Schooling up on home refueling. You've been serving yourself for too long already.

available this autumn to your garage and start fueling at night while you watch TV.

Or, buy a neighborhood electric vehicle and claim 10 percent of the selling price as a credit on your 2003 federal return. Use the electric car around town, and save gas and short-trip abuse to your gasoline-powered mainframe.

The tax breaks can apply whether you drive these vehicles for business or personal use. A few states offer tax benefits as well. You can get similar relief by buying a hydrogen vehicle, but you'd be hard-pressed to find any place to fill it. One day, you might just fuel one of these at home. But that's probably a trillion dollars or so in the future.

**All the Comforts of Home**

After a week of testing a GEM neighborhood electric vehicle around town, plugging in at the end of a ride became nearly second nature. That it could be an autonomous reflex had been demonstrated earlier in the winter after a road test of a ZENN NEV around the streets of Hollywood Beach, Fla., during the electric vehicle show.

That day, the owner of a homebuilt EV pickup truck pulled in beside a small group of show attendees and started up a technical chat with the representative from Feel Good Cars of Toronto, which makes the ZENN. As they talked, the truck owner kicked about in the shrubs bordering the convention center until he found an outlet. Without slowing his pace, he plugged in the cord of his battery pack for a quick topping off.

Back in the cold Northeast, worry rode beside me on my first few trips out in the GEM. I feared being unable to make it home on the charge. But, soon I realized that electricity was practically dripping into the streets from the outlets that hang outside every house in the neighborhood. Talk about infrastructure!

For many years, I had resisted buying a gas grill on similar grounds. Nothing impresses guests less than having to run out for a tank just when the filet mignons are beginning to sear. “I’ll be right back,” you tell them, your tank in hand as you wonder where to find an open refueling station at 6 o’clock on a holiday afternoon.

However, a connection to the house’s natural gas line changed all that. Outdoor cooking is now just a flick of a lever away.

And so the thought began to take shape. Why wait for the hydrogen pipe?

Imagine leaving for work every morning with the car gauge pointing to “F.” Imagine tooting your horn and waving to the filling station attendant as you pass by once again without stopping. (Or, better yet, pulling in every so often just to say hello and take advantage of a free window cleaning and tire pressure check.) There’d be no more handling dirty pump nozzles or scent from petroleum perfume clinging to the rim of your second cup of coffee.

Toronto-based Fuelmaker Corp.’s Phill, a natural gas fueling appliance, starts from typical low household gas line pressure and boosts it 3,000 to 3,600 psi, to the pressure required by CNG vehicles. According to the manufacturer, the system can produce nearly a cubic foot of gas every hour, enough to put at least 100 miles of driving range nightly in a car like the Civic GX or the Chevrolet Bi-Fuel Cavalier. The latter travels 110-plus miles on compressed natural gas before switching automatically to gasoline operation, where it goes for another 300 miles on a tankful.

Ralph Rackham, Fuelmaker’s senior vice president of engineering and research, said the appliance uses oil-free compression, relying on Teflon/graphite rings in the first three piston stages, and close-clearance, ceramic elements for the fourth and final high-pressure stage. The unit delivers the pressurized gas to a CNG vehicle...
You are proud of your spotless garage. Now you can take that same orderliness with you in your travels.

through a Kevlar-reinforced nylon hose whose burst rating exceeds the unit's operational pressure fourfold.

The appliance's size matches the economy and range of smaller vehicles, such as the Civic GX or the Cavalier, which are driven 10,000 to 13,000 miles a year, Rackham said. Filling a bigger vehicle, like the Ford CNG Crown Victoria, would stretch the unit's capabilities somewhat, as would driving greater daily distances.

With gasoline so cheap, making the case for CNG vehicles and home filling is difficult based on economics alone. A person would have to log quite a few natural gas miles before he'd recover the cost of the home fueling station, Rackham cautioned.

So a decision to buy a natural gas vehicle has to be based on something such as convenience (assuming that the advantage of home refilling outweighs the disadvantage of scarce commercial CNG stations). Even with government incentives, deciding to drive a CNG vehicle depends heavily on a person's wanting to do good for the environment.

According to the Natural Gas Vehicle Coalition of Washington, D.C., a typical dedicated NGV can reduce carbon monoxide by 70 percent, nitrogen oxides by 87 percent, and carbon dioxide by 20 percent compared to gasoline-fueled vehicles. The Honda GX emits a tenth of the standard that defines ultra low-emission vehicles. The vehicle produces no emissions through evaporation or during refueling.

Engineers seeing the big picture on the hydrogen economy know that hydrogen has to be made, generally either by electrolyzing water or reforming hydrocarbons. Most of the time, that will mean burning coal or natural gas to produce the electricity needed for electrolyzing water—or reforming natural gas.

“Why not just put the natural gas in a modern car where it can be burned efficiently to begin with?” Rackham asks.

As far as emissions go, the Civic GX compares with a fuel cell vehicle. In wellhead-to-wheel comparison, the GX comes out cleaner, he said.

