



PRIUS+ Fact Sheet December 4, 2005



Photos of some of the people involved in the formation of CalCars (2002), creation of the first PRIUS+ (2004) and the EnergyCS and EDrive Systems prototypes (2005). For more identifications and details see <http://www.priusplus.org>

FACT SHEET: CalCars PRIUS+ Conversions **version 1.12 Decmber 4, 2005**

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This summary of three conversions completed since fall 2004 brings you up to speed on what we've done -- and where we're heading. This Fact Sheet is a work in progress (check at <http://www.priusplus.org> to make sure you're reading the latest version, and, if you're reading the email version, pick up a neatly formatted (currently 4-page version). For the latest technical discussions, see the **EAA Conversion Group** URL below. Subscribe to the **Newsletter** to keep up with the latest news coverage and milestones.

Note that all our mpg reports also include electricity use -- no free lunch!

Contact us if you're interested in becoming involved!

-**Felix Kramer** fkramer@calcars.org Founder, California Cars Initiative

-**Ron Gremban** rgremban@calcars.org -- Technical Lead, PRIUS+ Project

<http://www.calcars.org> and <http://www.priusplus.org> Info

<http://groups.yahoo.com/group/calcars-news> CalCars-PHEV Newsletter

<http://groups.yahoo.com/group/priusplus/> PRIUS+ PHEV Conversion Group

1. 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**, completely replacing Prius 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. (nominal 12 Ah, 2.4 kWh total at the car's high discharge rates, 216 Volt, 260 lb without associated hardware and components). (Pack replaced with new PbA batteries Oct 2005, after 11 months and approx. 200 charging cycles, pack 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 standard 120-volt outlet in 3 hours with Brusa NLG5 charger from MetricMind.com. (cheaper charger, longer time for larger packs).

* **Battery Management System and Controller/Display Unit** (CDU) by Energy Control Systems Engineering (EnergyCS.com) of Monrovia, CA,

replaced Toyota's Battery ECU. No change to the rest of Toyota's Hybrid Synergy Drive (HSD) -- what used to be called Toyota Hybrid System (THS).

* **Data** from battery and CAN (Controller Area Network) bus interface.

Dashboard analog meters display battery voltage and current. EnergyCS in-dash digital display includes battery voltage and current, Amp-hours used from the battery, vehicle power requested (e.g. via throttle position), battery state-of-charge (SOC) reported to THS, and gas used/trip (thousandths 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 the 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 gasolinemileage, or mixes of the two. Then operation reverts to normal HEV mode, still using the new battery pack.

2. PHEV PERFORMANCE DATA WITH LEAD-ACID BATTERIES

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

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

The following examples show improved performance (expected to be better with lighter, more efficient batteries. IMPORTANT: low PHEV and HEV mileage is due to short runs, hilly Marin County terrain, and other local factors.

* **Under 10-mile** all-electric propulsion (at under 34 mph), **infinite mpg** (i.e., no gasoline use) plus 262 grid Watt-hours/mile vs. 40-45 mpg as a 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 ability to store more recovered energy -- 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.)

3. ADDITIONAL PROTOTYPES, CONVERSIONS FOR CONSUMERS

* **Nickel-metal hydride (Ni-MH)** (30 Ah, 6.5 kWh, 190 lb extra after removal of existing battery); up to 20-25 mile all-electric range or 40-50 mile assisted range. In Oct 2005, CalCars [announced](#) a development program with [Electro Energy Inc.](#) (NASDAQ EEEI) to test their bi-polar Ni-MH batteries.

* **Lithium-ion (Li-Ion)** (35-40 Ah, 9 kWh, 160-190 lb extra after removal of existing hybrid battery) for the EnergyCS Prototype/EDrive cars (see next section); up to 30 mile all-electric range or 60 mile assisted range. Improved performance as well as additional electric range can be expected from the above batteries, due to significantly lower internal resistance losses.

* **"Do-It Yourself" project** for advanced experimenters with experience in high-voltage projects initiated by the **Electric Auto Association** in October 2005, timetable for specifications and plans undetermined.

* New efforts by CalCars on other platforms, including Ford Escape Hybrid.

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

* For the latest details (between updates of this Fact Sheet) see the CalCars Vehicles page and subscribe to our **CalCars News** (see section 5 below).

4. VERY PRELIMINARY ENERGYCS LI-ION PERFORMANCE DATA

EnergyCS's version of PRIUS+, completed Feb. 2005, uses off-the-shelf [Valence Technology](#) Saphion U Li-Ion batteries (for pack spec see Section 3 above), 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 to be available in 2006 from EDrive Systems.** (CalCars and EDrive have no contractual or relationship; we support their efforts.)

