

Alternate Fuel Technology - Hybrid Electric Vehicles

This is another in a continuing series of articles on alternate fuel vehicles and advanced technology vehicles. Please direct comments or questions to ASE's Bob Rodriguez at 703-713-3086 or brodriguez@asecert.org.

Rising gas prices have generated a wave of public interest and publicity about gas-saving hybrid electric vehicles (HEVs), and for good reason: Hybrids make good sense. Yet J.D. Powers studies show that only 19% of people interviewed are "somewhat knowledgeable", and 51% are not familiar at all about HEV technology. If you read the preceding issue of ASE *TechNews* (Summer 2001), you're already ahead of the curve.

to augment the primary power source. Under prescribed driving conditions, the secondary source will assist or even take over propulsion of the vehicle. In some hybrid designs, secondary power is used exclusively at low speeds or in urban traffic environments to reduce pollution and save fuel. While a variety of primary and secondary power sources may be employed (including plug-in power), the ultimate focus of R&D seems to be on developing zero-emission hydrogen fuel cells for hybrid EVs. Besides the basic series and parallel hybrid

powertrain systems described earlier, hybrids are often configured to operate in a variety of cross configurations.

To give you an idea of the extent of HEV activity going on, listed below are U.S. market-released hybrid automobiles, and some of those (hopefully) becoming available soon. Note that specifications are drawn from a variety of data sources; because the HEV landscape changes almost daily, the information included is subject to change. For the most current data, it's best to check with the OEs (See the sidebar listing online resources.)

U.S. Sold ICE Hybrid EVs

Honda: The *Insight* is a gasoline-electric 2-seater parallel HEV sports coupe featuring a 12 valve, 3 cylinder, 1 liter gasoline "VTEC[™] - E lean burn" engine. Insight's engine provides 67 hp / 66 lb. ft. of torque, has variable valve timing, and a 10.8:1 compression

ratio. The engine runs whenever the vehicle is underway, but shuts off under "idle-stop" situations. Power assist comes from a 10 KW PM motor. The 5 speed manual trans and NiMH batteries help the Insight get 70 EPA test mpg and over 600 miles of driving range. A lightweight aluminum chassis and special low rolling resistance tires help to achieve this goal. The Insight demonstrates the fuel economy gains possible using hybrid technology. Insight's Integrated Motor Assist (IMA) powertrain will be in the 2002 Civic, and will likely spread to other Honda models. A continuously variable automatic transmission will also be offered.

Toyota's Prius is a 4-5 passenger sedan touted as the "vehicle for the millennium." The gasoline-electric HEV features a 1.5 liter, 16 valve, 4 cylinder "low-rev" engine with reduced pumping losses and maximized thermal efficiency and fuel economy. A "high expansion ratio cycle" Atkinson cycle engine with variable delayed intake valve closing and 13:1 CR provide 70 HP / 82 lb. ft. of torque. The gasoline engine only runs when needed. Power also comes from a 33 KW / 258 lb. ft. PM electric motor. The planetary type "power-split" electronically controlled variable transmission (ECVT), regenerative braking, and NiMH batteries help current U.S. models get around 50-56 mpg and a driving range of 550-600 miles. (Images of the Insight and Prius appeared in the Summer 2001 ASE *TechNews*)

ICE Hybrid EV Automobiles under Development for the U.S. Market

Most industry experts recognize the heat-engine (ICE) powered hybrid EV will be an *interim step* to-

wards achieving near pollution-free (hydrogen powered) transportation and cargo handling. Projections indicate that hybrid-powered vehicles will take market share from conventional vehicles over the next 10-20 years. Purchase prices will depend on economy-of-scale, and government and OE subsidies. While some hybrids offer modest fuel economy improvements; others meet or exceed the stringent 80-mpg Partnership for a New Generation of Vehicles (PNGV) benchmark. Fuel cell hybrids will be discussed in a future *TechNews* article, but heat-engine hybrids

in the next couple of years might include:

Ford: *Escape* is Ford's hybrid SUV to be released in 2003. Ford cites the *Escape* as getting "nearly 40 mpg under city driving conditions." *Prodigy* is Ford's family PNGV hybrid entry. It uses the energy efficient DIATA 1.2 liter, 4 cylinder diesel engine (which shuts off at vehicle standstill), a combination manual/automatic trans, and aerodynamic features to get nearly 80 mpg. The prodigy utilizes Ford's LSR (low storage requirement) powertrain technology to help reduce vehicle weight and meet PNGV objectives. Ford also has announced a HEV *Explorer* for 2004 using Volvo's hybrid design system.

