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Recharging the Electric Car

Twelve months ago, **Toyota Motor Corp.** [TM] was crowing over the headway its Tundra pick-up had made in the U.S. full-sized truck segment. At the time, the company had seemed on track to be the first automaker to break the 10 million annual sales barrier by 2009.

Its hopes were dashed, however, this August when Toyota announced to investors that it was trimming 2009 vehicle sales forecast by nearly 7%, from 10.4 million to 9.7 million. It blamed sagging demand for large cars, SUVs and pickup trucks, and a worsening credit crunch.

But Toyota hadn't become the world's most profitable automaker by ignoring prevailing market trends. It tempered its negative forecast by also announcing its Mississippi plant would boost production of its more fuel-efficient Prius gasoline-electric hybrid sedan.

Even before crude oil prices peaked around $150/barrel last July, analysts—and motorists—had become convinced that the long-term economic, strategic and environmental costs of fossil fuels will only continue to trend upward. That conviction remains despite the free fall in oil prices this month, and it continues to fuel speculation in emerging automotive technologies that might minimize or entirely eliminate the reliance on foreign oil. As the biofuels sector searches for solutions more viable than ethanol (*see "Super Bugs May Save Bio-Fuels", February 2008*), automakers have focused on developing new electrically powered designs that minimized both fuel consumption and carbon emissions.

Barring development of some breakthrough alternative fuel, the brass ring for auto designers is a vehicle that is identical in every way to conventional gas-powered cars—minus the gas-powered engine. The most developed candidate power sources include hydrogen or electricity—the latter coming either from a battery or a fuel cell. As Toyota's Prius and hybrids from **Honda** [HMC] and **Ford** [F] indicate, electrically-driven power trains have a healthy head start. But, like hydrogen-powered engines, the pure-electric car remains a long-term solution at best, even with recent advances in battery technology.

"In the automotive business, there are solutions that work, and there are solutions that make money," said Shahin Farshchi, an associate at Lux Capital and former **General Motors** [GM] engineer. "For now, that would suggest we can expect more hybrid electric-gasoline designs like the Prius."

Hybrid vehicles improve fuel economy in several ways. Their enhanced battery and electric motors enable smaller gas engines to do less work while driving, and eliminate fuel use when the car is idling. Hybrids are more compatible with regenerative braking technology, which channels some of the energy it takes to slow a car down back into its battery.

GM's all electric Chevy Volt

The race to develop a better hybrid has seen more failure than success. GM launched its ambitious EV1 hybrid car in 1999, when gas averaged $1.39 a gallon. Although some models could travel up to 150 miles on a single charge, GM claimed the car was a money loser and pulled the model off the road. Honda fared slightly better with its two-seater Insight hatchback, which the company retired in 2006 after selling a mere 18,000 units.

But it's just as risky for automakers to sit this race out. Since its launch in 2001, Toyota's Prius has sold 1.5 million units globally. By 2006, Toyota owned 78% of the hybrid market—45%, of which, represented the Prius alone.

Plugging ahead

The race to develop an all-electric vehicle is still in its early laps, and Toyota's competitors hope to catch up when the race reached its next evolutionary curve. Currently, most hybrids—including the Prius—use a so-called parallel drive train, whereby power is delivered to the wheels by the electric motor, the gas engine, or both.

Contenders for the next-generation hybrid aim to replace this complex and costly configuration with a series drive train, wherein acceleration is powered entirely by the electric motor. Although some consider series hybrids to be all-electric, the models proposed by GM, Toyota and others include a gas engine that can either power the motor or recharges the battery.

Another evolutionary leap waiting around the bend is Li-ion battery technology, which is on track to replace the nickel metal hydride (NiMH)

cells in today's hybrids. More on that in a moment, but one key benefit is how well Li-ion technology lends itself to recharging. Practically speaking, that opens the door for plug-in electric vehicles (PHEV) that owners can effectively "refuel" by plugging it into a standard 120-volt outlet.

California-based Tesla Motors wins technical points for being first to market with a zero-emission plug-in series-style hybrid based on Li-ion technology. With a 0 to 60 mph acceleration of 3.9 seconds and a 14,000 rpm redline, Tesla's Roadster silences any arguments that electric cars lack the performance ability of conventional vehicles. But with a price in the low six digits, the Roadster won't appreciably accelerate the rate of adoption for PHEVs.

That may explain Tesla's announcement this month that it plans to build a new plant in Silicon Valley, and begin rolling out a more approachable $60,000 Model S hybrid sedan by the end of 2010. Like the Roadster, the Model S is designed as a plug-in series hybrid.

Fisker Automotive, also based in California, is hot on Tesla's heels with plans to begin commercial production of its own $80,000 plug-in sports car sometime late next year, with a sedan model due out in another four or five.

By then, PHEVs could be old news. Toyota, Mitsubishi and Nissan all hope to have at least one model on the road no later than 2012, while Ford has voiced similar if more ambiguous ambitions for a plug-in version of its Escape SUV for demonstration.