Granted, taking a natural gas car cross-country could present logistical problems. Planning your trip to coincide with the sparse availability of public CNG refueling stations
could diminish somewhat your freedom on the open road. Natural gas with home refilling makes better sense for daily commuting. Use of an alternative fuel vehicle rewards the choice with a waiver for a single-occupant vehicle to ride in the HOV lanes.

Gary Strong, vice president of applied metallurgy for Winsert Inc. of Marinette, Wis., said that natural gas combusts more completely than gasoline, precluding much opportunity for a film to form on the exhaust valves and their seats. This film of gasoline by-products acts to lubricate the valves as they seat, Strong explained. That reduces wear caused by sliding friction.

CNG engines in passenger cars tend to turn higher rpms than their bigger industrial counterparts, further prohibiting the buildup of any lubricating film. Passenger engine valves also tend to be thinner and more flexible than those used in bigger industrial engines.

To beef up wear resistance in the CNG valve seats it manufactures, Winsert adds alloying elements such as molybdenum, tungsten, and vanadium to the chrome and iron carbide used in typical seats. In many cases, the CNG seats increase the Rockwell C hardness ratings, from around R_c 40 to R_c 55, Strong said.

According to General Motors, which introduced its Bi-Fuel Cavalier in 1998, a CNG engine also differs from a gasoline engine in its fuel delivery system.

The GM bi-fuel engine relies on two independent fuel injection systems. Separate supply rails coexist side by side near the intake manifold. A second controller oversees the sequential firing of the CNG injectors, which GM manages through a powertrain control module running special software written for bi-fuel operation.

The Cavalier stores its natural gas supply in a trunk-mounted tank that holds the equivalent of 6.2 gallons of gasoline at a pressure of 3,600 psi. One regulator reduces the pressure of the fuel to 170 psi as it exits the tank and a second regulator attached to the transmission brings it down to the injector rail pressure of 45 psi.

The car is programmed to combust CNG before gasoline and offers the driver no control over this selection other than that which he seizes by choosing to fill, or not fill, the CNG tank.

Honda's CNG passenger car runs on natural gas alone, restricting its utility somewhat, but also qualifying it for the strict federal EPA designation of Inherently Low Emission Vehicle. (The U.S. Energy Policy Act of 1992 did not require that alternative fuels be used in alternative fuel vehicles, a loophole that has since been closed.) The sealed fuel system prevents evaporative emissions and the engine is supposed to maintain its emissions durability for 150,000 miles or 15 years, according to the company. This is an emission-warranty requirement in California.

A dedicated fueling system freed Honda engineers to increase the compression ratio of the natural gas engine, raising it from the 10:1 typical of gasoline engines to 12.5:1. They had to strengthen the connecting rods to withstand a punchier power stroke. The injection system was designed with larger injectors to handle the greater volumes of gaseous fuel.

According to American Honda’s Gunnar Lindstrom, senior manager of alternative fuels marketing, the company has manufactured up to 1,000 CNG vehicles a year since the GX debuted some five years ago. Mostly fleet operators have been buying the cars. Three years ago, it established a joint venture with Fuelmaker because drivers of electric vehicles had called the convenience of home charging an unexpected plus. Phill is the result of that partnership.

One advantage of home CNG refueling has to do with the quality of the fill, Lindstrom said. Commercial refueling stations generally fast-fill from storage tanks. Fast filling will heat the receiving tank enough so that when it returns to ambient temperature, it contains less than full pressure. The home unit's slow fill rate helps it avoid this trouble, maximizing the range of a tankful.

As the California Air Resources Board has demanded cleaner vehicles, tailpipe emissions have come down so much that other emissions—once practically ignored—now make up a bigger part of the whole, Lindstrom explained. But CNG cars, with sealed fuel systems, eliminate fuel loss due to filling and from evaporation.

Why should an engineer buy one? Hybrids get great fuel economy, Lindstrom said. They're wearing halos these days, he said, even as they burn gasoline. But natural gas cars produce almost no emissions. They are filled with fuel from North American reserves. Soon, they'll be refillable at home. In most states, you can drive alone in the HOV lane, he added.

Drivers of electric vehicles had called the convenience of home charging an unexpected plus.

Buying one could help make the business case for more public CNG stations. They're popping up along certain transportation corridors in response to the increase in commercial vehicles that use the alternative fuel.

At press time, a Natural Gas Summit in Washington, D.C., was discussing a looming short-term drop in natural gas supplies, one that was blamed on a cold winter in the northeastern and the mid-Atlantic states, as well as on declines in both domestic production and net imports. A hot summer was expected to exacerbate the
shortage. Potential buyer of CNG cars may want to monitor the possible natural gas crisis before plunking down any money on new technology.

**Plug or Pump**

A 2001 report from the Electric Power Research Institute in Palo Alto, Calif., showed a strong interest among potential buyers for home charging of hybrid electric vehicles. So-called plug-in HEVs add all-electric drive capability to the current crop of hybrids that run purely off gasoline.

