felix Kramer is founder of the California Cars Initiative (calcars.org), a non-profit group of engineers, environmentalists, and entrepreneurs that combines technology development and advocacy for plug-in hybrid vehicles.*

*"You fill it at home with electricity, at an equivalent cost of under \$1 per gallon."*



**CalCars.org**  
The California Cars Initiative

**100+ MPG  
Hybrids!**

# We Can Tackle National Security, Jobs, and Global Warming — All at the Same Time.

**Help cut U.S.  
oil imports by  
millions of barrels  
per day.**

Get “plugged in”  
to the new **solution**  
that national  
security experts,  
environmentalists,  
unions, the press,  
entrepreneurs and  
Congress are buzz-  
ing about:

**Plug-In Hybrid  
Electric Vehicles  
(PHEVs)**

## **Plug-in hybrid vehicles (PHEVs) are the cars of the future — today**

- PHEVs use the same technology as the Toyota Prius and other popular hybrids but they have larger batteries. Drivers get the **option** of plugging in to regular electrical outlets for fuel at the equivalent of under \$1/gallon.
- Compared to current hybrids, PHEVs can **use 40-80% less gas**. They produce less greenhouse gases even on the national power grid. PHEVs that substitute cleaner, cheaper electricity from domestic sources for imported oil can help tackle two great challenges: **global warming** and **energy security**.
- PHEV sedans and SUV prototypes **exist today**. DaimlerChrysler has built a handful of commercial PHEV vans. EDrive Systems will soon be selling installed conversions for Prius. Others are at UC Davis, and CalCars built PRIUS+.
- PHEVs can help **revive car companies and save jobs**. Fleet buyers and early adopters are organizing to demonstrate demand to automakers.

## **Californians have the opportunity to lead the way**

- In a few years, PHEVs could achieve **twice the ambitious greenhouse gas benefits** of California's pioneering law (now being adopted by 10 other states and Canada) that requires 30% greenhouse gas reductions for new cars and light trucks by 2016.
- Flex-fuel PHEVs running E85 (85% ethanol) are part of an **oil independence strategy** to stop supporting undemocratic societies and putting our troops in harm's way over oil fields — while helping avoid skyrocketing oil prices, interest rate hikes and trade deficits.
- PHEVs can be part of a **solar/bio-fuel/advanced auto technology plan to create jobs**. The Apollo Alliance estimates clean energy can bring California 438,000 new jobs and \$28 billion of economic activity over just 10 years.



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Environment-  
alists, unions,  
business leaders,  
military experts,  
evangelicals and  
neoconserva-  
tives are on the  
same side.

If by 2025, all cars on the road are hybrids and half are plug-in hybrids, US oil imports would drop by 8 million barrels per day (mbd). Today, the US imports 10 mbd.

— *Set America Free Initiative including the Institute for the Analysis of Global Security, Natural Resources Defense Council and Apollo Alliance*

All of the relevant technology is at hand," said Frank Gaffney, founder of the Center for Security Policy and an assistant defense secretary in the Reagan administration. "If you're thinking about this as an environmental issue first and foremost, you're missing the point.

— *The New York Times, 4/2/05, "Hybrid-Car Tinkerers Scoff at No-Plug-In Rule"*

These vehicles are quickly becoming the darlings of strange bedfellows: both conservative hawks and environmentalists, who see such fuel efficiency as key to ensuring national security and fighting climate change.

— *Business Week, April 11, 2005, "Giving Hybrids a Real Jolt"*

When you consider that almost 78 percent of Americans live within 20 miles of their jobs, and that most car trips — commuting, shopping and dropping the kids off at soccer games — are less than 20 miles, plug-in hybrids could run solely on electricity for these types of short trips and commutes.

— *Consumer Reports, May 2005, "Plug-In Hybrids"*

And some seemingly distant options are right under our noses; consider the plug-in version of the hybrid car.

— *Wired Magazine, December 2005, "Why \$5 Gas is Good for America"*

We should have a national program to promote plug-in hybrid cars running on electricity and biofuels. Since we're not getting leadership on this from the White House or the Energy Department, I'm happy that initiatives are coming from entrepreneurial groups like CalCars.org and from state and local campaigns.

— *Robert F. Kennedy, Jr., Senior Attorney, Natural Resources Defense Council, author, "Crimes Against Nature"*

The attractiveness to the consumer of being able to use electricity from overnight charging for a substantial share of the day's driving is stunning.

— *former Sec. of State George P. Shultz and former CIA Director James R. Woolsey*

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Help promote  
plug-in hybrids

**Contact the California Cars Initiative ([www.CalCars.org](http://www.CalCars.org)), a non-profit advocacy and technology development startup formed by entrepreneurs, engineers, environmentalists and consumers to get car companies to build flex-fuel PHEVs.**

- At [www.calcars.org](http://www.calcars.org), see PHEVs' benefits, read news coverage and **get our email newsletter** with breaking developments.
- Help jumpstart the PHEV market transition with a **tax-deductible contribution** to CalCars — we can accomplish far more if we have the resources.
- Bring your contacts and ideas to a **PHEV Plan** to leverage public and corporate fleets, citizen and legislative action, to gain a partnership with a major automaker.
- Learn how someday you'll be able to "green-tune"** your hybrid to become a PHEV (like our PRIUS+ conversions).
- Spread the word:** using website resources, write letters to editors, call talk shows, post to blogs, buttonhole reporters, meet with community leaders, lobby legislators — and contact us.

**Download and distribute this and other flyers!**

[www.calcars.org](http://www.calcars.org) | [info@calcars.org](mailto:info@calcars.org)  
PO Box 61045  
Palo Alto, CA 94306  
650.520.5555

The California Cars Initiative

CalCars



**120V  
+E85**

# Plug-In Hybrids Plus Ethanol: *We Can Tackle Global Warming*

Let plug-in hybrids (PHEVs) power your commute.

Let's get the cars of the future—today.

**In California, transportation emits over 40% of greenhouse gases. Nationally, it's about 33%. Globally, it's 20%—and rising fast.**

- Compared to current hybrid cars, PHEVs use **40-80% less gasoline** and produce far lower greenhouse gas levels, even on the national power grid.
- In a few years, PHEVs could achieve **twice the ambitious benefits** of California's emissions law that requires 30% lower greenhouse gas levels from new cars.
- With "flex-fuel" PHEVs, the range-extension fuel for long-distance travel becomes E85 (85% ethanol). Once that ethanol is cellulosic, we get close to **"zero-carbon" cars**.

"Vehicle emissions are the greatest challenge that we must overcome to stabilize climate. The plug-in hybrid approach, as being pursued by CalCars, seems to be our best bet for controlling vehicle CO<sub>2</sub> emissions in the near-term."

— James Hansen, Director of the NASA Goddard Institute for Space Studies

"Moving to these highly efficient plug-in gas-electric hybrids could cut U.S. gasoline use by 85%. Even more important, it could cut automobile carbon emissions by some 85%, making the United States a model for other countries."

— Lester Brown, President, Earth Policy Institute, author, "Plan B 2.0"

"We should have a national program to promote plug-in hybrid cars running on electricity and biofuels. I'm happy that initiatives are coming from entrepreneurial groups like CalCars.org and from state and local campaigns."

— Robert F. Kennedy, Jr., Senior Attorney, Natural Resources Defense Council

"When entrepreneurs and venture capitalists focus on environmental challenges, we can create whole industries and change behaviors. Innovative campaigns like CalCars' for plug-in hybrids hold up a guiding light to steer our efforts."

— Sunil Paul, co-founder, BrightMail, Power Lunch for Bay Area Energy Entrepreneurs

"As California leads on climate change policy, the transportation sector holds the key. PHEVs are ready to be rolled out, starting with corporate and local government fleets."

— Gail Slocum, Former Mayor, Menlo Park, Climate Change Regulatory Attorney

"[Plug-in hybrids equal] more energy security and less global warming."

— Nicholas Kristof, New York Times, February 5, 2006, "100 M.P.G. Cars: It's a Start"

"[Plug-in hybrids'] potential in terms of national policy, and in terms of global warming, ought to be focused on by anyone paying over \$2 a gallon. And yes, there is an infrastructure investment. Each family would need an extension cord."

— James Woolsey, Former Director, Central Intelligence Agency

*Organizational affiliations listed for identification only*

Electric vehicles generate a third as much greenhouse gas as gasoline cars, even on the national grid (half coal). As the grid gets more renewable, like California today, these numbers will further improve.

— Argonne National Laboratory/  
Electric Power Research Institute/  
California Air Resources Board studies



February 22, 2006

## 100+ MPG Hybrids

# As Toyota Goes . . .

So I have a question: If I am rooting for General Motors to go bankrupt and be bought out by Toyota, does that make me a bad person?

It is not that I want any autoworker to lose his or her job, but I certainly would not put on a black tie if the entire management team at G.M. got sacked and was replaced by executives from Toyota. Indeed, I think the only hope for G.M.'s autoworkers, and maybe even our country, is with Toyota. Because let's face it, as Toyota goes, so goes America.

Having Toyota take over General Motors — which based its business strategy on building gas-guzzling cars, including the idiot Hummer, scoffing at hybrid technology and fighting Congressional efforts to impose higher mileage standards on U.S. automakers — would not only be in America's economic interest, it would also be in America's geopolitical interest.

Because Toyota has pioneered the very hybrid engine technology that can help rescue not only our economy from its oil addiction (how about 500 miles per gallon of gasoline?), but also our foreign policy from dependence on Middle Eastern oil autocrats.

Diffusing Toyota's hybrid technology is one of the keys to what I call "geo-green." Geo-greens seek to combine into a single political movement environmentalists who want to reduce fossil fuels that cause climate change, evangelicals who want to protect God's green earth and all his creations, and geo-strategists who want to reduce our dependence on crude oil because it fuels some of the worst regimes in the world.

The Bush team has been M.I.A. on energy since 9/11. Indeed, the utter indifference of the Bush team to developing a geo-green strategy — which would also strengthen the dollar, reduce our trade deficit, make America the world leader in combating climate change and stimulate U.S. companies to take the lead in

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From hybrids to  
flex-fuels to  
geo-greens.

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producing the green technologies that the world will desperately need as China and India industrialize — is so irresponsible that it takes your breath away. This is especially true when you realize that the solutions to our problems are already here.

As Gal Luft, co-chairman of the Set America Free coalition, a bipartisan alliance of national security, labor, environmental and religious groups that believe reducing oil consumption is a national priority, points out: the majority of U.S. oil imports go to fueling the transport sector — primarily cars and trucks. Therefore, the key to reducing our dependence on foreign oil is powering our cars and trucks with less petroleum.

There are two ways we can do that. One is electricity. We don't import electricity. We generate all of our needs with coal, hydropower, nuclear power and natural gas. Toyota's hybrid cars, like the Prius, run on both gasoline and electricity that is generated by braking and then stored in a small battery. But, says Luft, if you had a hybrid that you could plug in at night, the battery could store up 20 miles of driving per day. So your first 20 miles would be covered by the battery. The gasoline would only kick in after that. Since 50 percent of Americans do not drive more than 20 miles a day, the battery power would cover all their driving. Even if they drove more than that, combining the battery power and the gasoline could give them 100 miles per gallon of gasoline used, Luft notes.

