Plug-In Hybrid Electric Vehicles (PHEVs)
Contributors: Bichlien Hoang

Visit: http://www.ieee.org/go/emergingtech

It may sound like science fiction today, but the era of the Plug-In Electric Hybrid Vehicle (PHEV) is about to begin. Currently, a PHEV is defined as a car, truck or other vehicle that can be driven solely by an electric motor for at least ten miles without consuming any gasoline (called a “PHEV-10”), and with batteries that can be recharged by plugging it into a wall outlet. The PHEV is seen as a game-changing technology that will have a major impact on our lives over the next several decades.

As one small example, getting ready for work in the morning will have at least one extra step: take a shower, eat breakfast and…..unplug the car. Of course, this last step could be optional if your garage is equipped with the latest wireless battery charger connecting car and A.C. power grid automatically.

While recharging at home would usually take place at night, it could also be done during the day at work where the needed electric power could come from the grove of solar trees shading the parking lot.

The drive home will be different too. When last night's charge gets you a 100 mile range without using a drop of gasoline, you'll only stop at your favorite gas station six times a year instead of six times a month.

Yet another change: having your car generate a little extra cash.

Today, utilities pay billions a year to keep power plants on standby. If a million Vehicle-to-Grid (V2G) cars were on the road by 2020, they could generate up to 10,000 megawatts of electricity –about the capacity of 20 average-size power plants. And with the right V2G electronics, once you park and plug in, you could sell your excess capacity to your local power company! This application alone will require rethinking many of our current assumptions about what is a generator and what is a load. It will also require sophisticated electronics to wirelessly communicate with the parked car to determine its geographic location and state of charge.

Standard hybrids like the Toyota Prius, Honda Civic and Ford Escape, have much in common with PHEVs except they use no electricity from the power grid. All incorporate an internal combustion engine, a generator for recharging and an electric motor. However, the electric motors in these cars only drive the wheels during acceleration, while a PHEV’s motor can drive the wheels continuously as long as the vehicle is within its rated all-electric range (e.g., 80 miles for a PHEV-80).
In May 2006, CalCars founder Felix Kramer happily reported on a typical day driving his converted plug-in Toyota Prius. After 51 miles of mostly highway driving, he averaged 124 miles per gallon (mpg) and 123 Watt-hours per mile of electricity. He used only 39% of the gasoline he would have used in a standard Prius, and reduced greenhouse gas emissions by nearly two-thirds. With gasoline at $3 per gallon, and electricity at 8½ cents per kWh, it cost him $1.76 instead of the $3.17 it would have cost before his Prius become a plug-in.

While PHEVs are not yet in production, in August 2007 Toyota began PHEV road tests. Also, Toyota, General Motors, and Ford have all announced their intention to introduce PHEVs in the near term. In January, 2007, GM unveiled the Chevrolet Volt, a PHEV-40 concept car designed to run all-electric for the daily commutes of most Americans (in 2003, 68% of U.S. workers reported a one-way commute of 15 miles or less). Using a small internal combustion engine hooked to a generator to recharge the batteries, the vehicle’s range can potentially be increased to 640 miles for highway driving.

Conversions of standard hybrids are also available from conversion kits and conversion services. The most prominent PHEVs on U.S. roads today are conversions of 2004 or later Toyota Prius hybrids, which add batteries to extend their electric-only range and add a plug for recharging. As recently reported in IEEE Spectrum, CalCars is now selling a do-it-yourself Prius conversion kit to turn a standard Prius into a PHEV Prius for US$5000.

**PHEV Benefits**

In addition to cutting fuel costs and increasing national security by reducing dependence on foreign oil, PHEVs also offer many other benefits. In July of this year, the Electric Power Research Institute and the Natural Resources Defense Council, issued the results of a environmental study of PHEVs. Among the study’s key findings were:

- Widespread adoption of PHEVs can reduce Greenhouse Gas (GHG) emissions from vehicles by more than 450 million metric tons annually in 2050 — equivalent to removing 82.5 million passenger cars from the road. This is a particularly important finding in an era when the U.S. is consuming 25% of the world’s energy with only 5% of the world’s population, when 40% of world oil output fuels the automotive industry, and when U.S. cars and light trucks are responsible for 45% of the CO2 emitted by automobiles globally.
- There is an abundant supply of electricity for transportation; a 60 percent U.S. market share for PHEVs would use less than 8% of grid-supplied electricity in 2050.
- PHEVs can improve nationwide air quality and reduce petroleum consumption by 1 – 1.5 billion barrels annually by 2050.
PHEV Challenges

From a recent report on PHEV research by the Argonne National Laboratory, there are at least three hurdles that must be overcome before PHEVs can be considered to be commercially viable:

- Increasing the reliability and performance, and reducing the cost and size, of PHEV batteries is crucial. U.S. Department of Energy (DOE) research is currently focused on lithium chemistries. Moreover, PHEV batteries, which can weigh hundreds of pounds, could pose a major environmental hazard unless regulated by mandatory recycling.
- The cost of power electronics, inverters, and controllers must also be reduced to produce a faster payback period for PHEV buyers.
- As yet there are no agreed-upon test and evaluation procedures for PHEVs.

Google.Org’s RechargIt RFP

Hoping to jump-start innovation in "sustainable transportation," Google.org - the search giant's philanthropic arm - recently issued a $10 million Request for Proposals (RFP) due Oct. 22, 2007, for projects that will “promote the commercialization of plug-in hybrid vehicles, electric cars and vehicle-to-grid technology.” The grants are part of Google.org’s RechargIt initiative. In June, 2007, the company unveiled a solar-powered parking bay and recharging stations it created with utility PG&E (PCG) where a fleet of PHEVs can be recharged for an employee car-sharing service. Google is also testing several converted Toyota Priuses to serve as mobile generators, transferring electricity back to the grid from their batteries during times of peak demand.

X Prize Foundation’s Automotive X Prize (AXP)

The X PRIZE Foundation “creates and manages prizes that drive innovators to solve some of the greatest challenges facing the world today.” In April 2007, the Foundation released the Automotive X PRIZE Draft Competition Guidelines. The stated goal of the Automotive X PRIZE (AXP) is “to inspire a new generation of super-efficient vehicles that help break our addiction to oil and stem the effects of climate change. The Automotive X PRIZE competition will focus on tangible results - the creation of practical, clean and super-efficient vehicles that people want to buy.” An informative AXP white paper can be found here: Why the Automotive Industry is Ripe for a Prize.