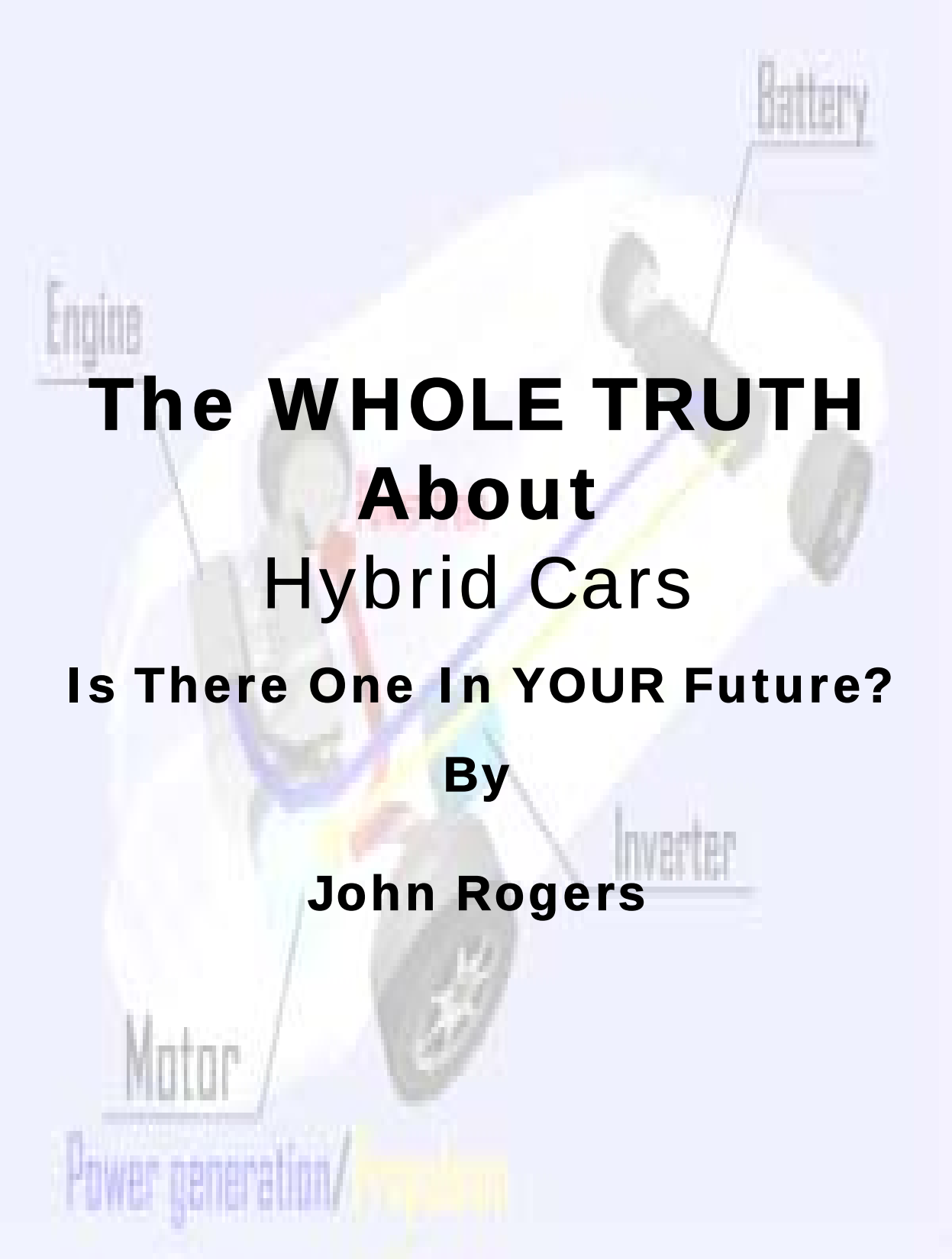

The WHOLE TRUTH About Hybrid Cars

Is There One In YOUR Future?

By

John Rogers

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Introduction

Hybrid Cars! Man! Is that a HOT topic right now! There are some good reasons why hybrids are so hot. If you've pulled your present car or SUV or truck up next to a gas pump and inserted the nozzle, you know exactly what I mean!

I written this book to give you some basic information on some things you may have been wondering about.