Right now Toyota does not sell plug-in hybrids. Some enthusiasts, though, are using kits to convert their hybrids to plug-ins, but that adds several thousand dollars — and you lose your Toyota warranty. Imagine, though, if the government encouraged, through tax policy and other incentives, every automaker to offer plug-in hybrids? We would quickly move down the innovation curve and end up with better and cheaper plug-ins for all.

Then add to that flexible-fuel cars, which have a special chip and fuel line that enable them to burn alcohol (ethanol or methanol), gasoline or any mixture of the two. Some four million U.S. cars already come equipped this way, including from G.M. It costs only about \$100 a car to make it flex-fuel ready. Brazil hopes to have all its new cars flex-fuel ready by 2008. As Luft notes, if you combined a plug-in hybrid system with a flex-fuel system that burns 80 percent alcohol and 20 percent gasoline, you could end up stretching each gallon of gasoline up to 500 miles.

In short, we don't need to reinvent the wheel or wait for sci-fi hydrogen fuel cells. The technologies we need for a stronger, more energy independent America are already here. The only thing we have a shortage of now are leaders with the imagination and will to move the country onto a geo-green path. □

**CALIFORNIA CARS INITIATIVE**  
**100+ MPG HYBRIDS!**  
**WWW.CALCARS.ORG**

BusinessWeek

## Giving Hybrids A Real Jolt

### A plug-in gas-electric vehicle may be key in saving fuel and cutting pollution

BusinessWeek April 11, 2005  
see [www.calcars.org](http://www.calcars.org)  
for links to article and graphics

IS THERE A CAR THAT CAN CUT America's oil imports to a trickle, dramatically reduce pollution, and do it all with currently available technology? Greg Hanssen thinks so. His company has already built one such car—a converted Toyota Prius that gets 100 to 180 mpg in a typical commute. Andrew A. Frank thinks so, too. The University of California at Davis professor has constructed a handful of such vehicles. His latest: a converted 325-horsepower Ford Explorer that goes 50 miles using no gas at all, then gets 30 mpg. “It goes like a rocket,” he says.

These vehicles are quickly becoming the darlings of strange bedfellows: both conservative hawks and environmentalists, who see such fuel efficiency as key to ensuring national security and fighting climate change. Reducing dependence on the turbulent Middle East “is a war issue,” says former CIA Chief R. James Woolsey, who calls the cars’ potential “phenomenal.”

What’s the secret? It’s as simple as adding more batteries and a plug to hybrids such as the Prius. That way, the batteries can be charged up at any electrical outlet—letting this so-called plug-in hybrid travel 20 to 60 miles under electric

sponsored by the Electric Power Research Institute (EPRI), several utilities, government agencies, and DaimlerChrysler, the carmaker is building a fleet of up to 40 PHEV delivery vans.

Four will be coming to U.S. cities for tests starting in June. Research at EPRI predicts that the plug-in vehicles, based on DaimlerChrysler’s popular Sprinter van, will get a gas mileage boost of at least 50% over conventional vans.

EPRI Program Manager Robert Graham is convinced that Toyota already has prototype plug-ins running. Toyota says no. “We keep looking at the concept, and at some point it might be feasible, but it isn’t there yet,” says David Hermance, Toyota’s executive engineer for environmental engineering. For its part, DaimlerChrysler sees its van project “as a great opportunity to

develop the vehicles we foresee in the future,” says technology spokesman Nick Cappa. The company’s first hybrid offerings will be conventional, but plug-ins might eventually be an option, he says.

Auto makers’ reluctance to plunge in quickly frustrates evangelists like Professor Frank. “If it is such a damn good idea, why are the car companies not adopting plug-ins?” he asks. “The simple answer is that they don’t want to change what they are making.” But it’s also not clear how much more people will pay for the cars. Hybrids are estimated to cost \$2,000 to \$5,000 more than conventional cars to make, and the larger batteries for plug-ins would add several thousands dollars more.

#### “UNCERTAINTY”

PROponents predict costs will drop with high-volume production. But making the investment to build hundreds of thousands of PHEVs is a giant risk, especially since there are competing approaches to higher fuel efficiency, such as advanced diesels or upgraded gasoline or hydrogen engines. Plus, no one knows if gas prices will rise enough to spur demand for high mileage cars. “All these technologies are great. But there is a tremendous amount of uncertainty,”

power alone. Since most Americans drive fewer than 30 miles a day, such a car could go months without visiting the filling station (table). “The only time you would have to gas up is when you go out of town,” says Felix Kramer, who founded the nonprofit California Cars Initiative to promote plug-ins. Run the internal combustion engine on a blend of gasoline and biofuels like ethanol, and it would use almost no oil products at all. “That changes the world,” says Frank J. Gaffney Jr., president of the Center for Security Policy.

#### “TRIVIAL MATTER”

PROFESSOR FRANK, 72, first began thinking about a plug-in hybrid electric vehicle (PHEV) years ago. “But now all the pieces are here,” he says. Toyota Motor Corp. has solved the big engineering problems with the Prius, so “it’s a trivial matter to make a plug-in,” says Joseph J. Romm, a former Energy Dept official. Greg Hanssen and his colleagues at EnergyCS, for example, replaced the Prius’ existing 1.3-kilowatt-hour nickel metal hydride battery with an advanced 9-kWh lithium ion battery pack. They hope to offer a conversion kit to Prius owners. The weight penalty? About 170 pounds.

Car owners might not want to try this at home. Such a conversion will probably void Toyota’s warranty. But big companies are building their own vehicles. In a project

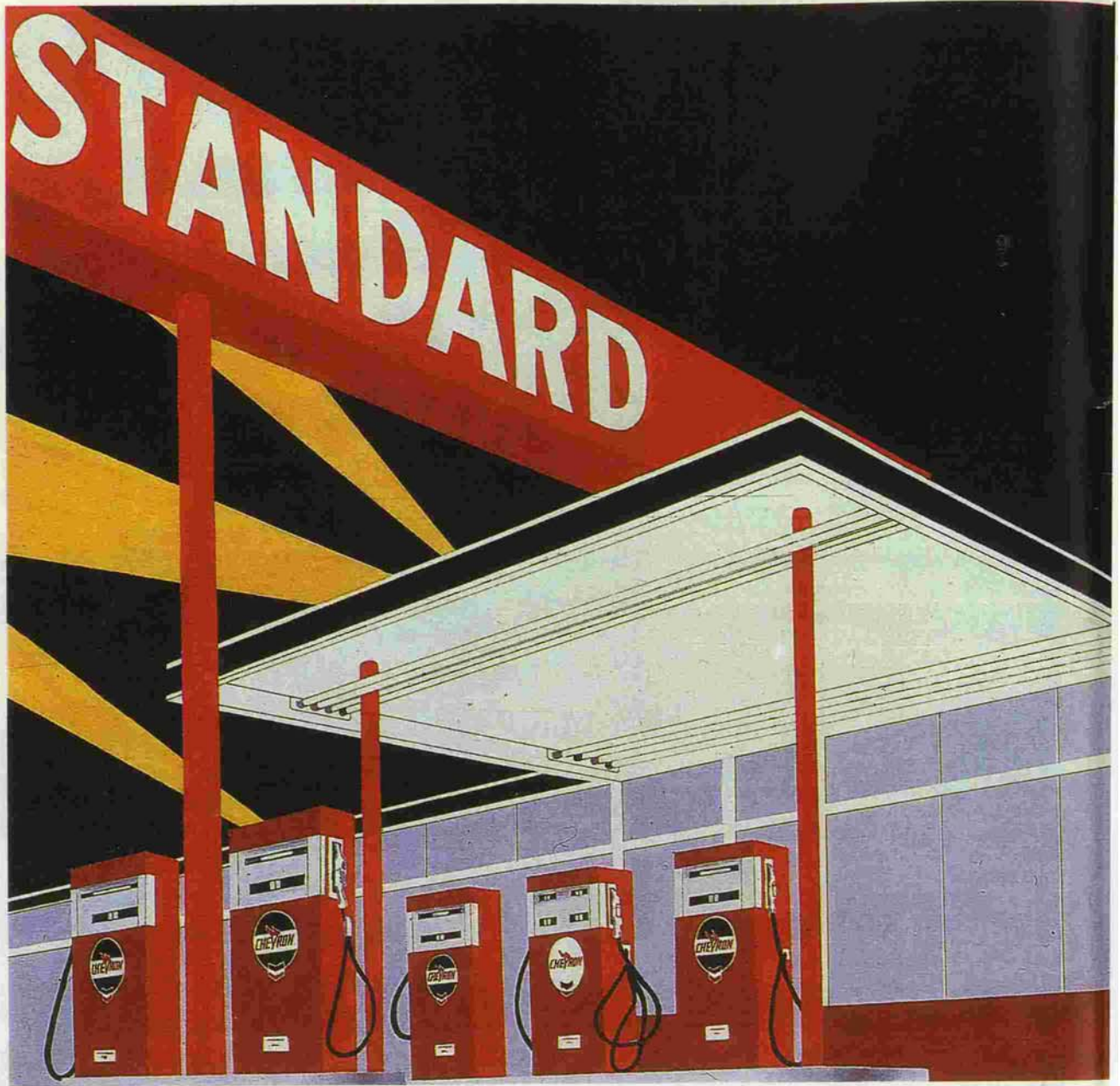
says David E. Cole, chairman of the Center for Automotive Research.

That’s why some plug-in advocates are striving to create a market for auto makers. On Mar. 3, the city of Austin, Tex., passed a resolution calling for rebates for plug-in purchases and asking local businesses and governments to buy the vehicles. “We can reduce costs [of driving] to consumers, improve the air quality, and increase revenues to the city,” says Roger Duncan, deputy general manager of city-owned Austin Energy.

