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Why the future is hybrid

Automotive technology: Hybrid petrol-electric cars such as the Toyota Prius are becoming increasingly popular. But are they any more than a rest-stop on the road to the hydrogen car?

WHY has the Toyota Prius become the car industry's most talked about product? Since 1997, only about 250,000 have been sold, a paltry number by the industry's standards. The Prius is hardly big, fast or beautiful—the attributes that usually appeal to commentators, aficionados or, for that matter, buyers. And yet it is significant because it is the world's first mass-produced petrol-electric hybrid car, powered by both an internal-combustion engine and an electric motor. The second-generation Prius, launched in 2003, won some of the industry's most prestigious awards—it has just been named European Car of the Year 2005—and generated a buzz out of all proportion to the car's prevalence on the roads.

By choosing to drive a Prius, buyers can demonstrate how green they are without paying any penalty other than a slightly higher purchase price. Compared with a new American car of the same size, the Prius consumes roughly half as much petrol, and so releases half as much climate-changing carbon dioxide. Moreover, its emissions of smog-forming pollutants, such as nitrogen oxides and hydrocarbons, are 90% lower. Yet the Prius still manages to deliver the comfort and performance of a conventional car.

The success of the Prius has taken Toyota by surprise. The average wait at American dealerships is currently six months, even though the company increased its sales target for North America from its initial estimate of 36,000 units to 47,000 for 2004. To meet demand, Toyota announced another increase in August, saying it would push monthly global production up next year by 50% to 15,000 cars, and double its allotment for America to 100,000 units. While that number is still only one-quarter of last year's sales for America's most popular Toyota model, the Camry, it shows that consumers are willing to pay a premium for clean, environmentally friendly cars—as long as there is no need to compromise on performance.

Other carmakers are scurrying to catch up. CSM Worldwide, an automotive research firm, reckons that at least 20 new hybrid models will appear in America by 2007. Besides this year's new Ford Escape and Honda Accord hybrids, Toyota will add two sport-utility vehicles (SUVs) to its hybrid line-up early next year. DaimlerChrysler recently announced that it will introduce a Mercedes hybrid within the next five years, and Porsche is considering a hybrid version of its Cayenne SUV. Even General Motors, one of the strongest proponents of hydrogen fuel-cell cars, has jumped on the hybrid bandwagon with two pick-up trucks, a sedan and several SUVs to follow. Thanks to the convergence of geopolitics, technology and fashion, hybrids are picking up speed.

An old new idea

While the arrival of mass-produced hybrids is new, the idea itself is not. Indeed, it dates back to early automotive history when cars powered by electric motors, steam or internal-combustion engines all accounted for significant shares of the market. Why hybrids failed then is best illustrated by the example of an American engineer named H. Piper, who filed a patent for a petrol-electric hybrid vehicle in 1905. His idea was to use an electric motor to assist an internal-combustion engine, enabling it to achieve a thrilling 40kph (25mph). Unfortunately for Mr Piper, petrol-powered internal-combustion engines achieved those speeds on their own just a few years later, undermining the more complex and expensive hybrid approach. Petrol engines soon ruled the roost.

Priorities began to change in the early 1970s, when the oil crisis increased demand for less fuel-thirsty cars. As a result, the overall fuel efficiency of cars and trucks improved dramatically (though it stalled in America in the late 1980s as cheap petrol and a regulatory loophole encouraged sales of SUVs and light trucks). Moreover, in the 1990s, concern began to grow over the impact of fossil-fuel consumption on climate change.

During the 1990s, all of the big three American carmakers developed diesel-electric hybrid concept cars, though none made it into production. Instead, the focus shifted to pure-electric vehicles, which are technologically simpler than hybrids. But their high cost and limited range deterred consumers. Even the most advanced models could only go about 100 miles before they needed to be plugged in and recharged for several hours. By 2000, most electric cars had been taken out of production.

Meanwhile, Toyota released its first Earth Charter in 1992, setting the goal of minimising its overall environmental impact. In September 1993, the company began to plan the development of a car for the next century, dubbed Globe 21st Century, or G21. Originally, the plan was to produce a car with 50% better fuel economy than existing vehicles. But over the course of the project this target was raised to 100%, at which point it became clear that tweaking a petrol engine would not suffice. Instead, a more radical solution would be needed: a hybrid.

