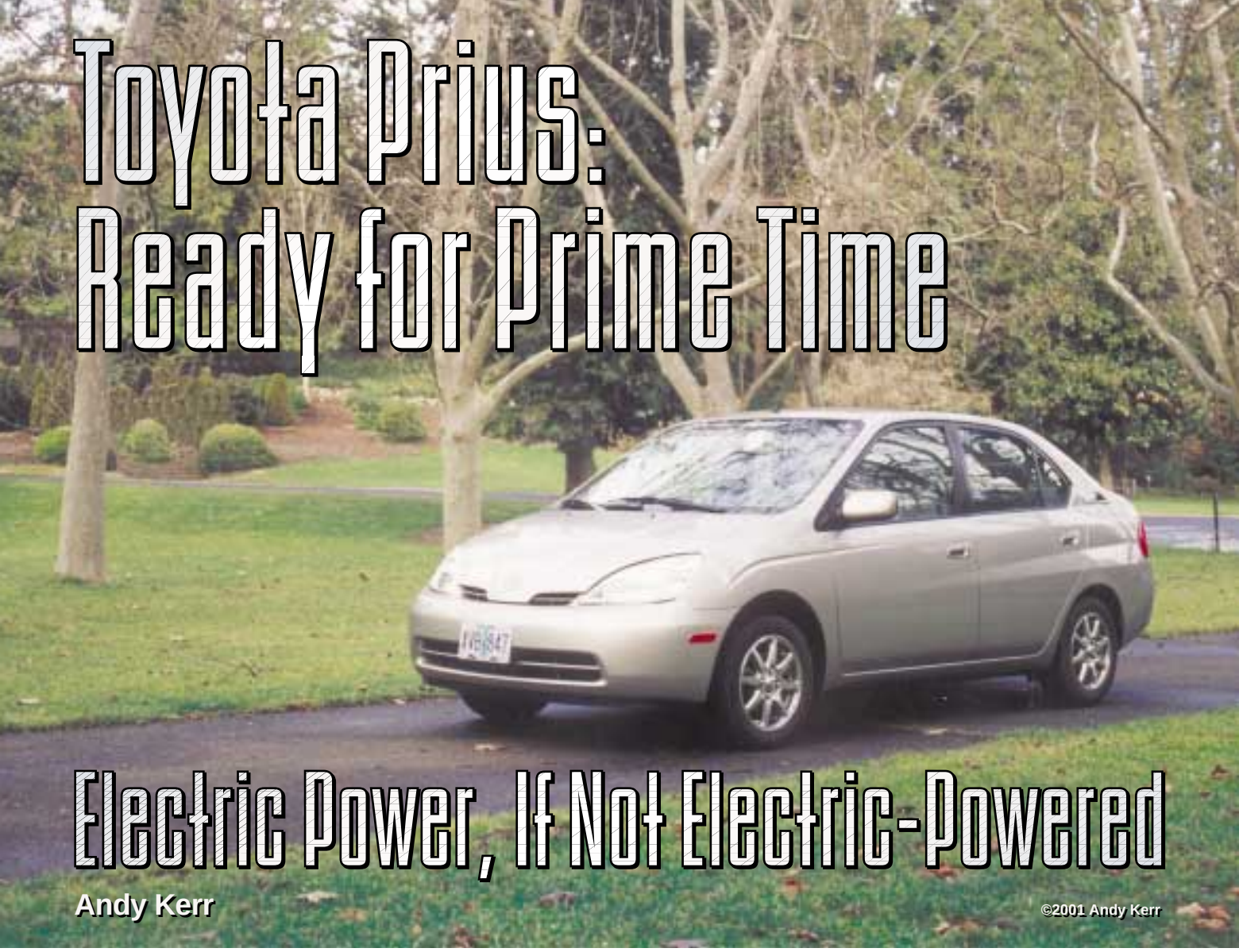
Toyota Prius: Ready for Prime Time



Electric Power, If Not Electric-Powered

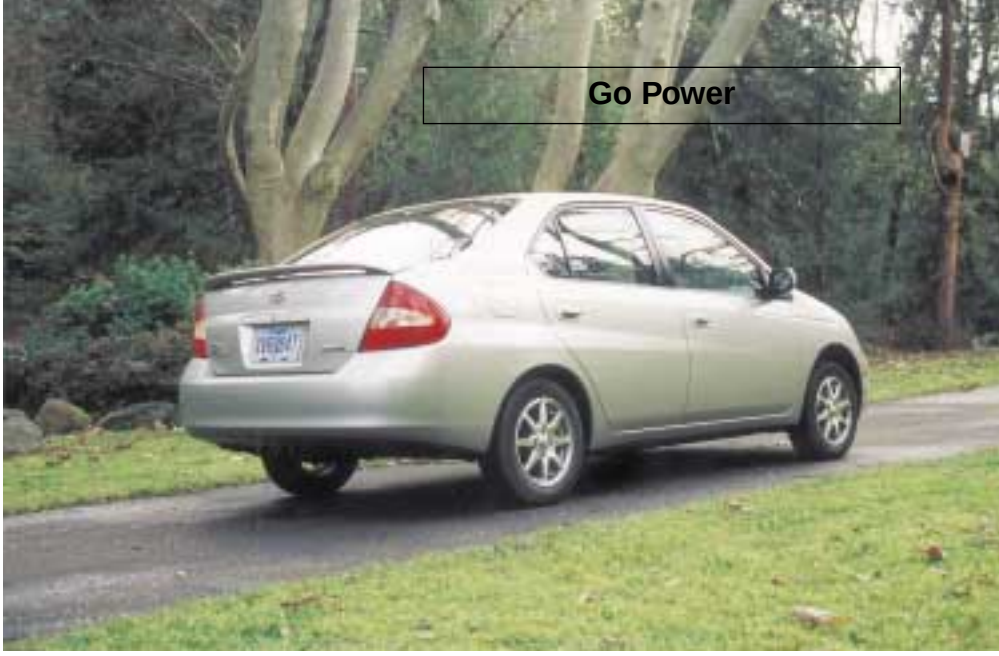
Andy Kerr

In late 1998, Toyota first announced its intent to produce a "hybrid" gasoline-electric vehicle for U.S. sale. The first Toyota Prius (2001 model year) left dealer showrooms in late summer of 2000. More than 50,000 are already on the road in Japan, where they are manufactured. In the United States, demand exceeds supply—there is currently a five month waiting period. Toyota claims it will produce 300,000 hybrids by 2005.

The Prius ("to go before" in Latin) propulsion system is a gasoline-electric hybrid that uses a small gasoline engine, a motor/generator, and a "traction" battery. It also has a normal car battery for accessories. The electricity is generated onboard by the gasoline engine turning the motor/generator, which helps to power the wheels or charge the traction battery as needed. At low speeds, the traction battery can provide all the power to the wheels; during acceleration, it assists the gasoline engine.

The car is still fundamentally powered by an internal combustion engine. Its lower pollution levels are attributable to a very clean burning engine and the overall design that maximizes mileage. From insulation (which reduces the air conditioning load) to the aerodynamic design, the vehicle is engineered to perform adequately with the smallest possible engine.

Using a special Toyota Web site, my wife and I ordered our Prius on the first day possible, June 25, 2000. Our beloved 1990 Subaru had already long been on life support, but nonetheless, we kept the faith and waited anxiously for delivery. We wanted the least polluting, most fuel efficient vehicle available. And we also wanted a Toyota since we were very satisfied with our 1995 Toyota four cylinder 4WD pickup. Our Prius arrived on September 15, 2000.