Ordinary hybrids such as the Prius are already popular. Moving to plug-ins is the next logical step—and the idea is getting high-level endorsements. Last December, the bipartisan National Commission on Energy Policy tapped plug-ins as a key part of its energy strategy. The Set America Free coalition, a group of conservatives and enviros, is pushing for \$2 billion in incentives, pointing out that “if all cars on the road are hybrids and half are plug-in hybrid vehicles, U.S. oil imports would drop by 8 million barrels per day.” Americans will be “gassing up” their cars with electrons, predicts Romm: “I would bet the mortgage on it.” But not quite the whole house. ■

—By John Carey in Washington

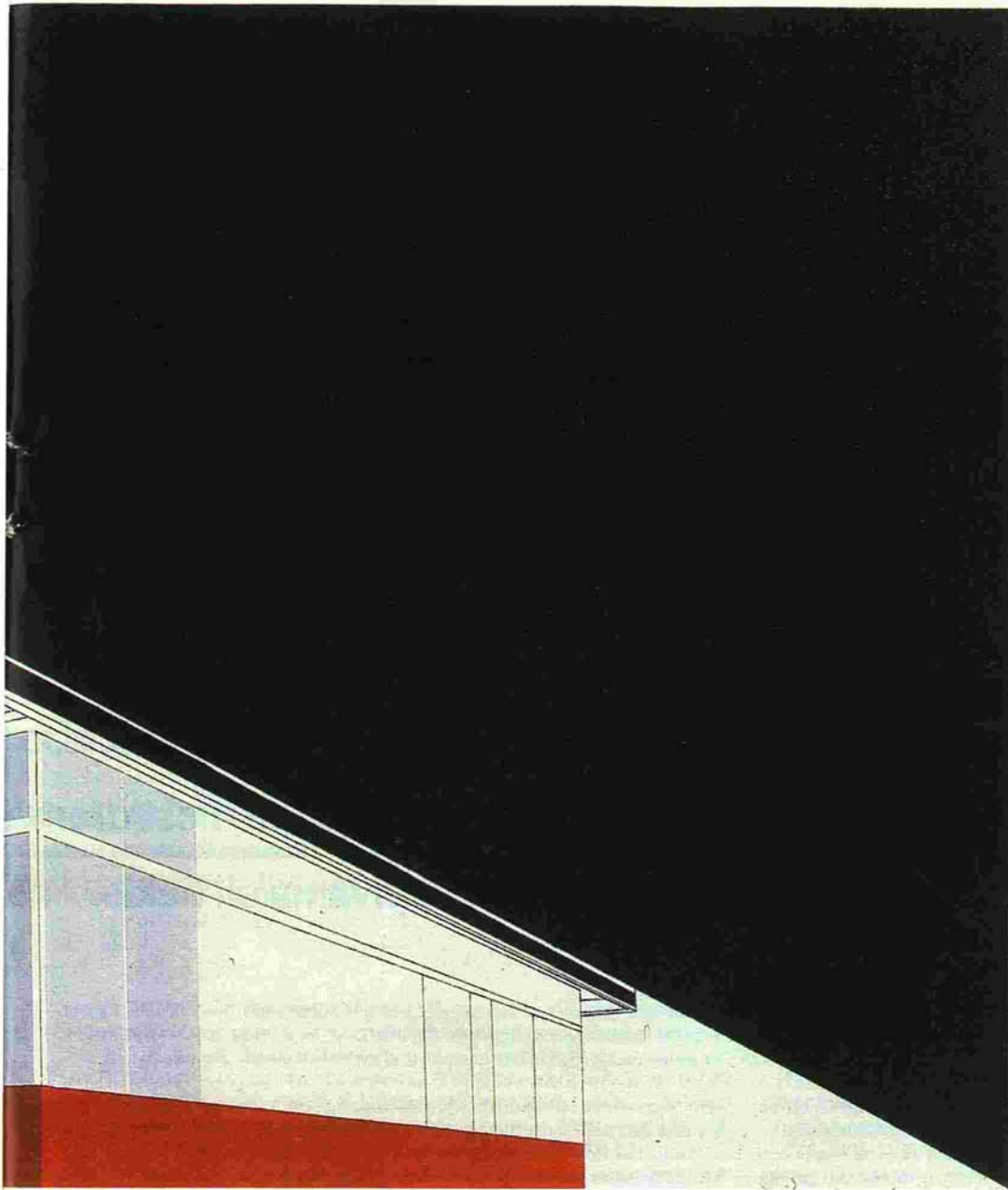




## Running on Empty

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



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

**h**OW 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 HANSSEN 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



# Breaking That Dirty Oil Habit

AN UNLIKELY ALLIANCE OF HAWKS, DOVES AND GREENS HAS A PLAN TO HELP AMERICA GUZZLE LESS GAS. COULD IT WORK?



BY UNMESH KHER

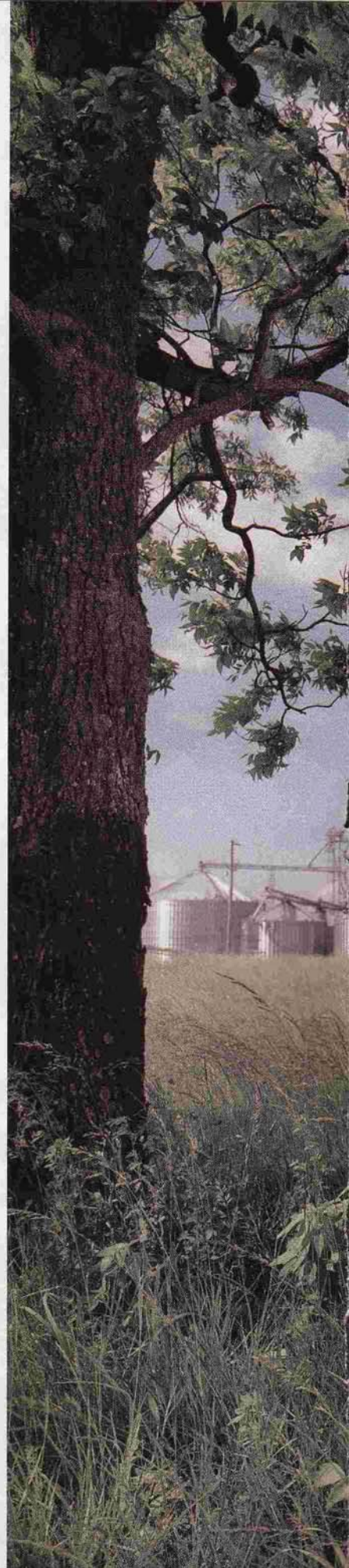
A Republican loyalist and canny political strategist, C. Boyden Gray has been quite busy lately. The former White House counsel to the first President Bush heads up the Committee for Justice, an advocacy group that has worked closely with the White House to push Bush 2's most controversial judicial nominees through the Senate. John Podesta has been busy too. The former chief of staff to President Bill Clinton who today leads the liberal Center for American Progress has worked hard to foil Gray.

Yet even as the two party generals square off in a battle that has roiled the Senate, they manage



◀ Joining forces: From left, National Wildlife Federation CEO Larry Schweiger, conservative activist Gray, U.N. Foundation chief Tim Wirth and the U.N.-bashing Gaffney are working together on energy policy

▶ Mick Henderson, left, with Kentucky farmers, is producing the fuel that could help the 500-m.p.g. car become a reality







STEPHANIE DIANI FOR TIME

## ◆ IN CALIFORNIA, HANSSSEN'S FIRM WILL SOON SELL A KIT THAT CONVERTS A TOYOTA PRIUS INTO A PLUG-IN

to find common cause: energy policy. "Boyden and I agree on virtually nothing," says Podesta, "but we do agree on this: the security of the country depends on a whole new generation of vehicles and fuels."

What does alternative energy have to do with national security? Gray and Podesta are part of an unlikely alliance of neoconservatives, farmers and union and environmental leaders who want to wean the U.S. of its oil habit—some for purely green reasons (to stave off global warming), but others for the sake of cutting U.S. dependence on the volatile Middle East. And they have some radical ideas about how to do it. "We live in a world in which a terrorist attack in the Middle East could push oil well over \$100 a barrel and send the world economy into a tailspin," says former CIA Director James Woolsey, now a vice president at consulting firm Booz Allen Hamilton. One organization he belongs to, the Energy Future Coalition, shot off a letter last month to Pete Domenici, chairman of the Senate Committee on Energy and Natural Resources, calling for a federal investment in alternative fuels and advanced automobile technology. But it's another arm of this movement, the Set America Free alliance (which also counts Woolsey among its members), that has identified a Holy Grail of sorts. Co-founded by Frank Gaffney, the neoconservative chief of the Center for Security Policy, the group is touting the idea of a car that gets 500 m.p.g. of gasoline.

As oil prices have soared in recent years, there has been increasing attention on renewable-energy sources such as wind and solar power. But even if those sources are expanded, they would not change the U.S.'s fundamental dependence on foreign oil and its derivative, gasoline, to which our car-obsessed culture is addicted. Unless we could plug in our cars and charge them off the electrical grid instead of filling them up at the pump, all those options would leave us as hooked on gas as ever. And while pure electric-car technology has been around for years, it is plagued by a crucial problem: a lack of range.

Gaffney and his cohorts have envisioned a clever solution: a

hybrid car that combines gas-free plug-in technology with the boost of made-in-the-U.S., ethanol-based fuel to give it range. The plug-in hybrid could run for short distances on batteries charged by the same grid that powers our home appliances. On longer drives, it would use a fuel mix of 80% ethanol—alcohol, in the U.S. made mainly from corn—and 20% gas. Given that half the cars on the road travel fewer than 20 miles a day, such hybrids would travel mostly on grid-charged battery power. The rest of the time, those plug-in hybrids would run primarily on alcohol, not imported gas.

A 500-m.p.g.-of-gas car may sound like a pie-in-the-sky dream. But in fact, it is technologically possible. Green-car enthusiasts in California are experimenting with innovative plug-in technology, while DaimlerChrysler will soon be testing its own plug-in van. And ethanol has long been used as a fuel. Indeed, Domenici's committee last month adopted a measure in the energy bill requiring gasoline

refiners to increase the ethanol they use each year to 8 billion gal. by 2012, up from 5 billion gal. mandated by the House.

That's bound to raise hackles. Ethanol has always been controversial (*see box*). Most car companies, meanwhile, have little interest in any electric vehicles beyond the standard hybrid because they consider them too costly and limited in range for American tastes. "I don't think [electric cars] will ever be a significant percentage of the vehicles out there," says Sam Shelton of the Georgia Institute of Technology, citing such obstacles.

It would be too easy, though, to dismiss the 500-m.p.g. movement as all hype and hope. After all, not long ago, hybrids like the Toyota Prius sounded like a laughable idea. These days they are being snapped up by consumers more than willing to pay a premium. So before this pipe dream is summarily cast aside, it's worth exploring. Could it be that the motley coalition of tree huggers and hawks is on to something?

### PITCHING PLUG-INS

MEET GREG HANSSSEN, A PARTNER IN A SMALL BATTERY-prototype testing firm in California called EnergyCS. Hanssen was approached last year by Felix Kramer for help in building a dashboard monitor for a Prius that he and CalCars, his group of plug-in advocates, had converted into a crude plug-in. (The original Prius' batteries charge up when the car brakes.) Hanssen was inspired. He enlisted the support of another privately held firm, Clean-Tech, to devise a more sophisticated version of the plug-in Prius. Hanssen recently showed off his prototype at the 2005 Tour de Sol, a green-car race in Saratoga Springs, N.Y., where it didn't win but did deliver a fuel economy of 102 m.p.g. over a 150-mile course. The cost of charging the batteries? A buck.