DaimlerChrysler: *Durango* hybrid SUV slated for 2003 uses the "through the road" system (described in the previous article) for a modest 15% mpg gain and reduced tailpipe emissions. A 3.9 liter engine powers the rear wheels, and a 3 phase AC motor the front. Combined city/highway mileage of 18.6 mpg is reported. The *Dodge RAM* hybrid-electric pickup features a 15% mpg improvement, but can supply up to 20 kilowatts of electrical energy for auxiliary power use. *Dodge's ESX3* is an exciting PNGV 5 passenger family sedan entry which gets 72 mpg and features an all-aluminum 1.5 liter diesel (6 gallon tank of zero-sulfur fuel) and lithium-ion batteries; its range is 400 miles. DaimlerChrysler also will offer its 8 passenger *Powerbox* SUV with a 2.7 liter V-6 CNG fueled ICE, and a 70 hp electric motor to get 25 mpg GGE (gasoline gallon equivalent), and a 350 mile range. Rated SULEV, the *Powerbox's* top speed is reportedly 125 mph, doing 0-60 in seven seconds.

General Motors: *Precept* - a highly technologically advanced PNGV 5 passenger mid-size 4WD car- is reported to achieve around 80 mpg, and over 90 on the highway using a 3 cylinder, 1.3 liter CIDI Isuzu diesel engine paired with two electric motors. One electric motor powers the front wheels and the other adds motive

power as required or serves as a generator to recharge the batteries. Power reaches the wheels through an automatically shifted manual trans, and the sleek *Precept* uses a 3 camera rear-vision system to eliminate drag associated with exterior rear-view mirrors. GM is also working on its *ParadiGM* hybrid system for

2004, featuring a 3.6 liter V-6 powered hybrid SUV with 2 electric motors for a 20% mpg improvement. GM claims it will also offer a full sized *Silverado/Sierra* style HEV pickup in 2004 with a 15% mpg improvement over the conventional ICE designs.

Pininfarina: *Metrocubo* is a mini 5 passenger sedan with a 505 cc, 2 cylinder Lombardini Motori MPFI engine, and a Siemens 35 KW liquid cooled motor which runs up to 10,000 rpm. *Metrocubo* has regenerative braking and a single-speed fixed ratio transmission.

Medium and H-D Hybrid EVs under Development for the U.S. Market

Medium and HD applications are also rapidly moving to HEV technology (see page 6), and promise to provide an even greater return on HEV research investment. Trucks and buses typically rack up highway mileage with its associated emissions, and stop-and-go urban vehicles operate where tailpipe emissions must be curtailed. Both driving situations lend themselves to hybrid technology. Engine manufacturers like Cummins, GM and others, along with truck & coach and drive system manufacturers are working together to produce HEVs, often co-partnering with state and federal agencies. Along with clean fuel diesel ICEs, natural gas or propane fueled microturbines are being used for electro-motive power.

The military is testing a hybrid version of its *HMMWV*, powered by a 1.9 liter diesel and two 125 hp brushless DC motors—one for each axle. Using one-half the fuel normally needed, it gets around 15 mpg, can travel at 70 mph and climb a grade of 60% while fully loaded at 10 mph. It can operate in a battery-only "stealth mode," or can serve as a 55 KW field generator.

Overseas Offerings— For Sale, or Soon to Be...

An admittedly partial list of overseas ICE powered hybrid automobiles to keep an eye on might include the following:

(continued on page 6)



Ford Escape

You'll recall that hybrids are here, and many more are coming. In this article you'll find out who's doing the R&D, what kind of vehicles to expect, and perhaps most important, how to tap into the wealth of knowledge available on hybrid EVs and keep up to date.

Hybrid vehicles use "two or more energy conversion technologies." Often, an internal combustion or "heat" engine (ICE) using gasoline or diesel fuel develops primary power for traction and driving the on-board generator. Other fuels used include natural gas, propane, ethanol, methanol and dimethyl ether, and other engine types include natural gas and propane powered micro turbines, and hydrogen fuel cells (more on fuel cell vehicles in future editions).

Hybrid EVs also use a source of stored secondary backup power, such as advanced batteries, ultracapacitors, or even flywheels,



GM Precept

Want more Info on Hybrids?... Online Resources

Hybrid-electric vehicle (HEV) R&D is going on in many countries. To find out where and by which OEs, do an on-line data search using key words like "hybrid electric vehicle." Listed below are some websites to get you started.

Hybrid Electric Vehicle Information

- EIN Publishing** — www.eco-web.com/cgi-local/sfc?a=index/index.html&b=register/06161.html
- ETVI** — www.etvi.org/ (click on the electric car picture > "Just the Facts" > "What is a Hybrid EV")
- EV World (news)** — www.evworld.com/archives/main.html
- Hybrid Vehicles (news)** — www.energy-futures.com/
- Intertech** — www.intertechusa.com/Division_Energy/index.htm
- NE Sust. Energy** — www.nesea.org/
- NE Vehicle Consort.** — www.navc.org/
- NREL** — www.ctts.nrel.gov/
- PNGV** — www.ta.doc.gov/pngv
- RP Publishing** — www.rppublishing.com
- SAE** — www.sae.org/servlets/techtrack?PROD_TYP=PAPER (search: hybrid vehicles)
- SW Research Inst.** — www.swri.org/4org/d03/vehsys/home.htm
- U.S Dept. of Energy** — www.afdc.doe.gov/afv/hybrid.html
- Your Next Car (org)** — www.yournextcar.org, <http://www.yournextcar.org/Hybrids.html>, <http://www.yournextcar.org/Resources.html>