Though it looks like any other car, the Toyota Prius utilizes advance designs for maximum efficiency.

Cleaning Up Our Act

The U.S. Environmental Protection Agency (EPA) rates the Prius at 52 miles per gallon (22 km/1) city, 45 mpg (19 km/1) highway, and 48 mpg (20 km/1) combined. Unlike every other car on the road, the Prius gets better mileage in town than on the open road, due to a combination of factors. The engine shuts off when the car is stopped, and the motor uses excess energy from the engine, which has been stored in the battery. Despite what we may all wish, most of us do the majority of our driving in short, low-speed trips, which happens to be what the Prius does best. But even on the freeway, with a cruising speed of 75 mph (120 kph), we are getting 41 to 44 mpg (17–18 km/1).

The only current competition in the hybrid arena is the Honda Insight, a smaller (two passenger, two door) and more polluting vehicle. The Insight is classified as an ultra low-emission vehicle (ULEV), while the Prius is a Super ULEV (SULEV), emitting about 90 percent less pollution (other than carbon dioxide) than a standard modern vehicle on the road today. The Prius runs 75 percent cleaner than a ULEV.

Until concerns about global warming surfaced, carbon dioxide wasn't considered a pollutant. It doesn't smog our view like the ozone precursor nitrogen dioxide, or affect our breathing like particulates (soot). The amount of CO_2 a vehicle produces is directly correlated with fuel economy. The more fossil fuel burned, the more CO_2 emitted.