EnergyCS and Clean-Tech have launched a start-up called E-Drive Systems, which plans to sell by next year kits to convert the Prius into a plug-in (though the modifications will void the warranty). At speeds below 35 m.p.h., Hanssen's Prius sails along on its 18 lithium batteries for up to 30 miles at a go—well within



the range envisioned by Gaffney. The conversion cost isn't cheap: \$15,000, which Hanssen hopes to cut to around \$10,000. "It won't pay for itself in gas savings," Hanssen admits, "but neither does the Prius. People will do this for other, philosophical and environmental reasons."

Toyota isn't exactly jumping on the bandwagon. "Customers," says Ed LaRocque, Toyota's national manager of advanced technology, "are not telling us plug-in hybrids are something they'd like to see at no cost, let alone what we estimate would be an additional \$15,000." Other car companies, including Ford and General Motors, seem to feel the same way. But DaimlerChrysler sees the field differently. It has spent millions to modify a handful of gas and diesel-powered Mercedes Sprinter vans into plug-ins, which will be tested as early as this fall by commercial partners in the U.S., such as utilities. Chrysler says the vans can run 20 miles on batteries charged both via the socket and, like the Prius, by braking. Cost will matter, says Rolf Bartke, head of the Mercedes-Benz van division. "In the end it should be viable and economic for our customers." Bartke says the aim is to bring the battery cost down below \$10,000 within four years.

Several U.S. utilities are supporting the technology. Plug-in cars would open a new market for electricity at night, when utilities have excess capacity. In fact, the Electric Power Research Institute in Palo Alto, Calif., helped build the plug-in Sprinter. Ed Kjaer, director of electric transportation at Southern California Edison, argues that plug-ins represent a natural evolution of hybrid technology, which today essentially burns gas to generate electricity. "The more hybrids are sold," he says, "the stronger the business case will become for the electric vehicle."

## ETHANOL DREAMS

DAVID WIMPY, 49, CULTIVATES 800 ACRES OF CORN AND OTHER crops in Kentucky's hilly Amish country. As a member of the 2,300-strong Hopkinsville Elevator Cooperative, he is also part owner of the hottest new thing to hit town, Commonwealth Agri-Energy, an ethanol plant that started up a year ago in a stream-fed rock quarry a mile south of his land. The cooperative has a 94% stake in the \$32 million plant, which has made an estimated \$40 million in sales over the past year from ethanol and its by-products. Plant manager Mick Henderson says he expects that investors will get returns better than 13%. "Ethanol is a win-win for consumers, farmers and for the country," says Wimpy.

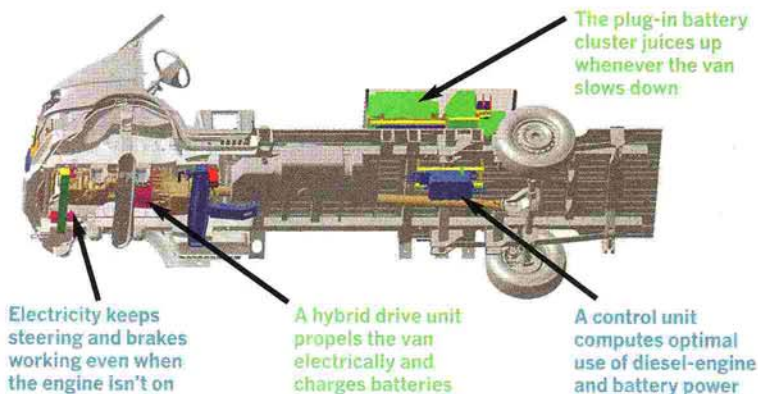
If electricity provides half of the 500-m.p.g. dream, ethanol provides the other: an alternative to gas. Hopkinsville's ethanol experience is hardly unique. Since 2001, 26 plants have been built in the U.S., bringing the total to 87, as political support for the fuel has grown. Roughly 40% of the plants are owned by farmers, although a single corporation, Archer Daniels Midland, retains a 25% share of the market.



## A Plug-In Play

This prototype Mercedes Sprinter runs on diesel fuel—and on socket-rechargeable batteries

◀ DaimlerChrysler has converted some Sprinter vans into plug-in hybrids



Today's ethanol boom has nothing to do with Gaffney & Co.'s extreme solution, but if ethanol use were to evolve into the mainstream, it would multiply the plug-in's gas savings. Gaffney's group calculates that if by 2025 all cars are hybrids, half of them plug-ins and all of them running on an 80% ethanol blend, U.S. gas imports could drop from the projected 20 million bbl. a day to 8 million bbl. But today it is not national security that drives ethanol demand so much as environmental regulation. Refiners buy ethanol because it helps gasoline burn more cleanly—and it is one of two additives the government requires polluted cities to use to cut down on certain tailpipe emissions. Because the traditional additive, a toxic substance called MTBE, tends to pollute groundwater, many states are opting for ethanol.

But there are huge debates about ethanol's economic via-

## Weighing the Benefits

THE DEBATE STILL RAGES OVER ETHANOL FUEL

■ **PRO** Wholesale ethanol, at \$1.24/gal. in Los Angeles, is cheaper than gas at around \$1.55

■ **CON** Gas-ethanol blends can't be piped to terminals because the alcohol separates out. Transport adds to costs

■ **PRO** Cars can be built to run on an 85% ethanol blend at marginal extra cost

■ **CON** Only 600 U.S. gas stations sell the fuel. There are 167,000 retail gas stations in the U.S.

■ **PRO** Ethanol boosted the price of a bushel of corn by 25¢ to 50¢ last year

■ **CON** Taxpayers support ethanol via state subsidies and a 51¢/gal. federal tax exemption

■ **PRO** Ethanol helps reduce tailpipe emissions from cars

■ **CON** Badly blended ethanol makes gas more vaporous on hot days, promoting ozone pollution. Corn farming and alcohol production are also very polluting



bility. The Federal Government provides a 51¢ tax exemption to gasoline refiners for every gallon of ethanol used, to keep the product competitive. (Conservative activist Gray points out that the oil industry has long enjoyed far larger tax breaks.) And now, Senate mandate aside, Illinois Senator Barack Obama has slipped an amendment into the energy bill providing a \$30,000 tax credit to encourage gas stations to pump "E85," an 85% blend of ethanol and gas used by so-called flexible-fuel vehicles. There are already 4 million such cars on U.S. roads. The Set America Free plan calls for just such incentives.

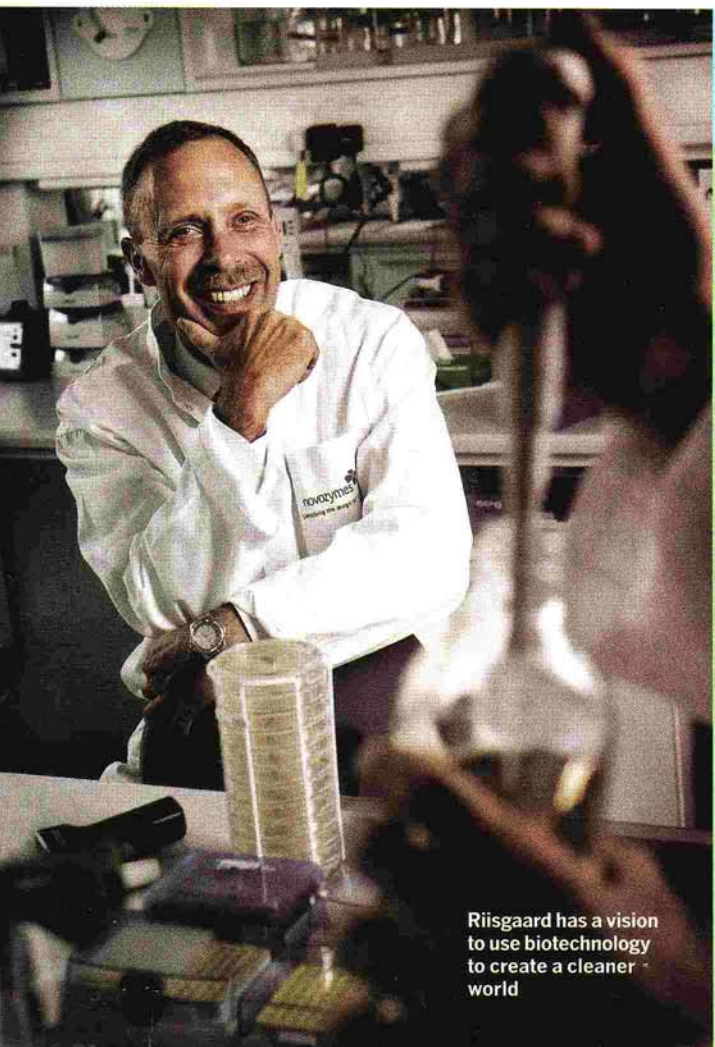
Debate has long raged over whether ethanol takes more energy to make than it delivers—something called the energy balance. Most experts now agree that from cornfield to factory vat, the amount of energy expended in making the fuel accounts for about 80% of the energy in it. But refiners say ethanol is still an inefficient option. Because it tends to separate from gas in pipelines, it has to be trucked to terminals and blended there by specially modified machines. That increases costs. "There is a question about the real cost of this product," says Robert Slaughter, president of the National Petrochemical & Refiners Association. "How many federal-assistance programs do you need to make it work?"

In fact, the real answer to such cost issues is bioethanol, which is the same stuff as ethanol but is made from wood or plant wastes like cornstalks. One of the few oil companies to back bioethanol

is Shell. It invested in a pilot plant run by a small Canadian biotechnology firm named Iogen, which put itself on the map by shipping the first commercial batch of ethanol made from straw last year. Iogen CEO Brian Foody says he expects to break ground on a 50 million-gal.-a-year plant next year. The hawk-and-dove coalitions want bioethanol to fuel future cars. It's loved as much by fiscal conservatives for turning waste into treasure as it is by environmentalists for its overwhelmingly positive energy balance. A bioethanol industry would even help deplete the global-warming gas carbon dioxide from the atmosphere, notes Woolsey. And corn ethanol can't be produced in sufficient quantities to dent oil imports: roughly 4 billion gal. will be made this year. Vehicles in the U.S. consume that much gas in just 11 days.

Whatever the future of the electric car and bioethanol, the notion that America must end its oil habit is gaining currency in Washington. George W. Bush, the former Texan oilman, has begun talking up corn ethanol and clean diesel and has endorsed a \$4,000 tax credit for purchases of hybrid cars. That has not gone unnoticed by energy's new coalition of convenience, even if the President hasn't yet mentioned plug-in hybrids or bioethanol. "We drive to high-tech jobs today in cars built with 100-year-old technology, using 100 million-year-old fuel," says Podesta. "We can do better than that." Maybe 500 m.p.g. isn't so crazy after all. —*With reporting by Marc Hequet/St. Paul, Kristin Kloberdanz/Hopkinsville and Jeffrey Ressler/Los Angeles*

CASPER DALHOFT—CORBIS FOR TIME



Riisgaard has a vision to use biotechnology to create a cleaner world

## Turning Waste into Fuel

A DANISH BIOTECH FIRM WORKS ON ANSWERS

When the hawks and greens of Washington's new anti-oil coalitions talk about ethanol fueling the future car, they aren't talking about the brew distilled from cornstarch. What they are referring to is a more fiscally and environmentally defensible alcohol, brewed from prairie grasses or agricultural waste, like straw. Trouble is, the technology required to commercialize bioethanol is in its infancy.