The report surveyed a number of people to find out if they’d be willing to pay more initially for a car that could save them fuel expenses over the vehicle’s life. Survey participants were asked to rate their desire for four vehicles: a conventional automobile, a non-plug-in hybrid, and two plug-in hybrids—one with a 20-mile and one with a 60-mile all-electric range. The plug-in hybrids fared well, especially the long-range version.

In December 2002, EPRI’s electric vehicle area manager, Bob Graham, made the business case for plug-in hybrids when he went before the California Air Resources Board, calling it “the logical next member of the family of hybrid vehicles.”

Citing a personal-transportation survey that was conducted in 1990, Graham reported that half the automobiles on the road travel 20 or fewer miles in a typical day. Those same autos are, on occasion, asked to travel hundreds of miles in a single day.

A plug-in hybrid with a range of 20 all-electric miles, an HEV 20, could sop up many of the inefficient stop-and-go trips around town as a pure EV without hampering a driver’s freedom to dash off for a weekend getaway.

As you would expect, electric utilities could benefit from a proliferation of plug-in HEVs. Electricity providers have to possess sufficient capacity to meet the peak demand for their product, which occurs between the afternoon hours of 3 and 7 o’clock, Graham explained. They must also be able to meet the additional loads brought on by air conditioners running during the hottest times of the year.

At night, when most plug-in HEVs would begin their slow recharging, many of the afternoon loads have diminished. But, you can’t just shut down a steam plant and bring it back up again in the morning. That’s a specialty of gas turbine peaking units. So, plug-in HEVs make a sensible repository for the electricity that’s being generated at night anyway.

“Plug-in HEVs add value by flattening the curve,” Graham said.

Andy Frank, a staunch supporter of plug-in hybrids, teaches engineering at the University of California, Davis. He attended the electric vehicle show in Hollywood Beach last December with the plug-in hybrid sport utility vehicles he and his students had created. Built on a donated Ford Explorer glider, it is the seventh plug-in HEV the group has made over 10 years, a lineup that includes a Chevy Suburban, a Mercury Sable, and even a GM EV-1. The latest one was designed to better the performance of a conventional car.

“It’ll do zero to 60 in 6½ to 7 seconds instead of 9 or 10,” Frank said.

And those first 50 miles will be all electric. “You ‘fill’ it while you sleep,” he added.

The car charges at any conventional 110-volt outlet, so there are no infrastructure issues. After expending its allotment of all-electric miles, the car’s engine kicks on to maintain the batteries at 20 percent of full capacity. Frank’s battery banks range in capacity from 15 to 30 kilowatts compared to the 1½ to 2 kW the two Japanese production hybrids employ.

Even with all those NiMH batteries, Frank’s team matched the weight of the drivetrain that normally pro-
There's something under the GX's hood even a mechanical engineer could love: near fuel-cell cleanliness with lots of moving parts.

pels the Explorer. The team simplified it mechanically, too, with 90 percent fewer components, in part, by using a CVT, or continuously variable transmission. What it loses in mechanical complexity it makes up for with more complicated controls.

But that helps the car compete on price, Frank explained, referring to an EPRI study that showed a plug-in HEV 60 could come within 20 percent of a conventional car's price if it were built in volumes of 100,000 units annually. Another study suggests that the breakeven point for plug-in HEV 20s may be even lower, he said.

Frank said that a plug-in hybrid can double fuel economy in city and highway cycles operating solely in the gasoline sustaining mode. Trips made on batteries alone are, of course, pure EV miles.

Plug-in hybrids remain experimental. You can't buy one, and it doesn't appear as if automakers are planning on selling you one anytime soon. They may have had their fill of plug-in vehicles. Even Toyota, whose all-electric RAV4 EV was selling in California for a brief time, has pulled that program's plug.

**What's an Engineer to Do?**

Practically all the major carmakers offer some sort of natural gas vehicle for sale. Soon, a home fueling appliance will be available. If you weren't among the early adopters who purchased the Insight, there's still a chance now to drive something that's a little different.

You don't have to wait for a fuel cell car.

Asked what he would recommend for engineers needing a car today and wanting to buy green, EPRI's Graham said, "Hybrid." But, he also said that he would start asking the automakers why plug-in HEVs aren't available.

Honda's Lindstrom called plug-in hybrids "extremely impractical" because they need two complete systems in one car. Perhaps that echoes your first reaction to the hybrid Honda Insight or Toyota Prius.

If you aren't ready to commit to a full-size alternative vehicle, you might pick up a neighborhood electric vehicle for quite a few dollars less and practice charging it at home. You could tinker with ways of improving it for not much money, perhaps boosting its range, acceleration, or top speed in the process.

For even fewer dollars you could pick up an electric cycle, such as the Vento, made by the Electric Cycle Co. of Los Angeles. Those folks riding them at the EVAA exposition generally came back with smiles on. The bike's quiet, zippy acceleration may change your mind about electric drive.

Even the Segway human transporter is beginning to show up on the sidewalks of New York. In the past month alone, this reporter has observed two rolling by near ASME headquarters at Three Park Ave.

Sure, you'll get a few strange looks driving some of these vehicles around town. But engineers are used to that. Experiment a little. That's what you do.