I'm sure, if you've even thought about a hybrid car, you've probably asked yourself the following questions: Just What IS A Hybrid Car? Why Should I Be Interested In Hybrid Cars? Is A Hybrid Car For Me? How Does A Hybrid Car Work? Do I Have To Drive Differently? Do They REALLY Save Gas? How Can I Get The Best Gas Mileage? What's The Future For Hybrid Cars?

I've answered all of those questions and more in this great little book. It isn't a technical manual. By any means. This book is meant to answer your general questions, give you a general overview of hybrid cars and prepare you to decide if you want to explore them further.

Some people think that hybrid cars can make a HUGE difference in our world, while others think they're just a passing trend. This book will help you sort out how you feel and what to do next, if you like what you read. Enjoy, learn a little, and get to know all about hybrid cars!

Wishing you the best,
John Rogers

Just What IS A Hybrid Car?

Any vehicle can be termed a hybrid if it combines two or more sources of power. In fact, you may well have owned a hybrid vehicle at some point. For example, a moped (a motorized pedal bike) is a type of hybrid because it combines the power of a gasoline engine with the pedal power of its rider.

You actually see hybrid vehicles everyday and don't even know it! Most of the trains we see pulling freight are diesel-electric hybrids. They use their electrical motors to move when there aren't heavy grades or heavy loads and then switch over to diesel when the going gets tough.

Many cities have been using diesel-electric buses…these hybrids draw electrical power from cables that are either overhead or embedded in the ground and run on diesel when they are away from the wires. The famous San Francisco trolley is an example of this type of hybrid. As a matter of fact, many subway cars have both an electrical motor, powered by the "third rail" and a diesel motor for power outages.

Those giant mining trucks you often see on TV or at mining sites are often diesel-electric hybrids. Just imagine the amount of gas it takes to haul 40 tons of rock! These trucks use the electrical power to move around when they aren't loaded down.

Submarines are also hybrid vehicles -- some are nuclear-electric and some are diesel-electric. You can even call a sailboat a hybrid vehicle since they have a diesel (or gasoline) motor onboard to power them when there isn't any wind!

Any vehicle that combines two or more sources of power that can directly or indirectly provide propulsion is a hybrid.

The gasoline-electric hybrid car is just that -- a cross between a gasoline-powered car and an electric car. Right now, the gas-electric car is available to consumers, but research is proceeding very quickly into the effective use of solar power, backed up by gasoline power, to power vehicles.

So, hybrid vehicles have been around quite a while…they just weren't called hybrids! You can see the reasons for their development…for the most part, they were developed by companies to save themselves money on diesel fuel and gasoline. The current, and re-current, fluctuations in consumer gas prices have brought the technology into our lives full force.

Why Should I Be Interested In Hybrid Cars?

Well, maybe you shouldn't be! That is, if you don't mind paying $3.00 or more, maybe a LOT more, for a gallon of gas on a consistent basis. That's already happening right now, at least sporadically! That is, if you don't mind breathing automobile emissions every day. Have you ever been in a big city during rush hour on a hot August day? Then you know exactly what I'm talking about. Those burning eyes and coughing fits just can't be normal…or good for you!

The fact of the matter is there is only a certain amount of oil existing in the world today. Yes, there are vast, untapped oil fields throughout the world that can still be used…but, with more and more of the world starting to drive cars and trucks instead of oxen and carts, that supply just can't last forever…even if we do tap every available source of oil!

Here in the U.S., we've just seen what a hurricane can do to our supply of gasoline. We've also seen what the oil-producing nations of the world can do to that same supply of gasoline. Not only is gasoline limited, but it's easily disrupted by both man and nature.

It doesn't matter if you believe in "global warming" or "the greenhouse effect". You KNOW that the stuff that comes out of the tailpipe of a car or truck is not good for you. That's made obvious when someone uses it to end his life! That's always a sure sign it's not the best stuff in the world to breathe into your lungs!

So, 99% of us either drive or are driven in, a vehicle that uses gasoline. That gasoline is made from oil, which, at some time in the future, isn't going to be available…no matter how much money we have! Maybe that's far in the future…after you're not around anymore. What will it matter to you if you're dead? It will probably matter a lot to your grandchildren or great grandchildren!

And…just looking at today…is it wise to be addicted to using more and more of something that other people and other forces control? Is it wise to be addicted to using something that may be slowly deteriorating our health?