People like CEO Steen Riisgaard, a passionate environmentalist who went into business because he thought he could do good, are helping the technology mature. Novozymes, the \$1 billion, Copenhagen-based company he leads, sells microbes and enzymes made from genetically engineered bugs that improve consumer products and make dirty industrial processes more environmentally friendly. But as the volume of ethanol brewed in the U.S. has doubled since 2001, to 3.4 billion gal., the farm-fuel business has become Novozymes' fastest-growing source of revenue.

Enzymes that help transform

cornstarch into ethanol are fairly run-of-the-mill in biotech terms. The same can't be said of those needed to brew bioethanol from indigestible plant fibers. Making enzymes efficient and cheap enough for that has long been an obstacle to a viable bioethanol industry. Canada's Iogen is the only biotech firm to have shipped a batch of commercial bioethanol (see *main story*). But Novozymes is making waves as well. It announced in March that with \$17 million in U.S. Department of Energy (DOE) funding, it had reduced the cost of enzymes for making booze from corn stover from \$5 per gal. of ethanol in 2001 to a mere 10¢ to 18¢.

"We are involved in this because we believe there is a market," says Riisgaard, though he thinks a large bioethanol industry is still years away. With more funds from the DOE, Novozymes will supply enzymes for a bioethanol plant to be built in Nebraska next year by a subsidiary of the Spanish firm Abengoa. More than a few people in Washington will be watching. —*By Unmesh Kher. Reported by Ulla Plon/Copenhagen*





# THE HYBRID CO

## THE PLUG-IN HYBRID

BY KELLEN SCHEFTER

It's hard to imagine a more gripping state of affairs at the start of the 21st century. A cloud of smog hangs over our cities while the threat of global warming looms ever larger. Oil prices are rising to record highs and while there's no imminent danger of running out of petroleum, no one knows how long supplies will last. For a final dramatic touch, most of that oil sits beneath the powder-keg that is the Middle East.

A hydrogen hero is on the way, but many worry that we don't have time to wait, unsure of what happens if oil supplies drop off and we're caught without a safety net. A growing chorus is clamoring for a near-term solution, something that can be implemented now to significantly

reduce oil consumption. The stage has been set for plug-in hybrids.

The plug-in hybrid is an evolution of the "conventional" hybrid vehicle. Plug-in hybrids function the same way, assisting the engine with battery power or electric energy captured during deceleration, but take the idea a step further. Increased battery capacity allows plug-ins to rely more on electricity and less on gasoline, extending electric-only driving range and delivering even better fuel economy. The extra electric power is drawn from the electrical grid by plugging into power outlets while a vehicle isn't being driven.

The virtue of the plug-in hybrid comes to light with some statistics. A majority of Americans live within 20 miles of

their jobs and most trips are less than 20 miles long. With an electric-only range of up to 60 miles, daily drives to work in a plug-in hybrid might not require any gasoline at all as long as the battery is recharged each night. For longer trips, the vehicle reverts back to conventional hybrid operation. If plug-in hybrids are ever designed and built from the ground up, rather than being converted from existing models like we're seeing today, an even smaller engine could improve fuel economy at every stage.

Though the Toyota Prius is not a plug-in hybrid, it serves as a good platform for a conversion. The California Cars Initiative, a non-profit organization, first built one to show it could be done. The conversion turned out to be so promising



# CONNECTION

that some companies are looking to make a for-profit business out of it.

Engineering firms EnergyCS and Clean-Tech have joined forces to form EDrive Systems, which is developing a conversion kit for the second-generation Toyota Prius. The kit removes the stock Panasonic nickel-metal-hydrate (NiMH) battery and replaces it with a Saphion lithium-ion battery from Valence. The new battery adds 170 pounds to the Prius, but also makes about 9 kWh instead of the original's 1.3 kWh. That means there's much more electrical power available to drive the car.

Some careful software tweaks are made to handle the extra power of the hardware. The EDrive system takes advantage of a built-in "EV mode" that forces the Prius to run purely on electric power until speeds reach 33

mph. This ensures that no precious fuel is sapped until the computer deems it absolutely necessary. According to EDrive, in a stock Prius, the batteries would only provide about one mile in this mode; the company's converted plug-in Prius extends that range to as much as 35 miles.

To further hold off engine intervention, the computer is told the battery is full until the actual state of charge dips below 20 percent. This bit of misinformation forces Toyota's Hybrid Synergy Drive to inject as much electric power as possible into the drive system. After the battery is about 80 percent depleted, the EDrive Prius carries on like a normal hybrid and maintains the charge of the battery as needed. Once the EDrive Prius is parked, it's plugged into an external 110-volt charger that can

replenish a fully depleted battery in about seven to nine hours.

An additional dash-mounted readout precisely meters fuel consumption and displays how far the throttle pedal can be depressed before prompting the engine to start up. It's a useful tool because driving style matters. Aggressive driving and 75 mph cruising will yield 70-80 mpg, say the EDrive folks, while relatively mellow driving earns well over 100 mpg. Low speed city driving and cruising at 55 mph can reportedly push fuel economy closer to 200 mpg. And when the battery is depleted after 50-60 miles of driving, fuel economy reverts back to the roughly 45-50 mpg of the stock Prius.

EDrive Systems hopes to sell its conversion kit for \$10,000 to \$12,000 in early 2006. At this cost, EDrive's market



Greg Hanssen behind the wheel of his EDrive plug-in hybrid. Green Car Journal got over 100 mpg in this car.

is limited to those with the bucks to support making such a statement, but it's a start.

The Prius is not the only vehicle lending itself to plug-in conversion. DaimlerChrysler is working with the Electric Power Research Institute (EPRI) to build 40 plug-in hybrid versions of its Sprinter commercial van for use in demonstration fleets. Electric boost comes from a 70 kW motor positioned between the transmission and clutch, which is fed by a 14 kWh NiMH battery stowed beneath the cargo floor.

Drivers of the plug-in Sprinter hybrid can push a button to put the vehicle in electric-only mode, which is good for a range of about 19 miles. When not selected, the hybrid's electronic controller alternates power between the vehicle's diesel engine and electric motor to optimize fuel economy, or combines the two when power demands are high. This plug-in variant is designed

for recharging on Europe's 230 volt network, a task that takes about six hours for a fully depleted battery.

The stock Sprinter, with its small, 4-cylinder diesel engine, is already quite the efficient hauler with fuel economy as high as 30 mpg. Converted to a plug-in hybrid, DaimlerChrysler says fuel economy improves anywhere from 10 to 50 percent, depending on use. That means up to 45 mpg from a commercial delivery vehicle – simply unheard of in its class. So far, DaimlerChrysler is the only automobile manufacturer producing its own plug-in hybrids.

One of the most notable forces behind the rising profile of the plug-in is Felix Kramer and his Palo Alto-based California Cars Initiative. The group is mobilizing support from fleets, government agencies, and private buyers in an attempt to break the vicious cycle that plagues many new technologies: Motorists won't buy plug-ins on a large

scale unless the price is right, and the price won't come down until automakers are convinced there will be buyers.

Not content to wait around for the manufacturers, Kramer is looking at other ways to put plug-in hybrids on the road. The plan is to utilize venture capital, set up a Qualified Vehicle Modifier company that could work with automakers in a fully certified capacity, and convert existing hybrid models without voiding original vehicle warranties. In Kramer's mind, conversion possibilities include Ford's Escape Hybrid and models using Toyota's Hybrid Synergy Drive such as the Prius, Highlander Hybrid, Lexus RX400h, and other upcoming models.

The potential of the plug-in hybrid in reducing emissions and oil dependency has put environmentalists and conservative think-tanks in an unusual position: They're on the same side. Set America Free, the Center for Security Policy, and others have joined electric vehicle die-hards in calling for mass production of plug-in hybrids. Support from former Secretary of State George Shultz and former CIA director James Woolsey lends considerable credibility to the cause.

Despite this clamoring, the U.S. government has yet to respond in a big way. An amendment to the massive energy bill recently approved by President Bush allocates a relatively tiny \$40 million for hybrid vehicle development, some of which could go toward plug-in hybrids...but there's no guarantee.

This leaves local government to take charge. The City of Austin, Texas, with help from its municipal utility Austin Energy, has become the first city to develop an incentive plan for plug-in hybrids. "Plug-In Austin" is looking to raise \$50-\$100 million to provide



rebates on plug-in hybrid purchases for public and private use, as well as for running an educational campaign to generate consumer interest. Austin is one of 10 cities that will begin testing DaimlerChrysler's Sprinter plug-in hybrid next year.

The "Plug-In Austin" campaign is designed to expand to other communities around the country. Representatives from Austin Energy are approaching the nation's 50 largest cities in an effort to encourage them to replicate Austin's program. Already, Seattle City Light in Washington state has shown interest in offering customers incentives to buy plug-in hybrid vehicles in the Puget Sound region. Across the country and across the political spectrum, the plug-in hybrid is winning fans.

Professor Andy Frank at the University of California, Davis is an ardent proponent of plug-in hybrids and, having built plug-in prototypes since 1972, is also one

of the most experienced. Rather than an intermediary step to hydrogen, Professor Frank believes the plug-in could be an end in itself. A plug-in hybrid with a 60 mile electric range, like the ones Frank and his students build, reportedly uses only 10% gasoline and 90% electricity on

## Like other hybrids, the Highlander shuts down its gasoline engine during coast-down and idling to conserve fuel and reduce emissions.

an annual basis. "That 10% of gasoline could be replaced by biofuels," says Frank, taking an interesting direction that could find gasoline use eliminated altogether.

The possibilities don't end there. "We have the capability, for the first time, of integrating the electric grid with transportation," explains Frank. The electrical grid right now has enough excess capacity to support half the nation's vehicle fleet if they were converted to plug-in hybrids, says Frank. The energy is domestically

produced, the infrastructure already exists, and, though much of our electricity today comes from coal-burning powerplants, renewable and non-polluting sources such as wind and solar power could play a larger role. "People don't think of plug-ins as

alternative fuel cars, but they are," says Frank. "You could be running your car on solar or wind power."

At less than a dollar per gallon during off-peak hours, when most plug-ins would be recharged, plug-in hybrid drivers would be paying a lot less in fuel costs. As for the extra up-front cost, Frank points to a UC Davis study that shows how automakers could build plug-in hybrids by adding only \$7,000 to the price of a \$20,000 car. So why isn't this already happening? Some in the auto industry maintain that battery technology isn't ready yet, a claim that Frank and others dismiss. More significantly, Frank asserts there's a general reluctance to invest, with struggling giants in the industry unwilling to take risks unless convinced there's a good chance that a sizeable return will result.