Equivalent mpg numbers and operation costs depend on patterns of use (total miles driven/day, speeds driven). EnergyCS will document performance under third-party testing auspices. Following are examples reported by EnergyCS:

* 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 ability to store more recovered energy -- 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).

5. HOW AND WHEN CAN I GET A PLUG-IN HYBRID?

Thanks for asking. Quick answer: most people will have to wait for automakers to build them. To keep people up-to-date on the progress of CalCars, plug-in hybrids (PHEVs) in general, and conversions, please join our CalCars-News

list. At <http://groups.yahoo.com/group/calcars-news>, you can subscribe to our low-traffic newsletter -- or watch the News Archive for our progress.

Prius conversions will operate like any other Prius, with no necessity to drive slower or differently. They will re-charge overnight from conventional 120-volt outlets (no need to hunt for a place to plug in during the day).

The initial EDrive Prius systems are proof of concept prototypes. EDrive Systems, LLC is working with technology partners EnergyCS, Clean-Tech and Valence Technology to reduce component, manufacturing and installation costs. EDrive's goal is to have a commercial retrofit option available in 2006 with an installed cost of \$10-\$12,000. Initial systems will be installed in Southern California. Additional licensed installers may make EDrive systems available elsewhere later in 2006. To find out more, see **EDrive Frequently Asked Questions** at <http://www.edrivesystems.com/EDrive-FAQ.html>

EDrive's first conversions will be for 2004-2006 Prius (not 1997-2003 "Classic"). Later, conversions from EDrive, CalCars or others, including the EAA project described in Section 3 may be possible for other Toyota and Ford hybrids. Because of Honda's different architecture for Insight, Civic, Accord (in Integrated Motor Assist cars, the engine always runs when the electric motor is in use), and we'll wait for Honda to make PHEVs.

Toyota could decide that the conversion voids some or part of your car or hybrid system warranty (unless the company worries that will tarnish its green image). We won't know how dealers will respond to service requests for this car until we start driving them. Read the Specialty Equipment Marketing Association [perspective](#) on warranties and aftermarket conversions.

To learn more about PHEVs, hybrids and alternative fuel vehicles:

<http://www.seattleeva.org/wiki/EAA-PHEV> -- Electric Auto Assn. conversions

<http://groups.yahoo.com/group/priusplus/> - PRIUS+ PHEV Conversion Group

<http://groups.yahoo.com/group/gridable-hybrids> -- PHEV general discussions

<http://groups.yahoo.com/group/Prius-2G> -- 2004 Prius issues

http://groups.yahoo.com/group/Prius_Technical_Stuff -- Prius nuts and bolts

<http://www.priuschat.com> -- general Prius info and talk

<http://www.hybridcars.com> -- all about hybrids

<http://www.evworld.com/electrichybrid.dfm> -- focus on PHEVs at site for general coverage of alternative fuel and advanced technology vehicles

Meanwhile, we thank you in advance for your encouragement, and hope you'll spread the word about our efforts. If you know of any individuals in a position to discuss fleet purchases, provide us with substantial support or celebrity endorsements, please send them our way. If you want to contact automakers to tell them you'd like PHEVs, we suggest you contact your local dealer, and feel free to send a copy of any email you write to info@calcars.org.

6. INTRODUCING CALCARS, SPONSOR OF THE PRIUS+ PROJECT

The California Cars Initiative <<http://www.calcars.org>> is a Palo Alto-based nonprofit startup. We're a group of entrepreneurs, engineers and environmentalists promoting high-efficiency, low-emission cars and harnessing buyer demand to help commercialize advanced technologies. Somewhat uniquely, we focus both on public policy and technology development. Formed in 2002, our efforts for "100+MPG Hybrids" began to be noticed in early 2005 when we were covered in The New York Times, Business Week, TIME, Newsweek, National Public Radio, and local and national TV. (See <<http://www.calcars.org/kudos.html>> for print, audio and video clips.)

We're demonstrating the immediate opportunity and benefits of "plug-in" hybrids (PHEVs). The next generation of hybrid cars can be based entirely on existing components. They're basically like some current hybrids but with larger batteries and the ability to re-charge conveniently, so local travel is electric, yet the vehicle has unlimited range. We see it as the future pathway to multi-fuel and biofuel/cellulosic ethanol PHEVs -- the cars that get 500 MPG (of gasoline) that people are talking about. Here's how we describe PHEVs:

It's like having a second small fuel tank you always use first. You get to fill it at home with electricity at an equivalent cost of under \$1/gallon. How much under depends on your car and your electric rate. You refill from an ordinary 120-volt socket, with energy that's much cleaner, cheaper and not imported. Or another way of thinking about this: at \$3 for a gallon of gas, driving a non-hybrid car costs 8-20 cents/mile (depending on its MPG). With a PHEV, all-electric local travel and commuting can drop to 2-4 cents/mile.