With the technology that's available to us today, it just isn't feasible …or even possible…to completely stop using gasoline to power our vehicles. However, we DO have technology that will allow us to use less of it until, someday, we can stop using it all together. Hopefully, the day will come when we can VOLUNTARILY choose to stop using gasoline, BEFORE it's MANDATORY…because, there "ain't no more"!

So, yes…you probably should be at least a little interested in hybrid cars. They're going to affect your future, or your children's future, or your grandchildren's future significantly, so you might as well know what's going on.

Is A Hybrid Car For Me?

That depends a LOT on you! If you're bothered by the price of gasoline…if you're worried about where all of that oil that is made into gasoline is going to come from…if you're worried about the air quality in your city or state or country…then a hybrid car may well be worth taking a look at.

Hybrid cars aren't for everyone. They don't have as much of that "pedal to the metal" power that we've all become used to feeling. Most of the hybrids available today are smaller cars…not a box, but not a limousine either! There are a few SUV type hybrids just becoming available to the public.

Generally, you may not even know you're driving a hybrid car unless you were told it was a hybrid. The feel of driving is changed very little. You may feel like you're driving a car with a smaller engine than you're used to, but you won't be worried about driving on any Interstate highway, in most cases.

You won't have to "plug it in" or anything like that! Daily or weekly maintenance is virtually the same. You may…no, you WILL…notice a difference when you raise the hood of your new hybrid. But, then again, if you raised the hood of a 1965 Ford Mustang and then raised the hood of a 2005 Ford Mustang, you definitely notice a difference as well!

So, yes, a hybrid car may very well be a good choice for you. Especially if you're tired of putting a lot of your household budget into the gas tank of your present vehicle!

How Does A Hybrid Car Work?

Remember, a hybrid car, by definition, has two different power sources that are combined to power the vehicle. You can combine those two power sources in a couple of different ways. One way, known as a parallel hybrid, has a fuel tank, which supplies gasoline to the engine. But it also has a set of batteries that supplies power to an electric motor. Both the engine and the electric motor can turn the transmission at the same time, and the transmission then turns the wheels

By contrast, in a series hybrid the gasoline engine turns a generator, and the generator can either charge the batteries or power an electric motor that drives the transmission. Thus, the gasoline engine never directly powers the vehicle.

All hybrid cars have to contain the following parts:

- Gasoline engine - The hybrid car has a gasoline engine much like the one you will find on most cars. However, the engine on a hybrid is smaller and uses advanced technologies to reduce emissions and increase efficiency.
- Fuel tank - The fuel tank in a hybrid is the energy storage device for the gasoline engine. Gasoline has a much higher energy density than batteries do. For example, it takes about 1,000 pounds of batteries to store as much energy as 1 gallon (7 pounds) of gasoline.
- Electric motor - The electric motor on a hybrid car is very sophisticated. Advanced electronics allow it to act as a motor as well as a generator. For example, when it needs to, it can draw energy from the batteries to accelerate the car. But acting as a generator, it can slow the car down and return energy to the batteries.

- Generator - The generator is similar to an electric motor, but it acts only to produce electrical power. It is used mostly on series hybrids.
- Batteries - The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.
- Transmission - The transmission on a hybrid car performs the same basic function as the transmission on a conventional car. Some hybrids, like the Honda Insight, have conventional transmissions. Others, like the Toyota Prius, have radically different ones.

As we stated above, there are 2 basic types of hybrid cars right now. The parallel and the series design. Let's take a quick look at each of them.

In a **parallel design**, the energy conversion unit (the gasoline engine) and electric propulsion system (the batteries and electric motors) are connected directly to the vehicle's wheels. The primary gasoline engine is used for highway driving; the electric motor provides added power during hill climbs, acceleration, and other periods of high demand.

In a **series design**, the primary gasoline engine is connected to a generator that produces electricity. The electricity charges the batteries, which drive an electric motor that powers the wheels.

Hybrids are also being built to use the series configuration at low speeds and the parallel configuration for highway driving and acceleration.

In conventional vehicles, energy from deceleration is wasted as it dissipates. In some hybrid vehicles, regenerative braking systems capture that energy, store it, and convert it to electricity to help propel the vehicle…ultimately increasing overall efficiency. Some hybrids also use ultra-capacitors to extend the life of a hybrid vehicle's on-board battery system because they are better suited to capturing high power from regenerative braking and releasing it for initial acceleration.