"What I'm trying to demonstrate is that if a bunch of students can do it, the car companies should be able to do even better." Andy Frank, the California Cars Initiative, the City of Austin, and many others feel it's up to them to take the lead in getting the word out and generating demand. With the success they've met, and the wide-ranging benefits that plug-ins put within reach, there's every reason to believe that at least some in the auto industry are paying very close attention.



Saphion lithium-ion batteries used in this plug-in hybrid are positioned in the rear cargo area.



# Hybrid-Car Tinkerers Scoff at No-Plug-In Rule

By DANNY HAKIM

DETROIT, March 31—Ron Gremban and Felix Kramer have modified a Toyota Prius so it can be plugged into a wall outlet.

This does not make Toyota happy. The company has spent millions of dollars persuading people that hybrid electric cars like the Prius never need to be plugged in and work just like normal cars. So has Honda, which even ran a commercial that showed a guy wandering around his Civic hybrid fruitlessly searching for a plug.

But the idea of making hybrid cars that have the option of being plugged in is supported by a diverse group of interests, from neoconservatives who support greater fuel efficiency to utilities salivating at the chance to supplant oil with electricity. If you were able to plug a hybrid in overnight, you could potentially use a lot less gas by cruising for long stretches on battery power only. But unlike purely electric cars, which take hours to charge and need frequent recharging, you would not have to plug in if you did not want to.

"I've gotten anywhere from 65 to over 100 miles per gallon," said Mr. Gremban, an engineer at CalCars, a small nonprofit

group based in Palo Alto, Calif. He gets 40 to 45 miles per gallon driving his normal Prius. And EnergyCS, a small company that has collaborated with CalCars, has modified another Prius with more sophisticated batteries; they claim their Prius gets up to 180 m.p.g. and can travel more than 30 miles on battery power.

"If you cover people's daily commute, maybe they'll go to the gas station once a month," said Mr. Kramer, the founder of CalCars. "That's the whole idea."

Conventional hybrid electric cars already save gas. But if one looks at growth projections for oil consumption, hybrids will slow the growth rate of oil imports only marginally, at best, with the amount depending on how many hybrids are sold. To actually stop the growth of oil imports and potentially even reduce consumption, automakers have focused on developing cars powered by hydrogen fuel cells.

But fuel cells would require a complete reinvention of the automobile, not to mention the nation's gas stations, and the technology to put them on the road is still a long way from fruition. Advocates of plug-in hybrids say the technology for these vehicles is available now to the point that people are

building them in garages.

"All of the relevant technology is at hand," said Frank Gaffney, founder of the Center for Security Policy and an assistant defense secretary in the Reagan administration. His group was among a coalition of right-leaning organizations that released an energy plan this year promoting plug-ins as one way to increase fuel efficiency in light of the instability of the Middle East.

"If you're thinking about this as an environmental issue first and foremost, you're missing the point," Mr. Gaffney said. Curbing dependence on foreign oil, he added, "is a national security emergency."

Toyota, however, says the plug-in is not ready for prime time.

"They say this is the next great thing, but it just isn't," said David Hermance, an executive engineer at Toyota. "The electric utilities really want to sell electricity and they want to sell it to the transportation sector because that expands their market. They have an agenda."

But the plug-in hybrid is not just coming out of the garages of enthusi-

*Continued on Page 3*

asts in California. DaimlerChrysler has developed several dozen plug-in hybrid vans in cooperation with the Electric Power Research Institute, a group financed by more than 300 utilities, including the New York Power Authority and Southern California Edison. Testing of the vans will start this year, and one will be used by The New York Times on a newspaper delivery route in Manhattan. Several small companies are also developing or have developed plug-in hybrid prototypes.

"We think it's the only way to rekindle interest in electric transportation," said Robert Graham, who manages research into electric vehicles for the Research Institute. "There are no technology hurdles at all. It's simply a matter of getting the vehicle built out on the street and getting people to recognize its value."

For power companies, the notion of people plugging in cars overnight represents not only a new way to make money, but the vehicles would also draw power mostly during off hours which would improve efficiency, because power plants cannot simply shut down at night as demand diminishes.

As it stands, though, modifying a hybrid like the Prius to enable it to plug in would add perhaps \$2,000 to

\$3,000 to the cost of a car that is already roughly \$3,000 more expensive than conventional gas cars. Advocates say the costs would be much lower if such cars were mass-produced by a major automaker.

But Nick Cappa, a spokesman for DaimlerChrysler, was cautious, calling the technology one of many the company was exploring.

"The concern on plug-in hybrids is that we not substitute addiction to one polluting fuel for addiction to a more polluting fuel," said Dan Becker, the head of the Sierra Club's global warming and energy program. "Coal is more polluting than gasoline, and nearly 60 percent of U.S. electricity is generated by burning coal."

Roger Duncan, a deputy general manager of Austin Energy, a utility owned by the City of Austin, Tex., said that "it's hard to say what impact it will have on the nation as a whole," but that in regions that use cleaner-than-average power sources, like Austin or California, it would provide a clear emissions benefit. Mr. Duncan even imagines a day when drivers could be paid to return energy to the grid during times of excessive demand.

Plug-in hybrid prototypes have been around for several years, but

the idea of modifying a Prius stemmed from the curiosity of some Prius owners in the United States, Mr. Kramer said. They were aroused by a mysterious unmarked button on their Prius and discovered that in Priuses sold in Europe and Japan, the button allows the car to drive for a mile in electric-only mode. Mr. Hermance said the feature was disabled in Priuses sold in the United States because of complications it would have created in emissions-testing rules.

Mr. Kramer said "a bunch of engineers reverse-engineered it in the United States and figured out how to hack it."

But they soon wanted to travel on batteries for more than a mile and began to collaborate through CalCars on adding batteries to the Prius that would allow for longer pure electric travel. With the help of dozens of volunteer engineers collaborating online, the group retrofitted a Prius in Mr. Gremban's garage to travel about 10 miles on nothing but battery power.

Mr. Duncan said the plug-in hybrid was "very realistic, because it's not that big a leap in technology."

"Look what Felix has done with Prius off the street," he added. "This isn't rocket science."

Table 4-1

### Summary of Renewable Fuel Options

The most promising renewable transportation fuel alternatives meet four criteria: (1) they can be produced from ample domestic feedstocks; (2) they have low or near-zero carbon emissions during production and use; (3) they work in existing vehicles and with existing infrastructure; and (4) they have the potential to become cost-competitive with petroleum fuels given sufficient time and resources dedicated to technology development.

	Hydrogen	Corn Ethanol	Cellulosic Ethanol	Bio-Diesel	Electricity
<b>Ample, Domestic Resource</b>	<b>Yes</b> Hydrogen can be produced from water through electrolysis or by separating hydrogen from fossil fuels. The U.S. has plentiful coal deposits and abundant water supplies to generate sufficient hydrogen to fuel the domestic transportation system.	<b>No</b> In 2003, roughly 7% of the U.S. corn crop was used to make ethanol. Corn ethanol production will continue to grow, but even use of 100% of the current crop would displace only 25% of current gasoline use on an energy-equivalent basis.	<b>Yes</b> Greater diversity of biomass and waste feed stocks means cellulosic ethanol is likely to be less limited by competing land uses for food and forest products. NCEP analysis suggests potential for substantial production w/o constraining food supply.	<b>Yes</b> Bio-diesel can potentially be made from a wide variety of organic materials, including animal and crop waste, vegetable oils, used grease, etc. Waste quantities generated in the U.S. could support significant production if new technologies for making bio-diesel prove cost-competitive and widely applicable.	<b>Yes</b> The diversity of fuels and technologies used to provide electricity is now much greater than the diversity of fuels used in the transportation sector. Moreover, nearly all electricity used in the U.S. is produced using domestic resources.
<b>Low-Carbon</b>	<b>It depends . . .</b> Three times more carbon intensive per mile than gasoline if produced using electricity from existing power plants. Use of natural gas, renewable, nuclear, or coal power with sequestration would make hydrogen low-carbon, but these technologies will provide greater benefits by directly displacing fossil-based electricity than by indirectly displacing gasoline.	<b>Yes</b> Corn ethanol is roughly 20% lower in greenhouse gas emissions than gasoline. Most emissions result from upstream energy inputs required for the cultivation, harvest, and processing of corn. CO <sub>2</sub> reductions from corn ethanol are modest compared to cellulosic ethanol.	<b>Yes</b> Unlike corn ethanol, has potential to achieve near-zero net carbon emissions. Cultivation of cellulosic feedstocks requires very low energy inputs and, if sustainably managed, the carbon released during fuel combustion is re-absorbed by the growth of new feedstocks.	<b>It Depends . . .</b> Provided it is produced from agricultural crops or wastes, bio-diesel would have very low carbon emissions (similar to cellulosic ethanol).	<b>It Depends . . .</b> Depends on the manner in which the electricity used was generated. The carbon intensity of future electricity production could be greatly reduced by more reliance on renewables and development of next-generation nuclear and fossil technologies with carbon sequestration.
<b>Compatible with Existing Infrastructure</b>	<b>No</b> As a gas, would require a new national distribution infrastructure estimated to cost hundreds of billions of dollars.	<b>It Depends . . .</b> Can be blended with gasoline at varying levels, but cannot now be transported by pipeline and must be moved by barge or truck.	<b>It Depends . . .</b> Infrastructure and vehicle compatibility issues are the same as for corn ethanol.	<b>Yes</b> New synthetic, waste-derived bio-diesels are compatible with existing diesel engines and infrastructure. Some existing vegetable oil bio-diesel can cause problems in older engines at blends greater than 20%.	<b>Yes</b> Assuming plug-in hybrids with short all-electric range, recharging could be done using the existing grid.
<b>Potentially Competitive with Gasoline by 2020</b>	<b>No</b> Substantial technological breakthroughs and dramatic cost reductions are required. National Academy of Sciences estimates 50-year time horizon to full development.	<b>No</b> Technology is mature, but still costs more than twice as much to produce as gasoline (~\$1.40/gal). Current market for corn ethanol is supported by large public subsidies.	<b>Yes</b> Significant progress still needed, but costs have already declined by a factor of three since 1980. NCEP analysis suggests production cost below \$0.80/gal. is attainable.	<b>It Depends . . .</b> Economics of early deployment depend heavily on feedstock costs. In the case of waste-derived fuels, avoided cost of waste disposal can in some instances help to make bio-diesel cost-competitive.	<b>It Depends . . .</b> Battery technology, not electricity itself, is main cost hurdle. Plug-in hybrids are more promising than all-electric vehicles.

Data Sources: National Academy of Sciences, 2004; Romm, 2004 (I); Lynd, Lave, and Greene, 2004; Lynd, Greene, and Sheehan, 2004; International Energy Agency, 2004; Energy Information Administration, 2004; Romm, 2004 (II).