Vehicle-Specific HEV Sites

- DaimlerChrysler** — www.daimlerchrysler.com/index_e.htm?/products/products_e.htm
- Fiat** — www.torque.co.za/Upmodels/mar00/multipla9.htm
- Ford** — www.ford.com/ (click on: environmental vehicles)
- GM** — www.gm.com/company/gmability/environment/products/technologies.html
— www.gm.com/company/gmability/environment/gm_and_the_env/releases/release_hybrid080200.html
- Honda** — www.hondainsight.com/
- No. Am. Bus Ind.** — www.nabiusa.com
- Nissan** — www.nissan.co.jp/MS/TOKYO00/ENGLISH/MAIN/enviro8.html;
— www.21stcentury.co.uk/cars/nissan_tino_hybrid.shtml
- Renault** — www.renault.com/presse/document/RP_D_1226996708.doc
- Solectria** — www.solectria.com
- Toyota** — prius.toyota.com/

HEV Training

OE technician training — American Honda; Toyota Motor Sales USA

Aftermarket training

- Automotive Career Development Center** — www.auto-careers.org/
- Mid-Del Technology Center** — www.evtraining.com/ (click on "hybrid technology")

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In Japan, Toyota's *Prius* (supposedly achieving 80+ mpg) and Honda's *Insight* are sold with somewhat different configurations and reconfigured software. This summer Toyota will also sell the hybrid *Estima* van. Nissan is offering the frugal compact 5 passenger *Tino* HEV minivan featuring a 1.7 liter gasoline engine, 17 KW motor, lithium-ion batteries and a continuously variable transmission (CVT). Hino is developing a hybrid bus for mountainous roads and extended highway travel. The HEV bus features a small supercharged diesel engine and a high degree of regenerative braking (used on downslopes) to save brake lining wear and provide almost complete battery recovery. Hyundai is reportedly developing a 30 KW microturbine powered SUV called the *Sante Fe*.

In France, Renault has two new hybrid vans, the *Modus* and *Operandi*, which use only battery-electric power in the city, then switch

to hybrid mode once outside city limits. Renault's *Koleos* is an all-terrain hybrid 4WD, 2 liter turbocharged SUV with lithium ion batteries powering a 30 KW motor driving the rear wheels. In Italy, Fiat's *Multipla* hybrid sedan (not yet released) can be plugged in overnight, and can be run in three different modes—including battery-only for ZEV compliance. In Germany, BMW, Opel, DaimlerChrysler, Mercedes Benz, et al. are involved in hybrid EV research—check the web for further details.

Other developments

To further shave weight, improve economy, and lower emissions of hybrid (and other) vehicles, you'll see "ultracapacitors" being used not only for traction power reserve, but also at accessory locations (power door/trunk locks and window lift motors) to store up to 10X electrical energy reserve until it is needed. Flywheel "batteries" are still under development but look promising. Increasingly,

the use of bi-directional multiplexing (*Prius*) and fiber optics communications between components is being used to save power and weight, and vehicles will soon switch (as early as next year-Nissan) to badly needed 42 volt charging / 36 volt battery systems. The higher voltage system allows for the ultimate elimination of engine drive belts, and the addition of components/features like electronically controlled variable valve timing (no camshaft), electric steering and AC. Drive-by-wire and brake-by-wire systems will become commonplace as will navigation, communication, and collision avoidance systems.

If you think these hybrid electric vehicles with their futuristic designs and systems are way down the road, think again. Some are already here, with more just around the corner. Technologies only dreamed of a few years ago are becoming reality. Stick around—it's an exciting time to be an automotive technician!

U.S. Hydro-Electric Trucks and Buses On The Road (or soon to be)*

OEM	Model	Power
Advanced Vehicle Systems	AVS-22 shuttle bus; AVS-30,35, and 40 transit bus	CNG, LNG (microturbine), diesel
APS	22 to 40 foot transit bus	
DUETS project	urban transit bus (3 types)	NG
ISE Research-Thundervolt	TB-30H bus and 801H truck	NG & propane (microturbine)
New Flyer	transit bus	diesel
Novabus	urban transit bus	diesel
Orion	urban transit bus	diesel
TransTeq	45 foot (specialty) transit bus	CNG
Van Hool N.V.	A308H (low floor) shuttle bus	CNG

* This list is offered for information only and is not to be considered all-inclusive.

(Future TechNews articles will cover Fuel Cell (hybrid-electric) Vehicles (FCVs) and other alternative fuels.)