To squeeze every last mile out of a gallon of gasoline, a hybrid car can:

- **Recover energy and store it in the battery** - Whenever you step on the brake pedal in your car, you are removing energy from the car. The faster a car is going, the more kinetic energy it has. The brakes of a car remove this energy and dissipate it in the form of heat. A hybrid car can capture some of this energy and store it in the battery to use later. It does this by using "regenerative braking." That is, instead of just using the brakes to stop the car, the electric motor that drives the hybrid can also slow the car. In this mode, the electric motor acts as a generator and charges the batteries while the car is slowing down.
- **Sometimes shut off the engine** - A hybrid car does not need to rely on the gasoline engine all of the time because it has an alternate power source…the electric motor and batteries. So the hybrid car can sometimes turn off the gasoline engine, for example when the vehicle is stopped at a red light.

- **Use advanced aerodynamics to reduce drag** - When you are driving on the freeway, most of the work your engine does goes into pushing the car through the air. This force is known as aerodynamic drag. This drag force can be reduced in a variety of ways. One sure way is to reduce the frontal area of the car. Think of how a big SUV has to push a much greater area through the air than a tiny sports car.

  Reducing disturbances around objects that stick out from the car or eliminating them altogether can also help to improve the aerodynamics. For example, covers over the wheel housings smooth the airflow and reduce drag. And sometimes, mirrors are replaced with small cameras.

- **Use low-rolling resistance tires** - The tires on most cars are optimized to give a smooth ride, minimize noise, and provide good traction in a variety of weather conditions. But they are rarely optimized for efficiency. In fact, the tires cause a surprising amount of drag while you are driving. Hybrid cars use special tires that are both stiffer and inflated to a higher pressure than conventional tires. The result is that they cause about half the drag of regular tires.
- **Use lightweight materials** - Reducing the overall weight of a car is one easy way to increase the mileage. A lighter vehicle uses less energy each time you accelerate or drive up a hill. Composite materials like carbon fiber or lightweight metals like aluminum and magnesium can be used to reduce weight.

So, a hybrid car, in general, uses a gas engine for either charging batteries which power electric motors which turn the wheels…or…to turn the wheels while being assisted by the electric motors in times of high demand. All hybrids use various methods to charge the batteries, which power the electric motors.

Essentially, a hybrid car isn’t a lot different from your car of today.

So, Do I Have To Drive Differently?

Yes…No…Maybe! How's that for an answer? If you're not really worried about gas mileage, then just drive like the vast majority of drivers on the roads today…fast, "jack rabbit" starts, quick stops, under-inflated tires, poorly maintained cars…and you won't have to change a thing! The gas mileage you get will probably be a little better than what you were getting in your old vehicle, but it won't be anything to go around bragging about!

BUT…if you really want to save some money on your gas purchases, you're gonna have to drive a little differently, as outlined in the chapter on getting the best gas mileage.

Your routine driving shouldn't change much at all. You still use a steering wheel and a gas pedal and a brake…just like before!

Hybrids are like almost any car today! So, if you're considering buying one just to be cool or to have the newest thing…you won't have to change your driving habits one little bit! You can go right ahead driving like usual and not worry about your gas mileage so much. You'll still be cool and trendy and not have to change a thing in your driving habits.

BUT…if you really DO want to save yourself some money when it comes to the gas pumps, then….YES…you'll need to change your driving style if you're a typical driver as discussed above. In order to get the best mileage out of your new hybrid, you'll need to read the chapter entitled, "How Can I Get The Best Gas Mileage?" that's further on in this book.

Probably, what will happen to most drivers is, they'll drive to save gas whenever they actually think about it and then turn around and drive like usual the rest of the time. That qualifies as the "maybe" at the start of this chapter. The whole secret behind getting the most out of your new hybrid is to slowly change those old driving habits until they become new ones!

So, yes…no…maybe…you'll have to drive differently!

Do They REALLY Save Gas?

You might wonder why anyone would build such a complicated machine when most people are perfectly happy with their gasoline-powered cars. The reason is twofold: to reduce tailpipe emissions and to improve mileage. These goals are actually tightly interwoven.

California emissions standards dictate how much of each type of pollution a car is allowed to emit in California. The amount is usually specified in grams per mile (g/mi). For example, the low emissions vehicle (LEV) standard allows 3.4 g/mi of carbon monoxide.