Today's average car on the road is a low-emission vehicle (LEV). Also available are zero emission vehicles (ZEVs), such as the Toyota RAV-4 EV. Of course, it's only possible to call them ZEVs if you ignore the upstream pollution caused by generating the electricity. While it is less polluting to make electricity from fossil fuel (such as coal or oil) and transport it across the grid to power an electric vehicle's batteries, it still causes pollution. The pollution just goes up a large smokestack rather than out a little tailpipe.

Another option is the hydrogen-powered vehicle. Most hydrogen today comes as a byproduct of liquid fossil fuel production. So hydrogen-powered cars are not pollution-free either, unless the fuel is made using renewably generated electricity.

The other major automakers are promising their own hybrid offerings, but all are still vaporware. Perhaps they'll be supplanted before they are released by fuel cell-powered vehicles, but these are even more vaporous at this time.

Our local Toyota dealership knew next to nothing about the pending Prius. I ended up being pushier as the car buyer than the car salespeople were. Fortunately, our Toyota dealer did decide to spend the several hundred thousand dollars for new equipment and training necessary to service the Prius. Not all dealers have.

Though it took longer than expected, the process went rather smoothly, in spite of some irregularities. With the novelty and limited production, the normal sales and

With a coefficient of drag of 0.29 the Prius is as slippery through the wind as some sports cars.

Under the hood—the gasoline engine and electric motor/charger.

distribution channels weren't yet working when we bought our Prius. We were getting e-mails from Toyota regional representatives as to when the vehicle would arrive, and then informing our salesperson who informed her superiors. We knew more about the Prius than anyone at the local dealership. We trust this won't be the case when the first service is necessary.

Marketing

In its marketing literature for salespeople, Toyota describes the probable Prius buyer profile as one of three major mindsets:

- Technology Pioneers—those who are interested in the latest technology, and who must be the first on the block to own this technology.
- Environmentally Friendly—those "somewhat concerned" about the environment who are looking for easy expressions of their concern without being inconvenienced.
- Value Conscious—those desiring a vehicle that provides the ideal combination of high fuel economy, low maintenance costs, and an affordable price.

They had us pegged. I'm all three, and my wife is the latter two. We wanted the convenience of a "regular" car. We didn't want the limited range or carrying capacity of the current crop of all-electric automobiles. We wanted more than a golf cart on steroids. We didn't want any vehicle that required the constant care and feeding of a bank of batteries, or one that couldn't get too far from a charging station. We didn't want to be hustling used french-fry oil from restaurants. We wanted a car that seats four in almost any combination of people and dogs. We wanted a normal car, with all the safety features and a modicum of conveniences.

The Prius is a modern, good looking car that includes halogen headlamps, intermittent wipers, automatic transmission, power steering, remote powered outside mirrors, cupholders, quartz clock, AM/FM/CD/cassette player with four speakers, power windows and locks, ABS brakes, front airbags, keyless entry and anti-theft systems, and other comparable features.

It meets current federal motor vehicle safety standards. It seats five (four comfortably) and weighs 2,765 pounds (1,254 kg). Suspension features include independent MacPherson struts with stabilizer bar for the front end, and a torsion beam with stabilizer bar in the rear.

The Prius comes with a basic 36 month/36,000 mile (58,000 km) warranty. The powertrain, restraint systems, and corrosion damage are covered for 60 months/60,000 miles (97,000 km). The hybrid vehicle system (the battery, motor/generator, advanced control system, etc.) is covered for 96 months/100,000 miles (160,000 km). Toyota also offers free roadside assistance, available with a toll-free call (including flat tires). Routine maintenance is recommended at 7,500 mile (12,000 km) intervals.

Good Ride

Driving the Prius is like driving any other American car, except for six things that I've noticed:

- The engine starts after releasing the key. You don't crank it until it starts (It's too quiet to hear anyway).
- The shifting mechanism is best described as a stick shift lever sticking out of the dash. The two-speed automatic transmission is labeled the usual "D" for drive, but low is labeled "B" for braking. When downshifting down a steep hill, regenerative braking puts more energy back into the battery.
- The ABS regenerative brakes can have the slightest sensation of grabbing while applying foot pressure. We've now gotten used to it and don't notice it.
- At a long wait at a stoplight, the engine may shut itself off to save fuel (no need to restart; just press the accelerator to continue).
- The dashboard lights and gauges are center-mounted

in the dash where it meets the windshield, rather than in front of the steering wheel.