We began with a prototype conversion we call "PRIUS+" to bring attention to plug-in hybrids and encourage car makers to build them. We "green-tuned" a stock 2004 Prius by adding batteries and grid-charging. (We replaced the battery control system but didn't modify the hybrid controls.) Our proof-of-concept used lead-acid batteries. We document our effort at our open-source-style technology discussion group at <<http://groups.yahoo.com/group/priusplus>> (see chronology from June '04-May '05 at <http://autos.groups.yahoo.com/group/priusplus/message/421>). We're working with **Electro Energy Inc.** (NASDAQ: EEEI) to demonstrate the viability for PHEVs of nickel-metal hydride (Ni-MH) batteries used in current hybrids: see <<http://autos.groups.yahoo.com/group/calcars-news/message/175>>. And we expect to work with other battery suppliers.

EDrive Systems LLC, a for-profit integration company in Southern California <<http://www.edrivesystems.com>>, installed even better lithium-ion (Li-Ion) packs to get 100+MPG (plus costs of electric power). EDrive intends to begin selling PRIUS+-style retrofits in early 2006, with a goal of pricing conversions at \$10-\$12,000. At <<http://autos.groups.yahoo.com/group/calcars-news/message/37>> on May 2 we explained how our efforts intersect. View their Frequently Asked Questions at <<http://www.edrivesystems.com/EDrive-FAQ.html>>. A separate group of engineers experienced with high voltage has started a "do-it-yourself" conversion project we are advising: <<http://www.seattleeva.org/wiki/EAA-PHEV>>.

We're also involved in advocacy and public policy, bringing together the growing attention given to this "up-and-coming" technology. New organizations that

have in part been catalyzed by our efforts include **SetAmericaFree**, **Plug-In Austin** (soon to go national as Plug-In Partners), **PlugInAmerica**, and a trade association, the **Plug-In Hybrid Consortium**. A bipartisan Congressional coalition has introduced legislation promoting flex-fuel plug-in hybrids. We're educating the large market of car buyers who will pay extra for all the benefits to them and society of better cars. We're presenting PHEVs, along with wind and solar power, as a coordinated response to two of today's greatest challenges: global warming and energy security. We've spoken at high-visibility venues including the Palo Alto Research Center (former Xerox PARC) Forum. We've recently engaged with noted designer/architect William McDonough, responsible for the new Ford River Rouge plant, to incorporate Cradle to Cradle approaches to our future strategies.

Our goal is to motivate automakers to build PHEVs for a market we expect to expand as the Kyoto Protocols and parallel state and international greenhouse gas initiatives are phased in. We're exploring with public officials ways to provide incentives to auto makers to build PHEVs.

Working with other PHEV advocates, we're developing innovative ways to meet expected demand from utility, government and corporate fleets, and early adopters for 10,000-100,000 vehicles before a car company delivers production PHEVs. To take advantage of that who-knows-how-long window of opportunity, we're exploring ways for a California company to partner as a **Qualified Vehicle Modifier (QVM)** with an auto maker to design, assemble and sell PHEVs -- at a price several thousand dollars higher than conventional hybrids, which would provide a lower lifetime cost of ownership than any other vehicle type. For info on our plans see <<http://www.calcars.org/sjmercury-vcinsider+calcars-opportunity.pdf>>. Conversion possibilities include the Ford Escape hybrid, forthcoming hybrids from Hyundai and others, and all cars that use Toyota's "Hybrid Synergy Drive" (Prius, Lexus, Highlander, Nissan).

We're a mostly-volunteer effort. We've gotten contributions from, among others, a well-known entrepreneur and the Energy Foundation, with others to come. We accept tax-deductible donations and offer a unique bumper sticker to Charter Sponsors.

Founder Felix Kramer says, "I'm a startup person and environmentalist going way back <<http://www.nlightning.com/resume.html>>. In 2001, I sold eConstructors.com (marketplace for web development) and began advising Rocky Mountain Institute/Amory Lovins' Hypercar Inc. My change in focus from that futuristic simulation to immediate solutions led to the launch of CalCars in 2002. My personal motivation evolved from general environmental goals to seeing PHEVs as a keystone component of a strategy to address global warming both nationally and internationally. See <<http://www.calcars.org/globalwarming.html>>. I envision millions of PHEVs, charged from off-peak electricity from a modernized grid and from distributed photovoltaic and wind power, with the range extension engine powered by zero-carbon cellulose ethanol, as a way to significantly reduce the more than 30% of greenhouse gases that come from transportation. See my blog, Power, Plugs and People at <<http://www.hybridcars.com/blogs/power>>."

California Cars Initiative info@calcars.org
PO Box 61045 Palo Alto, CA 94306