The key thing here is that the amount of pollution allowed does not depend on the mileage your car gets. But a car that burns twice as much gas to go a mile will generate approximately twice as much pollution. That pollution will have to be removed by the emissions control equipment on the car. So decreasing the fuel consumption of the car is one of the surest ways to decrease emissions.

Carbon dioxide (CO2) is another type of pollution a car produces. The U.S. government does not regulate it, but scientists suspect that it may contribute to global warming. Since it is not regulated, a car has no devices for removing CO2 from the exhaust, so a car that burns twice as much gas adds twice as much CO2 to the atmosphere.

Automakers in the U.S. also have another strong incentive to improve mileage. They are required by law to meet Corporate Average Fuel Economy (CAFE) standards. The current standards require that the average mileage of all the new cars sold by an automaker in 2005 should be 27.5 mpg (8.55 liters per 100 km).

This means that if an automaker sells one hybrid car that gets 60 mpg (3.92 liters per 100 km), it can then sell four big, expensive luxury cars that only get 20 mpg (11.76 liters per 100 km)!

The hybrid is a compromise. It attempts to significantly increase the mileage and reduce the emissions of a gas-powered car while overcoming the shortcomings of an electric car.

In theory, you should get improved gas mileage. Recently, there has been some controversy on this point. Hybrid cars DO save gasoline, but, the controversies have come in when claims of projected miles per gallon were inflated, either on purpose or accidentally. If a hybrid car is driven the way a hybrid car is meant to be driven, it is very fuel efficient. It seems there is a bit of a learning curve for drivers before they see the optimum miles per gallon. Add to that the erroneous MPG claims and you get some questions.

So, yes, you will save some gas. The amount you save relies to a great degree on how you drive, as discussed in the next chapter. You just need to take claims of gas mileage that aren't actually written on the EPA sticker in the window of your new hybrid with a grain of salt…they may be erroneous!

How Can I Get The Best Gas Mileage?

You can get the best mileage from a hybrid car by using the same kind of driving habits that give you better mileage in your gasoline-engine car:

- **Drive slower** - The aerodynamic drag on the car increases dramatically the faster you drive. For example, the drag force at 70 mph (113 kph) is about double that at 50 mph (81 kph). So, keeping your speed down can increase your mileage significantly.
- **Maintain a constant speed** - Each time you speed up the car you use energy, some of which is wasted when you slow the car down again. By maintaining a constant speed, you will make the most efficient use of your fuel.
- **Avoid abrupt stops** - When you stop your car, the electric motor in the hybrid acts like a generator and takes some of the energy out of the car while slowing it down. If you give the electric motor more time to slow the vehicle, it can recover more of the energy. If you stop quickly, the brakes on the car will do most of the work of slowing the car down, and that energy will be wasted.

If you aren't driving that way now, you probably aren't getting the best gas mileage possible out of your present vehicle. So, you won't get the optimum gas mileage from your new hybrid car either. A lot of your gasoline consumption relies on you…no matter what type of car you're driving!

What's The Future For Hybrid Cars?

As I said earlier in this book, hybrid vehicles have been around for quite a few years now. Corporations have been using hybrid technologies for many years to decrease their manufacturing overhead. So, the ideas behind the technology have been tried and tested and refined.

When it comes to consumer vehicles, the cars and trucks and SUVs that you and I drive, that "older" technology has to be refined even further. It's one thing to drive a hybrid trolley on a rail at 10 or 15 miles per hour and quite another to drive a car, with your family inside, at 70 miles per hour on a congested Interstate!

So, you can look for further refinements to the two basic systems we've discussed. The challenge will be to add the feel of more power to a hybrid while increasing the fuel efficiency.

Battery technology will also be a major thrust for improvement. As batteries can grab hold of and store more power, they can contribute more to the operation of the hybrid. Right now, most battery systems don't require much maintenance. However, it isn't unusual for them to need to be replaced occasionally…at a cost of over $1000.00! So, battery life and battery power will be improvements that are being searched for.

As alluded to earlier, different types of hybrids are being worked on right now. Imagine a solar panel on the roof of your car that supplies the energy! Researchers at the University of Southern California are working on that right now.

Their goal is to completely power a workable vehicle that will run without a gas engine at all…just solar power. Now THERE'S a truly renewable source of energy that we can rely upon.