- A multi-function 4 by 6 inch (10 x 15 cm) computer screen gives the driver feedback on fuel consumption, momentary hybrid power configuration, and radio frequency or CD track.

Mileage seems optimized at 45 to 55 mph (70–90 kph)—too slow for freeways and too fast for most city driving. Acceleration is adequate for entering freeways and passing. Toyota claims a maximum cruising speed of 105 mph (170 kph)—but I wouldn't (and won't ever) know about that.

Technical Details

So how does it work? A computer constantly monitors the demands on the vehicle and continuously reconfigures operation to minimize fuel use. The advanced control system (ACS) monitors grade steepness, battery charge, accelerator pedal, brakes, air conditioning, and engine speed, and then selects the optimal combination of power.

Depending on need, the ACS chooses between three options:

- Gasoline engine and electric generator together for extra power;
- Gasoline engine off when coasting or standing still;
- Electric motor/generator powered by the battery for cruising or accelerating. During deceleration, the computer activates regenerative braking power to recharge the battery.

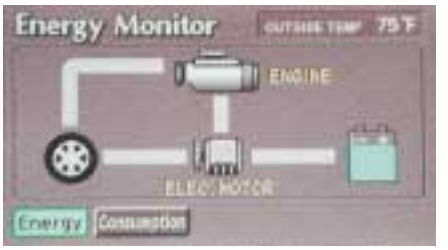
Based on the amount of power needed, the gasoline engine is either powering the wheels (and/or the electric generator that is charging the battery) or the engine is off.

The electric motor/generator is either powering the wheels by itself or in concert with the gasoline engine, or it is generating excess power for storage in the battery. The electric motor/generator can be powered by either the battery or the gasoline engine.

When coasting or braking, the electric motor/generator acts as a generator and charges the battery. If the vehicle is stopped for long (such as waiting for a light), the gasoline engine shuts off. Pressing on the accelerator moves the car with the electric motor. As the vehicle decelerates, about 30 percent of the energy traditionally lost in braking is captured by the motor/generator and stored in the battery.

When driving uphill, the gasoline engine splits its power between the wheels and the electric motor/generator that either sends power to the wheels or the battery for

Idling & coasting: The engine uses the motor to charge the battery.



Sitting stopped: If the battery is full the engine shuts off.

Heavy on the pedal: power comes from both the engine and the motor, drawing from the battery.

Medium on the pedal: power comes from both the engine and the motor, while charging the battery.

Light on the pedal: power comes from the motor only, drawing from the battery.

Coasting or breaking: power comes from the wheels to charge the battery.

The LCD screen also displays cumulative and instantaneous fuel economy.

Above: accelerating.

Below: Coasting

later use. When demand is high, the battery powers the electric motor/generator along with the gasoline engine to power the wheels. At highway speeds, the gasoline engine is the primary source of power, with the electric motor/generator assisting as necessary.

The hybrid system is designed to excel during city driving. I and other Prius owners I've consulted have not been able to achieve the 52 mpg EPA rating for city driving. My experience has been more like 44 to 48 mpg. But I live in a relatively small town that doesn't have many traffic jams. In serious stop-and-go traffic, the fuel economy may be better. The ACS is programmed to minimize gasoline consumption by relying on the electric motor/generator powered by the battery as much as possible. At low speeds, the gasoline engine comes on only to assist with acceleration or to charge the battery.

The permanent magnet electric motor (which doubles as a generator to store power in the battery that otherwise would go to waste) produces a maximum of 40 horsepower (33 KW). The 70 horsepower gasoline engine is a 4 cylinder, 16 valve, 1.5 liter double overhead cam that features variable valve timing to improve mid-range torque for passing, to maximize fuel economy, and to lessen emissions.

The battery was developed with Panasonic. It consists of 38 sealed, nickel-metal hydride modules, weighing 110 pounds (50 kg) total, and is designed for tens of thousands of charges. For safety, the battery is completely sealed in a carbon composite case and is positioned behind the rear seat. Toyota claims that the hybrid battery doesn't emit an electric or magnetic field. The 273.6 volt battery (228 1.2 volt cells) isn't something to mess around with.

The traction battery is small because it doesn't have to contain all the energy to power the vehicle. Its purpose is to capture wasted energy while the gasoline engine is running, and to recapture some of the energy normally lost during braking.

The lights and accessories run on a traditional 12 volt system. The 12 volt accessory battery is accessible through a cover panel in the trunk. You can run this battery down just like a regular car, and you can jump-start the car just like any other car.