Despite the higher cost and complexity of a hybrid system, Toyota decided to press ahead with a massive research and development effort. Improved technology—such as better batteries and cheaper, more powerful control electronics to coordinate the two propulsion systems—meant that a mass-produced hybrid was now feasible. In 1997, the Prius was launched in Japan. It was followed by Honda's Insight hybrid in 1999.

When the Prius went on sale in America in 2000, it did not cause much of a stir. Indeed, even last year, Honda and Toyota sold about the same number of hybrids in America. This year, however, Toyota will sell about twice as many as Honda. The Prius took off thanks to the combination of rising petrol prices, celebrity endorsements and a futuristic redesign. (There is no petrol version of the Prius, so the car makes a statement in a way that the Honda Civic, which is available in both petrol and hybrid versions, does not.) It is the first hybrid to become a hit.

Hybrid anatomy

There is more to the Prius than clever marketing, however. To understand why, it is necessary to look under the bonnet at the way different kinds of hybrids work—for not all hybrids are the same. The simplest kind is the "stop-start" or "micro" hybrid, which is not generally regarded as a true hybrid because it relies solely on an internal-combustion engine for propulsion. As the "stop-start" name implies, the engine shuts off when the vehicle

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"Consumers will buy environmentally friendly cars provided there is no compromise on performance."

comes to a halt. An integrated starter-generator restarts the engine instantly when the driver steps on the accelerator. All of this increases fuel efficiency only slightly, typically by around 10%. But few modifications to a conventional design are required, so it costs very little. In Europe, PSA Peugeot Citroën has just introduced a stop-start version of the Citroën C3, which sells for roughly the same price as a similarly equipped conventional C3.

Next come so-called "mild" hybrid designs, such as Honda's Integrated Motor Assist (IMA)—the hybrid configuration found in the Insight, the Civic and the new Accord. In addition to a stop-start function, an electric motor gives the engine a boost during acceleration. During braking, the same motor doubles up as a generator, capturing energy that would otherwise be lost as heat and using it to recharge the car's batteries. Since the electric motor is coupled to the engine, it never drives the wheels by itself. That is why this system is called a mild hybrid, much to Honda's dismay. The design is less expensive than Toyota's more elaborate approach, but can provide many of the same benefits, says Dan Benjamin of ABI Research, a consultancy based in Oyster Bay, New York. The hybrid version of the Civic achieves 48 miles per gallon, a 37% improvement over a comparable conventional Civic.

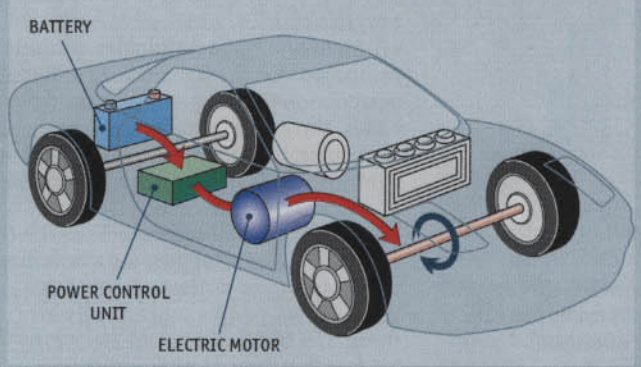
Toyota's Hybrid Synergy Drive, a "full" hybrid system, is much more complex. (The Ford Escape hybrid uses a similar system; Ford licenses a number of patents from Toyota.) Using a "power split" device, the output from the petrol engine is divided and used both to drive the wheels directly and to turn the generator, which in turn drives the electric motor and also drives the wheels. The distribution of power is continuously variable, explains David Hermance of Toyota, allowing the engine to run efficiently at all times. When its full power is not needed to drive the wheels, it can spin the generator to recharge the batteries. The batteries also get replenished when the car is coasting or braking. During stop-and-go traffic and at low speeds, when the petrol engine would be most inefficient, it shuts off and the electric motor, powered by the battery, takes over. That explains why the Prius has a better fuel economy rating for urban driving (60 miles per gallon) than for motorway driving (51 miles per gallon)—the opposite of a conventional vehicle.