So, the future looks bright for hybrids. Chances are, within a few years, a hybrid car may well be the norm rather than an oddity. The limited supply of oil, the concern for the air we breathe and the vagaries of both man and nature will continue to pressure us into adopting more and more hybrid technology. Chances are, we won't be going back to driving an ox and cart anytime soon!

Wrapping It All Up

Well, there you have it…a basic primer on hybrid cars. The technology that makes them work…some of the history behind them…some of their future…and a LOT of your questions answered.

When you look at the future of oil, you HAVE to see that, at some time in the future, there won't be enough of it to go around for all of us. The lessons of this past hurricane season shouldn't be forgotten…those kind of things WILL happen again! The lesson of the oil rich countries controlling the supply shouldn't be ignored either.

Forces outside of our control WILL make us change things. Oil scarcity, either man-made or natural; environmental concerns; changing economies…they all add up to the absolute need for a fuel efficient way to do something that has become a necessity…the transport of goods and people!

I hope you've learned something from reading this book. The subject of hybrid cars is extremely interesting…even to someone who thinks they'll never own one!

My Best To You,
John Rogers

Other Resources You May Want To Explore

Have you pulled your car up to the gas pump lately and been shocked by the high price of gasoline? As the pump clicked past $20 or $30, maybe you thought about trading in your car for something that gets better mileage. Or maybe you're worried that your car is contributing to the greenhouse effect.

The auto industry has the technology to address these concerns. It's the **hybrid car**. You're probably aware of hybrid cars because they've been in the news a lot. Most automobile manufacturers have announced plans to manufacture their own versions.

How does a hybrid automobile work? What goes on under the hood to give you 20 or 30 more miles per gallon than the standard automobile? And does it pollute less just because it gets better gas mileage? In this article, we'll help you understand how this amazing technology works, and we'll even give you some tips on how to drive a hybrid car for maximum efficiency.

Any vehicle is a hybrid when it combines two or more sources of power. In fact, many people have probably owned a hybrid vehicle at some point. For example, a **mo-ped** (a motorized pedal bike) is a type of hybrid because it combines the power of a gasoline engine with the pedal power of its rider.

Hybrid vehicles are all around us. Most of the locomotives we see pulling trains are **diesel-electric hybrids**. Cities like Seattle have diesel-electric **buses** -- these can draw electric power from overhead wires or run on diesel when they are away from the wires. Giant **mining trucks** are often diesel-electric hybrids. **Submarines** are also hybrid vehicles -- some are **nuclear-electric** and some are **diesel-electric**. Any vehicle that combines two or more sources of power that can directly or indirectly provide propulsion power is a hybrid.

The **gasoline-electric hybrid car** is just that -- a cross between a gasoline-powered car and an electric car.

You can combine the two power sources found in a hybrid car in different ways. One way, known as a **parallel hybrid**, has a fuel tank, which supplies gasoline to the engine. But it also has a set of batteries that supplies power to an electric motor. Both the engine and the electric motor can turn the transmission at the same time, and the transmission then turns the wheels

By contrast, in a **series hybrid** the gasoline engine turns a generator, and the generator can either charge the batteries or power an electric motor that drives the transmission. Thus, the gasoline engine never directly powers the vehicle.

Hybrid cars contain the following parts:

- **Gasoline engine** - The hybrid car has a gasoline engine much like the one you will find on most cars. However, the engine on a hybrid is smaller and uses advanced technologies to reduce emissions and increase efficiency.
- **Fuel tank** - The fuel tank in a hybrid is the energy storage device for the gasoline engine. Gasoline has a much higher energy density than batteries do. For example, it takes about 1,000 pounds of batteries to store as much energy as 1 gallon (7 pounds) of gasoline.
- **Electric motor** - The electric motor on a hybrid car is very sophisticated. Advanced electronics allow it to act as a motor as well as a generator. For example, when it needs to, it can draw energy from the batteries to accelerate the car. But acting as a generator, it can slow the car down and return energy to the batteries.
- **Generator** - The generator is similar to an electric motor, but it acts only to produce electrical power. It is used mostly on series hybrids.

- **Batteries** - The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.
- **Transmission** - The transmission on a hybrid car performs the same basic function as the transmission on a conventional car. Some hybrids, like the Honda Insight, have conventional transmissions. Others, like the Toyota Prius, have radically different ones, which we'll talk about later.