Design Details

While the hybrid power system and the regenerative braking have made the most news, the Prius is also better designed, engineered, and constructed to minimize fuel consumption. Several little things add up:

- The floor and roof are insulated to reduce the load on the air conditioner. The side and rear windows block out an additional 13 percent of unwanted ultraviolet rays, helping keep the cabin cool.
- The wheels are ultra-lightweight aluminum, and the tires are a special low rolling resistance design.
- Better aerodynamic shaping helps cheat the wind by causing less drag. A flat underbelly creates less turbulence. The sleek shape, combined with the rear spoiler, results in a sports car-like 0.29 coefficient of drag, like the new Toyota Celica.
- A two-level air conditioning system improves efficiency and thereby reduces the air conditioning demand on the power system. It's also CFC-free, giving the ozone layer a break.

As with the ACS system, all this efficiency occurs without the user being involved.

Use & Service

The "energy" display on the in-dash liquid crystal screen graphically represents what's going on under the hood—for the education and entertainment of the humans onboard. One touch away, the "consumption" screen displays cumulative and current fuel efficiency, along with the average fuel efficiency for the last six five-minute intervals. You can easily comprehend how fuel use changes as you slowly leave the garage, snake through the city streets, and accelerate onto the freeway. Bright yellow icons denote each 50 watt-hours of energy "recovered."

Don't even think about servicing this vehicle yourself. Yes, you can fill the window washer fluid and maybe even change the oil, but you don't want to mess with the computerized propulsion system. And tempting as it may seem, you can't power the car solely on the storage battery after running out of gas.

This is a highway vehicle with only a 4.9 inch (12 cm) road clearance. It is a comfortable ride, but it's not designed for driving on ungraded roads. Since it runs on gasoline, fueling is not an issue as with a pure electric (or biodiesel) vehicle.

There are other perks besides driving the least brown (I wouldn't say "greenest") car now widely available. At least two states (Oregon and Maryland) offer US$1,500 tax credits for purchasing a Prius. In Virginia, you can drive solo in the high-occupancy vehicle lane if you have special plates.

The Author is happy with his car, its affects, and its message.

Toyota estimates that the Prius costs US$35,000 to produce, and reports that the company is low-balling to gain market share. (The actual cost of production is a function of how many it sells.) Also, such a low-pollution vehicle helps Toyota meet the corporate average fleet efficiency (CAFE) standards required by the U.S. Clean Air Act, by mitigating the sale of gas-guzzling, sport utility vehicles.

Toyota sees the writing on the wall. The traditional internal combustion engine is on its way out. The Toyota Prius is a transition step that optimizes the efficiency of such an engine.

If gas prices continue to rise (even though in real cost terms, gasoline is about as cheap as it has ever been), you may be able to economically rationalize additional cost through anticipated fuel cost savings. It depends on how much you are spending on fuel annually.

The manufacturer's suggested retail price (MSRP) for the Prius is US$19,850. Demand is greater than supply, so don't expect to bargain. The straight gasoline Toyota counterpart is the Echo, a dead ringer for the Prius, save for no rear spoiler, with an MSRP of US$10,395. At today's prices, the difference is a lot of gasoline to not burn.

Assuming you are in the market for a new four-door sedan, the marginal additional cost of a Prius compared to an Echo is US$9,455, before any government rebates. Assuming you are "average" as defined by the EPA and drive 15,000 miles (45% highway, 55% city) annually, the average annual fuel cost (US$1.70/gallon regular gas) will be US$525 for the Prius and US$754 for the Echo (31 mpg city, 38 mpg highway). Dividing this US$229 savings by the marginal cost difference yields a return on investment of 2.42 percent, tax free.

A better rationalization is social and environmental in nature. Since the true cost of gasoline and its use are not rationally accounted for, you could get higher financial returns by investing your US$9,455 elsewhere. But if you buy a Prius, you're going to spend an extra few thousand bucks to do some of your part to reduce air pollution and global climate change.

What's it worth to you to not have the northern polar ice cap melt out from underneath the polar bears, or to not have penguins dying of heat stroke? To not have several island nations flooded out of existence, along with much of the developed shoreline of the world? To not have the Corn Belt move to northern Canada and tropical diseases to the continental United States? The gasoline-electric hybrid is an important transition step from the gasoline internal combustion engine to nonpolluting and sustainable propulsion systems of the future.

Access

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For more information on the Prius, see http://prius.toyota.com or your local Toyota dealer.