The next step may be the "plug-in" hybrid, which is not the backwards step its name suggests. Unlike the electric cars of the 1990s, none of today's hybrids needs to be plugged in—but if plugging were an option it would be a good idea. Andrew Frank and his team at the University of California Davis' Hybrid Electric Vehicle

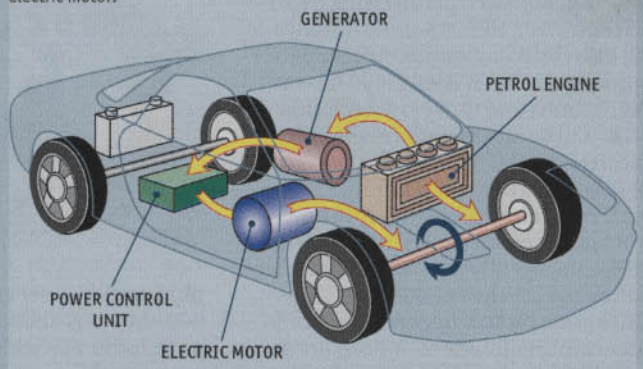
Hybrid vigour

How the Prius works

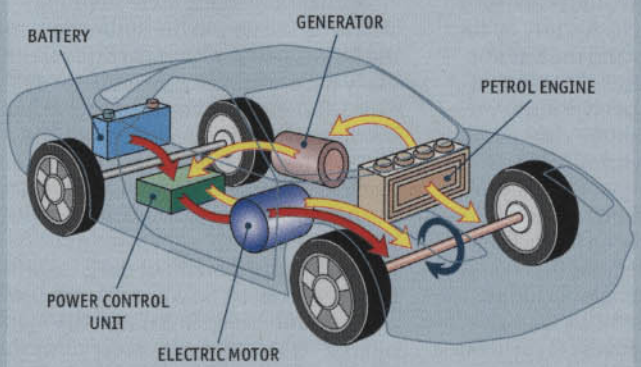
1. When starting and running at low speeds, the vehicle runs on battery power alone, which drives the electric motor.



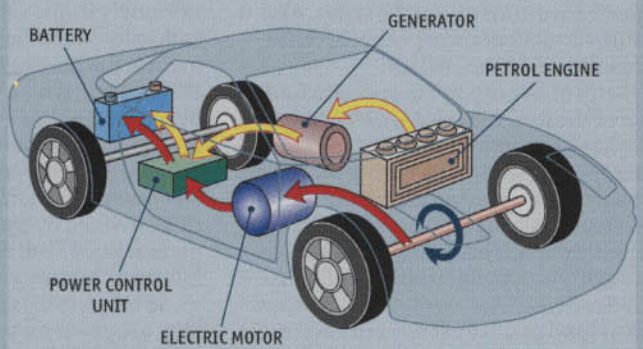
2. In normal driving conditions, power from the petrol engine is divided and used both to drive the wheels directly, and to turn the generator, which in turn drives the electric motor.



3. When sudden acceleration is needed, the battery provides extra power to the electric motor, supplementing the power from the petrol engine.



4. The battery is recharged in two ways. When braking, the electric motor acts as a generator, converting the vehicle's kinetic energy into electrical energy and storing it in the battery. The engine can also recharge the battery directly when necessary.



Source: Toyota

"The beauty of hybrids is that they do not require changes in driver behaviour or fuel infrastructure."

Centre are working exclusively on plug-in hybrids, which can operate as pure-electric vehicles over short distances (up to 60 miles, with a large enough battery pack) but can switch to a hybrid system when needed. Since the average American driver travels about 30 miles a day, plug-in hybrids could be recharged overnight, when electricity is cheaper to produce, and need never use petrol at all, except on longer trips.

According to studies carried out by the Electric Power Research Institute (EPRI), a non-profit organisation based in Palo Alto, California, plug-in hybrids could be one of the cleanest and most efficient kinds of car. In 2002, the EPRI teamed up with DaimlerChrysler to build five plug-in hybrid vans, the first of which was unveiled at a trade show in September. The larger battery packs make the up-front costs for plug-ins higher than for other hybrids. But Bob Graham of the EPRI says the added costs could be more than recouped over the vehicle's life.