## FACT SHEET: PHEV Conversions (March 31, 2006)

1. Specifications for PRIUS+
2. Additional prototypes and conversions for consumers
3. PHEV Battery Comparisons chart
4. Anecdotal performance data of PHEV conversions

This summary of conversions brings you up to speed on what we've done—and where we're heading. This is a work in progress—check at <http://www.priusplus.org> to for the latest. For technical discussions, see the **EAA Conversion Group** URL below. Subscribe to the [CalCars-News](#) newsletter to keep up with the latest PHEV coverage and milestones. See [How to Get](#) page at CalCars for latest information on availability, warranty information, and links to other resources.

Note that all MPG reports also include electricity use – no free lunch!

- Felix Kramer [fkramer@calcars.org](mailto:fkramer@calcars.org) Founder, CalCars.org
- Ron Gremban [rgremban@calcars.org](mailto:rgremban@calcars.org) Technical Lead, CalCars.org

### SPECIFICATIONS FOR PRIUS+ (FIRST PRIUS CONVERSION)

- **Conversion platform** is Ron Gremban's stock 2004 Prius hybrid (HEV).
- **Stock Prius hybrid battery pack** (Panasonic nickel-metal hydride [NiMH] 6.5 Ah, 201.6 Volt, 99 lb/45kg) remains unused during PHEV operation and can be used in normal hybrid mode as needed, e.g., for comparison (in future conversions, this battery will probably be removed).
- **CalCars' initial battery pack** (for our first prototype, we used low-performance, short-life but resilient lead acid (PbA) for testing purposes and to obtain design criteria for higher-performance packs): 18 electric bicycle B&B 20Ah 12Volt SLA batteries from [ElectricRider.com](#). Pack replaced with new PbA batteries Oct 2005, after 11 months and approx. 200 charging cycles; unable to handle 120A peak discharges beyond 70% of its capacity.
- **Batteries positioned** in empty well below hatchback deck, with independent manually switchable air cooling system.
- **Batteries recharged** via 120-volt outlet in 3 hours with Brusa NLG5 charger from [MetricMind.com](#) (cheaper charger; longer for larger packs).
- **Battery Management System, Controller/Display Unit** (CDU) by Energy Control Systems Engineering ([EnergyCS.com](#)) of Monrovia, CA, replaced Toyota's Battery ECU. No other changes to Hybrid Synergy Drive (HSD).
- **Data from battery and CAN (Controller Area Network) bus interface:** Dashboard analog meters display battery voltage and current. EnergyCS digital display includes battery voltage and current, Amp-hours used from

- the battery, vehicle power requested (e.g. via throttle position), state-of-charge (SOC) reported to THS, and gas used/trip (1000ths of gallons).
- **Simulated State of Charge** information sent to THS is set semi-automatically to force energy use and regenerative braking regimen (automation has been fine-tuned in later iterations of EnergyCS controller).
- **Configuration** permits rapid reversion to standard hybrid operation using the Prius's Battery Management System and the retained original battery.
- **Operation** permits electric-only mode at up to 34 mph (using reverse-engineered "EV" button available on European and Asian Priuses; above 34 mph, battery energy continues to assist the engine, contributing to lower gasoline consumption. The PbA battery is good for 10 all-electric miles, 20 miles of doubled gasoline mileage, or mixes of the two. Then operation reverts to normal HEV mode, still using the new battery pack.

### ADDITIONAL PROTOTYPES AND CONVERSIONS FOR CONSUMERS

For battery specifics, please see the Battery Comparison chart.

- **EDrive Systems:** The EnergyCS prototype and impending EDrive Systems commercial Prius conversions provide up to 30 mile all-electric range using Li-Ion. Improved performance and additional electric range can be expected from the above batteries, due to significantly lower internal resistance losses.
- **Hymotion:** In early 2006 Hymotion announced Li-Ion conversions for the Prius and, later this year, the Ford Escape Hybrid. These conversions will initially be sold only in bulk (100 units minimum), with consumer conversions available in late 2006/2007.
- **"Do-It Yourself" project** for advanced experimenters with experience in high-voltage projects initiated by the **Electric Auto Association** (EAA) in October 2005.
- CalCars and the EAA are developing an **"open-source"-style** effort to enable anyone with access to a qualified engineer to retrofit their Prius starting in 2006. Full documentation, as well as recommended materials and batteries, will be made available at the EAA-PHEV web site.
- New efforts by CalCars will continue on other platforms, including Ford Escape Hybrid, and in exploration of new batteries. In 2005, CalCars [announced](#) a development program with [Electro Energy Inc.](#) (NASDAQ EEEI) to test bi-polar Nickel-Metal Hydride (NiMH) batteries. This has resulted in a current prototype vehicle and a timeline for high-volume manufacturing of batteries in 2007.

**We estimate automakers could sell small, 30-mile (any speed) range PHEVs for \$3,000 more than a hybrid, \$5,000 more than a non-hybrid.**



### PHEV Battery Comparison Chart

Battery	Type	Description	Weight	Ah/kWhr	Range	Notes
CalCars PRIUS+	Lead-acid	CalCars prototype lead-acid	300lbs	12Ah, 2.4kWhr	10miles	Original pack replaced after 11 months, approx 200 charge cycles.
Electro Energy	NiMH	First-generation prototype NiMH proof-of-concept	400lbs	28Ah, 6kWhr	10-15mi	Present prototype, non-optimized battery used for integration and demonstration.
Electro Energy	NiMH	Second-generation prototype NiMH	220lbs*	30Ah, 6.5kWhr	20-25mi	Prototype optimized for reduced weight and improved performance; estimated being built and installed 3rd quarter 2006.
Electro Energy	NiMH	Production-ready NiMH (2007)	200lbs*	30Ah, 6.5kWhr	20-25mi	Production-ready, further optimized and produced using high-volume manufacturing capabilities presently being established. Expected availability 2007.
EDrive Systems	Lithium-Ion	Production-ready	160-190lbs*	35-40Ah, 9kWhr	30mi	Uses off-the-shelf Valence Technology Saphion U batteries.
Hymotion	Lithium-Ion	Production-ready	160lbs	5kWhr	30mi	Integrates with original Prius battery.

\* after removal of original Prius battery and controls (99lbs)

#### ANECDOTAL PHEV CONVERSIONS PERFORMANCE DATA

Equivalent mpg numbers and operation costs depend on patterns of use (total miles driven/day, speeds driven, etc.).

**CalCars' lead-acid PRIUS+:** The following performance is expected to be better with lighter, more efficient batteries. **Important:** low PHEV and HEV mileage due to short runs, hilly Marin County terrain and other local factors.

Heavy lead-acid batteries add approx. **300 lb (10%) total**, reducing mileage by approx. 5 mpg (10%) in standard HEV operation on city streets (due to acceleration losses), but by little or nothing at highway speeds (where wind resistance is the main factor). Lower weight from removing original pack and lower internal resistance of future batteries is expected to increase the efficiency of standard HEV operation to restore original HEV city mileage even when grid-charging energy is not involved.

- **Under 10-mile** all-electric propulsion (at < 34 mph): **infinite mpg** plus 262 grid Watt-hours/mile vs. 40-45 mpg as normal HEV.
- **14 mile round trips**, including approx. 10 miles on hilly freeways: **80 mpg** + 200 grid Wh/mi, compared to 36 actual HEV mpg on the same course, driving with the extra battery weight -- otherwise maybe 40 mpg.
- **26-28 mile trips** with many surface streets: **60 mpg** +144 grid Wh/mi.
- **Beyond 20 miles/day** (40 miles/day with NiMH or 60 miles/day with Li-Ion batteries): normal HEV mileage—except better mileage on long descents due to more recovered energy storage—and no further electricity use.

- **All-electric miles:** power cost, approx. 1.5 cents/mile (assumption of 310 grid Wh/mi and 5 cents/kWh on California off-peak EV "E-9" (PG&E) rate, and not amortizing battery cost), vs. approx. 5.6 cents/gasoline mile (\$2.50/gallon, 45 mpg). (2.5 cents for 10 cents/kWh rate)

**EnergyCS Li-Ion:** EnergyCS's version of PRIUS+, completed Feb. 2005, uses off-the-shelf [Valence Technology](#) Saphion U Li-Ion batteries, plus specialized monitoring and control circuits. These automatically select EV operation at low speeds during low power usage, and provide electric motor benefits at all speeds. This vehicle will be the starting point for **retrofits for sale in mid-2006 from [EDrive Systems](#)**.

- Under 35-mile trip all-electric propulsion (at under 34 mph): **infinite mpg** (i.e., no gasoline) plus 200 Watt-hours/mile.
- 70 mile trip, 80% 55 mph freeway, 20% city: **120-180 mpg** + 115-150 grid Wh/mi, compared to est. 55 mpg as a normal HEV.
- Beyond 50-60 miles/day: normal HEV mileage—except better mileage on long descents due to more recovered energy storage—and no further electricity use.
- **All-electric miles:** power cost approx. 1.0 cents/mile (assumption of 200 Wh/mi and 5 cents/kWh on California off-peak EV "E-9" (PG&E) rate, or 2 cents/mile at 10 cents/kWh electricity, not amortizing battery cost), vs. approx. 5.6 cents/gasoline mile (\$2.50/gallon, 45 mpg)

# *What will the next generation hybrid look like?*



\*Department of Transportation Federal Highway Administration, Nationwide Personal Transportation Survey, Volpe National Transportation Systems Center, Cambridge, MA.

The Plug-In Hybrid Development Consortium is made up of component suppliers working together to accelerate the commercial production of plug-in hybrid vehicles (PHEV). Consortium members cooperate to identify specifications, develop compatible technologies and deliver innovative new system solutions that make affordable plug-in hybrids possible.

The Consortium's cooperative efforts help automakers short-cut years of research and development, to leap ahead of the competition and offer the next generation of hybrid vehicles at a price that makes sense.

In addition to providing automakers with production ready PHEV components and system designs, the Consortium works to build political support and secure new funding to help automakers build PHEV prototypes using new technology from Consortium members.

We believe hybrid technology can improve every car... like fuel injection and electronic ignition. By helping to reduce the cost of plug-in hybrid components, the Consortium can help make PHEVs more affordable.

According to a U.S. Department of Transportation survey,\* most people drive less than 50 miles a day and only 5% of passenger cars travel more than 100 miles a day. By designing cars around

***We don't make plug-in hybrids...We make plug-in hybrids possible.***

the way we drive, the next generation hybrid could drive 50 miles a day in clean all electric mode without stopping for gas, and automatically switch to hybrid mode when needed. Using clean renewable electric fuel, generated in the US, costs just 1/4 the price of petroleum, often imported from abroad.

Working together we can provide automakers with the technology they need to deliver plug-in hybrids that make sense.

We invite innovators everywhere who share this vision to join us.