You might wonder why anyone would build such a complicated machine when most people are perfectly happy with their gasoline-powered cars. The reason is twofold: to **reduce tailpipe emissions** and to **improve mileage**. These goals are actually tightly interwoven.

California emissions standards dictate how much of each type of pollution a car is allowed to emit in California. The amount is usually specified in grams per mile (g/mi). For example, the low emissions vehicle (**LEV**) standard allows 3.4 g/mi of carbon monoxide.

The key thing here is that the amount of pollution allowed does not depend on the mileage your car gets. But a car that burns twice as much gas to go a mile will generate approximately twice as much pollution. That pollution will have to be removed by the emissions control equipment on the car. So decreasing the fuel consumption of the car is one of the surest ways to decrease emissions.

Carbon dioxide (CO_2) is another type of pollution a car produces. The U.S. government does not regulate it, but scientists suspect that it contributes to **global warming**. Since it is not regulated, a car has no devices for

removing CO2 from the exhaust, so a car that burns twice as much gas adds twice as much CO2 to the atmosphere.

Automakers in the U.S. have another strong incentive to improve mileage. They are required by law to meet **Corporate Average Fuel Economy** (CAFE) standards. The current standards require that the average mileage of all the new cars sold by an automaker should be 27.5 mpg (8.55 liters per 100 km). This means that if an automaker sells one hybrid car that gets 60 mpg (3.92 liters per 100 km), it can then sell four big, expensive luxury cars that only get 20 mpg (11.76 liters per 100 km)!

The hybrid is a compromise. It attempts to significantly increase the mileage and reduce the emissions of a gas-powered car while overcoming the shortcomings of an electric car.

The Problem with Gas-powered Cars

To be useful to you or me, a car must meet certain minimum requirements. The car should be able to:

- Drive at least 300 miles (482 km) between re-fueling
- Be refueled quickly and easily
- Keep up with the other traffic on the road

A gasoline car meets these requirements but produces a relatively large amount of pollution and generally gets poor gas mileage. An electric car, on the other hand, produces almost no pollution, but it can only go 50 to 100 miles (80 to 161 km) between charges. And the problem has been that it is very slow and inconvenient to recharge.

A driver's desire for **quick acceleration** causes our cars to be much less efficient than they could be. You may have noticed that a car with a less powerful engine gets better gas mileage than an identical car with a more

powerful engine. Just look at the window stickers on new cars at a dealership for a city and highway mpg comparison.

The amazing thing is that most of what we require a car to do uses only a small percentage of its horsepower! When you are driving along the freeway at 60 mph (96.6 kph), your car engine has to provide the power to do three things:

- Overcome the aerodynamic drag caused by pushing the car through the air
- Overcome all of the friction in the car's components such as the tires, transmission, axles and brakes
- Provide power for accessories like air conditioning, power steering and headlights

For most cars, doing all this requires less than 20 horsepower! So, why do you need a car with 200 horsepower? So you can "floor it," which is the only time you use all that power. The rest of the time, you use considerably less power than you have available.

Most cars require a relatively big engine to produce enough power to accelerate the car quickly. In a small engine, however, the efficiency can be improved by using smaller, lighter parts, by reducing the number of cylinders and by operating the engine closer to its maximum load.

There are several reasons why smaller engines are more efficient than big ones:

- The big engine is heavier than the small engine, so the car uses extra energy every time it accelerates or drives up a hill.
- The pistons and other internal components are heavier, requiring more energy each time they go up and down in the cylinder.

- The displacement of the cylinders is larger, so more fuel is required by each cylinder.
- Bigger engines usually have more cylinders, and each cylinder uses fuel every time the engine fires, even if the car isn't moving.

This explains why two of the same model cars with different engines can get different mileage. If both cars are driving along the freeway at the same speed, the one with the smaller engine uses less energy. Both engines have to output the same amount of power to drive the car, but the small engine uses less power to drive itself

The key to a hybrid car is that the gasoline engine can be much smaller than the one in a conventional car and therefore more efficient. But how can this smaller engine provide the power your car needs to keep up with the more powerful cars on the road?

Let's compare a car like the Chevy Camaro, with its big V-8 engine, to our hybrid car with its small gas engine and electric motor. The engine in the Camaro has more than enough power to handle any driving situation. The engine in the hybrid car is powerful enough to move the car along on the freeway, but when it needs to get the car moving in a hurry, or go up a steep hill, it needs help. That "help" comes from the electric motor and battery -- this system steps in to provide the necessary extra power.