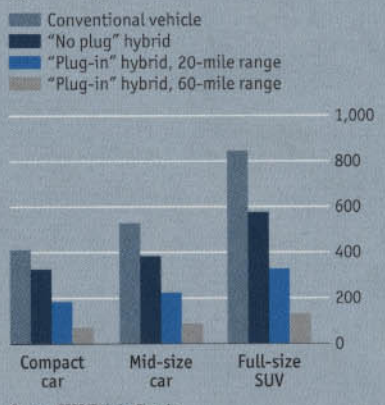
Not everyone is bothered by high fuel consumption, however, as the current enthusiasm for enormous SUVs demonstrates. So hybrids seem likely to remain a niche: ABI Research predicts that by 2010, less than 5% of all cars sold in America will be hybrids, assuming current petrol prices persist. But if Alan Lloyd has his way, hybrids and other low-emission vehicles will become far more commonplace. Dr Lloyd is head of the California Air Resources Board (CARB), a state agency that enforces arguably the most stringent air quality rules in the world. California recently passed landmark legislation to curb the emissions of greenhouse gases by 30% beginning in 2009. Since carbon-dioxide emissions are directly linked to a car's fuel consumption, critics charge that the new rules are in effect a way to legislate fuel economy, which is supposed to be regulated by the federal government, not the states. As a result, carmakers are expected to challenge the new rules in court.

Sales of hybrids in Europe are a fraction of those in America. Instead, diesel cars have become Europe's answer to reduce fuel consumption, curb greenhouse emissions and save money at the pump. Because diesel fuel contains more energy per unit, the fuel economy of diesel cars is roughly 30% better than that of petrol-powered cars. Moreover, diesel cars are not as loud or dirty as they once were, thanks to technologies such as electronically controlled "common rail" fuel-injection systems. Diesels now make up about 45% of all newly registered cars in Europe.

Even so, they still lag behind petrol engines in terms of cleanliness. In the process of combustion, diesels create a lot of pollution, including nitrogen oxides which cause smog, and particulate matter that can cause respiratory problems. That said, some carmakers have begun to equip their cars with particulate filters, notably PSA Peugeot Citroën. Together with two British firms, Ricardo and QinetiQ, the company is building a diesel-hybrid based on the family-sized Citroën Berlingo. The aim is to achieve a combined fuel economy of 70 miles per gallon with carbon-dioxide emissions of only 90 grams per kilometre. (In comparison, the Prius delivers 55 miles per gallon with carbon-dioxide emissions of 104 grams per kilometre.)

Easy on the gas

Average annual petrol consumption by vehicle type, US gallons



Source: EPRI/DaimlerChrysler

While it is uncertain whether the car will be mass produced, it is clear that a diesel-electric hybrid would make for an extremely frugal vehicle. A study by the Laboratory for Energy and the Environment at the Massachusetts Institute of Technology, which looked at energy use over the course of a vehicle's life, predicts that by 2020, diesel hybrids could achieve the same energy-efficiency and greenhouse-gas emissions as fuel-cell cars powered by hydrogen made from natural gas. The difference is that diesel-hybrid technology is available today.

So why are diesel hybrids taking so long to appear on the roads? Hybrid diesels impose a double price premium, explains Lindsay Brooke, an analyst at CSM Worldwide. Combining a diesel engine, (which costs around $2,000 more than a petrol engine) with a hybrid powertrain (which adds another $3,000 or so) would make for an expensive proposition. Systems to treat the exhaust would impose further costs. The prospects for diesels and diesel hybrids are particularly dim in America, where regulations in California (and, from 2007, nationwide) require diesels to be as clean as petrol-driven cars. Some progress has been made: particulate filters can now eliminate more than 90% of diesel soot. But traps for nitrogen oxides remain a challenge.

The car of the future, today

Hydrogen fuel-cell vehicles promise to be the cleanest mode of transportation, eliminating harmful tailpipe emissions altogether. But despite much publicity, and the fact that most carmakers are working on the technology, fuel-cell cars will not appear in significant quantities any time soon. America's National Academy of Sciences, which advises the government on new technologies, recently estimated that the transition to a "hydrogen economy" will probably take decades, since many challenges remain—in particular, how to produce, store and distribute hydrogen in sufficient quantities.

Hybrid cars, however, offer many of the benefits of fuel-cell vehicles, with the huge advantage that they are available now. Moreover, as the success of the Prius shows, people will actually buy them. The beauty of petrol-electric hybrids is that they do not require any changes in driver behaviour or the fuel-delivery infrastructure.

Rather than being mere stepping-stones on the way to the hydrogen cars of the future, petrol-electric hybrids are likely to be around for years, if not decades, to come. When and if fuel-cell cars become available down the road, they may not replace hybrids, but instead are likely to be descended from them, since they require many of the same components, from control systems to motors. As Joseph Romm, director of the Centre for Energy & Climate Solutions, a non-profit organisation based in Arlington, Virginia, puts it, "hybrids are almost certainly the platform from which all future clean vehicles will evolve." ■