Plug-In Hybrid  
Electric Vehicles  
(PHEVs)

# Plug-in Partners National Campaign

## Building a Market for Gas-Optional Flexible-Fuel Hybrids

### Plug-In Hybrid Electric Vehicles: The near-term solution

- Plug-in hybrid electric vehicles (PHEVs) can dramatically decrease American dependence on imported oil, reduce greenhouse gases and other air pollutants, as well as lower fuel costs for American consumers.
- PHEVs use the same technology as the popular hybrids on the road today, but have a more powerful battery that can be recharged in a standard home outlet.
- PHEVs are outfitted with a battery pack sufficient to power the vehicle from 20 to 60 miles on battery charge alone.
- Since half the cars on America's roads are driven 25 miles a day or less, a plug-in with a 25-mile range battery could eliminate gasoline use in the daily commute of millions of Americans.
- PHEV technology is already available and functioning. Daimler-Chrysler has developed and is testing a prototype PHEV commercial van with a 20-mile all-electric range. Conversions of existing hybrids ranging from sedans to SUVs are on the road today and show that the technology works.
- PHEVs can be manufactured with flexible fuel engines, magnifying the economic, environmental and security benefits while also benefiting American agriculture.
- An "electric" equivalent gallon of gas will cost 70-80 cents at prevailing electric rates versus the \$2.00+ national average gasoline price.
- The electric infrastructure is in place and available. Over 40% of the generating capacity in the U.S. sits idle or operates at a reduced load overnight, when most PHEVs would be recharged. Our power system could charge tens of millions of PHEVs without requiring new plants.



### Plug-in Partners Plan

- **Establish community grass-roots campaign to demonstrate that a market exists for PHEVs.**
- **Campaign components include rebates, "soft" fleet orders, petitions and endorsements.**
- **Campaign partners are local and state governments, utilities and environmental, consumer and business organizations.**

Visit us online at [www.pluginpartners.org](http://www.pluginpartners.org)



# Building a Market for a Flexible-Fuel PHEV

Plug-In Partners is a national grass-roots campaign to demonstrate that a market exists right now for flexible-fuel Plug-In Hybrid Electric Vehicles (PHEVs).

Key components of the campaign include rebates and incentives, “soft” fleet orders, petitions and endorsements. Partners in this campaign are local and state governments, utilities, and environmental, consumer and business organizations.

“Plug-In Austin” kicked off August 22, 2005. Cities and organizations across America are invited to use this identifying logo, and launch a Plug-In (name of City) campaign for their locale.



## Rebates and Incentives

Rebates and incentives could be provided through various sources, including electric utilities — a logical source, since the industry stands to receive additional revenues if PHEVs achieve significant market penetration.

Austin Energy has set aside \$1 million for rebates for local governments, businesses and citizens to buy down the additional cost of PHEVs above the cost of a regular hybrid. Rebates or incentives could also be provided by businesses or organizations to their employees, perhaps as a match to a utility rebate or tax incentive.

## Fleet Orders

Advanced commitments for PHEVs for future fleet needs are an important component of the campaign. These “soft” fleet commitments will demonstrate to automakers that governments and business fleet buyers are seriously interested in purchasing PHEVs. Committing to the future purchase of a fixed number of PHEV vehicles, when they become available, would be ideal.

## Petitions

The collection of signatures will allow a large number of Americans to speak directly to automakers. The petition being utilized in Austin simply states that the signer understands what plug-ins are, and that they will seriously consider buying such a vehicle if it is manufactured. [Petitions can be signed online at www.pluginpartners.org](http://www.pluginpartners.org)

## Endorsements

Endorsements demonstrate organizational support for plug-ins in the form of a City Council or County Court resolution, a legislative resolution, or a statement of support from a local or national environmental, consumer or civic group or other organization. When an organization endorses the Plug-In Partners campaign, it is voicing its support for the mass production of PHEVs and will promote plug-ins to its membership.

## National Database

The City of Austin will maintain a national database at [www.pluginpartners.org](http://www.pluginpartners.org) to which rebate and incentive offers, soft fleet orders, the number of signatures collected by each locale and endorsements can be reported. Summary data will be maintained, and a summary report will be issued to all campaigns, the media and automakers on a quarterly basis.

## Available Tools

To assist in the development of Plug-In (name of City) campaigns, the following can be downloaded at [www.pluginpartners.org](http://www.pluginpartners.org):

- Sample City Council and County Court resolutions
- Sample “soft” fleet order form
- Petition for the collection of signatures
- Letters of invitation seeking participation by environmental and business groups
- Plug-In logo and this Plug-In Partners brochure
- Links to a variety of resources.



# Why Plug-in Cars?

**No Gas Required**

**Gasoline is expensive and dirty.**

**No Tailpipe Required**

**Electricity is cleaner and cheaper.**

**No War Required**

**Electricity is made in America.**

**We need choices.**

**Demand Plug-in Hybrids and Electric Cars.**

*Plug In America  
advocates the use of  
plug-in cars, trucks and  
SUVs powered by cleaner,  
cheaper, domestic  
electricity to reduce our  
nation's dependence on  
petroleum and improve the  
global environment.*



**[www.PlugInAmerica.org](http://www.PlugInAmerica.org)  
[info@pluginamerica.org](mailto:info@pluginamerica.org)**



## Now you can plug it in.

Over 100 miles per gallon for the Toyota Prius®.

With an EDrive™ upgrade installed in your 2004 or later year Toyota Prius, you won't miss those trips to the gas station as your daily commute driving range expands to well over 1000 miles per fill-up. EDrive allows a substantial amount of gasoline to be displaced by electricity when you charge nightly and drive locally. Using any 110V wall socket, your EDrive Prius can be plugged in overnight to recharge an expanded lithium-ion battery system. With a full charge, expect to see over 100 miles per gallon for the first 50 miles of your daily drive under average conditions. On the open road past 50 miles, or if you forget to plug it in, your EDrive Prius will behave like a normal Prius gasoline-electric hybrid.

### How does the EDrive system for the Toyota Prius work?

The stock nickel-metal hydride battery for the Prius is replaced with an advanced lithium-ion battery system with nearly 20 times the usable energy capacity. The battery control system on the vehicle is also replaced with custom EDrive hardware to encourage the Prius to make use of the expanded battery. At low speeds and mild driving conditions, the Prius will behave like an electric car using only the battery and electric motors. Even at higher speeds when the gasoline engine is running, EDrive injects additional electricity from the battery to further reduce gasoline consumption.

EDrive can be installed in the rear of a Prius in less than a day without touching the motors, engine or hybrid control system up front. The lithium-ion battery system fits entirely under the rear cargo carpet.

The EDrive system for 2004 and later year Toyota Prius will be available in Southern California in early 2006 for an expected retail price (installed) of \$10,000-\$12,000. EDrive certified installers will open in other locations nationwide by late 2006. EDrive will soon announce systems for other hybrid vehicles including the Ford Escape® hybrid.

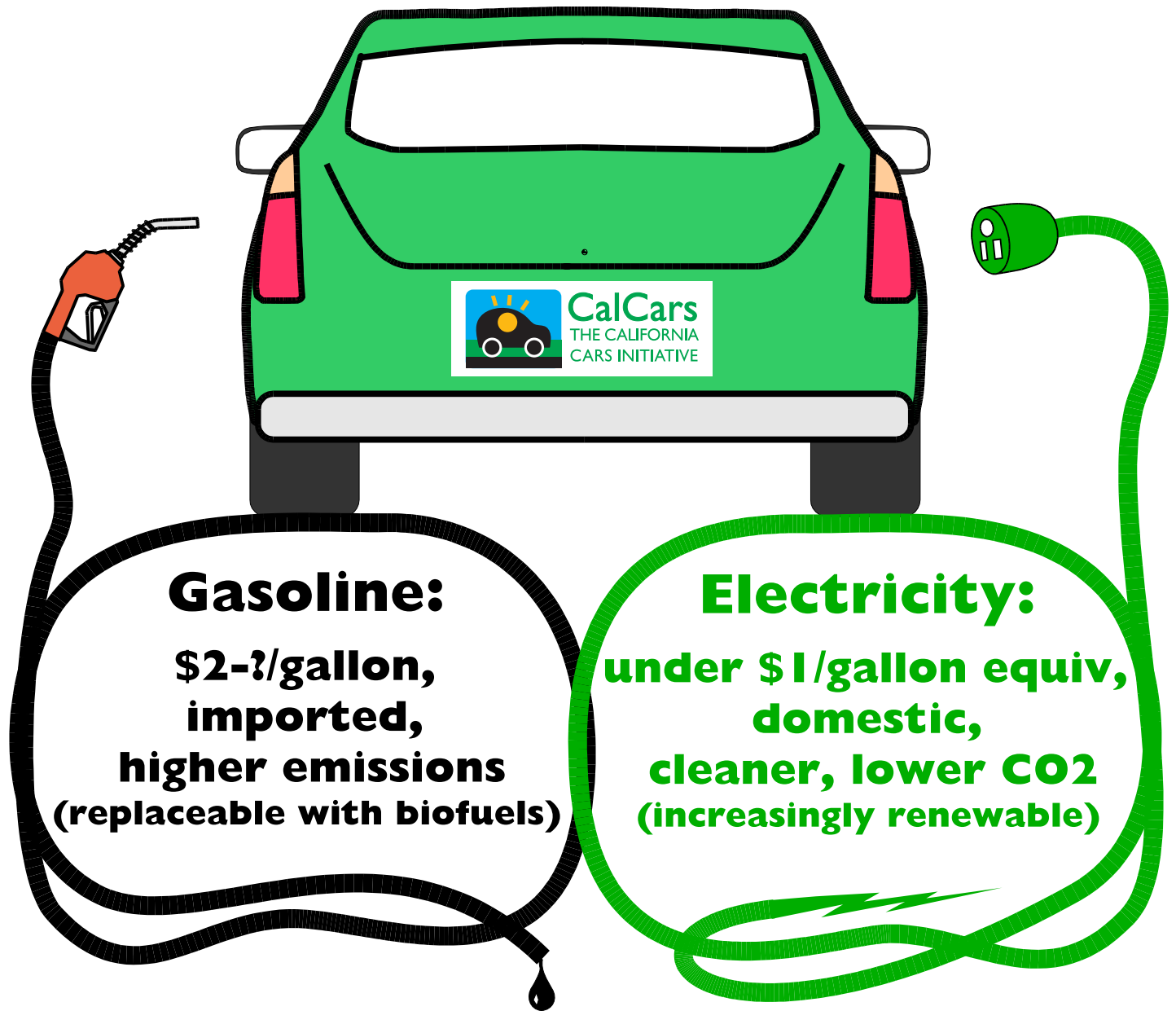
For more information about plug-in hybrid technology, please visit our web site at [www.edrivesystems.com](http://www.edrivesystems.com).



**EDRIVE**™



# 100+MPG plug-in hybrids: all-electric daily driving! gas for unlimited range



## **Gasoline:**

**\$2-3/gallon,  
imported,  
higher emissions  
(replaceable with biofuels)**

## **Electricity:**

**under \$1/gallon equiv,  
domestic,  
cleaner, lower CO2  
(increasingly renewable)**

# **One way or another, you're plugging it in.**

**The California Cars Initiative [www.calcars.org](http://www.calcars.org)**