"Everyone's talking about developing [a PHEV]," said Dave Cole, chairman of the Center for Automotive Research, a non-profit industry research group. "You can't not talk about it. But talking and doing are two different things."

GM appears farthest along the "doing" scale. The Detroit carmaker unveiled its all-electric Volt sedan this month, with plans for mass production in 2010. The Volt incorporates a series-style drive train based on a high-capacity Li-ion battery. GM claims the vehicle will range up to 40 miles on a fully charged battery—enough to fulfill most U.S. motorists' daily needs before needing to be recharged for six hours. Just in case the battery runs dry, however, GM added a small gasoline engine that will kick in to generate more electricity, bringing the Volt's full range to over 300 miles.

A higher charge

The key to the PHEV's success or failure will be its Li-ion battery. NiMH batteries helped enable the Prius and Civic hybrids by delivering twice the energy ounce-per-ounce than a conventional automotive lead-acid battery. Plus, NiMH cells are non-toxic, recyclable, relatively reliable and easy to maintain.

Li-ion technology nearly doubles the specific energy again, and it allows 5,000 recharge cycles compared to NiMH's 3,000, which makes it more suitable as a plug-in power source. The Volt has met all of its technology milestones so far, according to Cole, and his sources tell him that GM is developing a whole series of follow-on vehicles.

"That wouldn't happen if they were still running into technology roadblocks," he said.

The biggest downside of Li-ion batteries, however, is their cost. GM hasn't disclosed a price for the Volt, but optimistic estimates peg it around $35,000—nearly 75% more than the cost of a low-end Prius. A large chunk of that price tag stems from the Li-ion battery, which could cost upwards of $10,000.

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This challenge has led automakers to propose some innovative new business models, such as leasing the battery. Norway-based Think Global, for example, currently leases Li-ion batteries from **Ener1** [HEV] or A123Systems (*see "Billion Dollar Nanotech IPO Brewing", May 2008)* to buyers of its super-compact PHEV, the Think City.

California start-up Better Place is forwarding an even more ambitious proposal that, if successful, could address both the high battery costs of PHEVs and the absence of a comprehensive battery-charging infrastructure.

The company is applying the business model of wireless communications to the PHEV market. Namely, it intends to sell the PHEV, but not the battery. Instead, Better Place would own the battery as well as a national recharging network. Motorists would need to buy a subscription to tap into this network, but refueling would be simpler and faster. A computer chip in your car would synchronize daily recharging costs with a smart electric grid. For longer trips, you could simply swap batteries at an exchange station as quickly as it takes to fill your fuel tank today.

Power partners

Li-ion battery technology is still largely unproven in automotive applications, and several skeptics remain. Notable among them is Honda's CEO Takeo Fukui. Although his company aims to be selling 500,000 hybrids annually by next year, Fukui has publicly expressed his doubts about Li-ion technology's range.

That hasn't stopped some furious partnering between battery suppliers and automakers to develop the technology.

Mitsubishi is developing a large-capacity Li-ion battery in a joint venture with GS Yuasa, and last May Nissan finalized a partnership with NEC called Automotive Energy Supply Corp. to do the same. Meanwhile, Panasonic Electric Vehicle Energy—the Toyota and Panasonic JV that wields nearly 75% market share of the market for NiMH automotive batteries—announced it would add Li-ion cells to its production line in 2010.

Most eyes, however, are on Watertown, Mass.-based A123Systems, which is one of two contenders to supply the Li-ion battery for GM's Volt. The other is Compact Power, a Troy, Michigan-based unit of South Korean LG Chem.

GM, which owns about 5% of A123Systems, said it has already decided between the two, but hasn't revealed its choice. This has further tantalized investors considering the potential value of A123Systems' proposed IPO. The start-up claims its nano-enabled battery is safer, more durable and more powerful than other Li-ion cells. But it is perhaps more notable for turning its technology into profitable partnerships with big-name companies like **Black & Decker** [BDK], **General Electric** [GE] and possibly GM.

The road ahead

GM's gamble on the Volt has been called a "moon shot," alluding either to its lofty ambitions or its recent pattern of huge losses. After reporting a $38.7 billion loss for last year, the company shed another $15.5 billion in Q2 2008.

It's a complicated industry influence by countless variables, including the availability of credit, oil prices and the prevailing public moods toward new technology. It's worth noting that neither plug-in vehicles nor Li-ion batteries may even be contenders.

As I mentioned earlier, advances in biofuels could extend the natural life of the internal combustion engine. Another possibility is hydrogen, which is being considered longer term as a potential power source for a modified internal combustion engine, or a fuel-cell-driven electric motor.

There are some dark horses in this race too, such as Toronto-based **Zenn Motor Company**'s [ZNN.V] cityZENN, which could arrive in showrooms by Fall 2009. The proposed model would be powered by ultracapacitors from Texas start-up EEStor, and take less than 5 minutes to recharge.

It can be difficult to impossible to predict a winner with so many variables. But judging from the success of the Prius and the buzz surrounding GM's Volt, PHEVs and Li-ion batteries are a sector worth watching.