The gas engine on a conventional car is sized for the peak power requirement (those few times when you floor the accelerator pedal). In fact, most drivers use the peak power of their engines less than one percent of the time. The hybrid car uses a much smaller engine, one that is sized closer to the average power requirement than to the peak power.

Besides a smaller, more efficient engine, today's hybrids use many other tricks to increase fuel efficiency. Some of those tricks will help any type of car get better mileage, and some only apply to a hybrid. To squeeze every last mile out of a gallon of gasoline, a hybrid car can:

- **Recover energy and store it in the battery** - Whenever you step on the brake pedal in your car, you are removing energy from the car. The faster a car is going, the more **kinetic** energy it has. The brakes of a car remove this energy and dissipate it in the form of heat. A hybrid car can capture some of this energy and store it in the battery to use later. It does this by using "regenerative braking." That is, instead of just using the brakes to stop the car, the electric motor that drives the hybrid can also slow the car. In this mode, the electric motor acts as a generator and charges the batteries while the car is slowing down.
- **Sometimes shut off the engine** - A hybrid car does not need to rely on the gasoline engine all of the time because it has an alternate power source -- the electric motor and batteries. So the hybrid car can sometimes turn off the gasoline engine, for example when the vehicle is stopped at a red light.
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- **Use advanced aerodynamics to reduce drag** - When you are driving on the freeway, most of the work your engine does goes into pushing the car through the air. This force is known as **aerodynamic drag**. This drag force can be reduced in a variety of ways. One sure way is to reduce the frontal area of the car (**Figure 5**). Think of how a big SUV has to push a much greater area through the air than a tiny sports car.

Reducing disturbances around objects that stick out from the car or eliminating them altogether can also help to improve the aerodynamics. For example, covers over the wheel housings smooth the airflow and reduce drag. And sometimes, mirrors are replaced with small cameras.

- **Use low-rolling resistance tires** - The tires on most cars are optimized to give a smooth ride, minimize noise, and provide good traction in a variety of weather conditions. But they are rarely optimized for efficiency. In fact, the tires cause a surprising amount of drag while you are driving. Hybrid cars use special tires that are both stiffer and inflated to a higher pressure than conventional tires. The result is that they cause about half the drag of regular tires.
- **Use lightweight materials** - Reducing the overall weight of a car is one easy way to increase the mileage. A lighter vehicle uses less energy each time you accelerate or drive up a hill. Composite materials like carbon fiber or lightweight metals like aluminum and magnesium can be used to reduce weight.

You can get the best mileage from a hybrid car by using the same kind of driving habits that give you better mileage in your gasoline-engine car:

- **Drive slower** - The aerodynamic drag on the car increases dramatically the faster you drive. For example, the drag force at 70 mph (113 kph) is about double that at 50 mph (81 kph). So, keeping your speed down can increase your mileage significantly.
- **Maintain a constant speed** - Each time you speed up the car you use energy, some of which is wasted when you slow the car down

again. By maintaining a constant speed, you will make the most efficient use of your fuel.

- **Avoid abrupt stops** - When you stop your car, the electric motor in the hybrid acts like a generator and takes some of the energy out of the car while slowing it down. If you give the electric motor more time to slow the vehicle, it can recover more of the energy. If you stop quickly, the brakes on the car will do most of the work of slowing the car down, and that energy will be wasted.

Both technologies come together in hybrid electric vehicles, also known as HEVs or hybrids. Present-day hybrids are equipped with ICEs and electric motors. A hybrid's ICE engine, as in any ICE-powered car, produces power through continuous, controlled explosions that push down pistons connected to a rotating crankshaft. That rotating force (torque) is ultimately transmitted to the vehicle's wheels.

A hybrid's electric motor is energized by a battery, which produces power through a chemical reaction. The battery is continuously recharged by a generator that—like the alternator of a conventional car—is driven by the ICE.

Hybrids can have a parallel design, a series design, or a combination of both:

- In a **parallel design**, the energy conversion unit and electric propulsion system are connected directly to the vehicle's wheels. The primary engine is used for highway driving; the electric motor provides added power during hill climbs, acceleration, and other periods of high demand.
- In a **series design**, the primary engine is connected to a generator that produces electricity. The electricity charges the batteries, which

drive an electric motor that powers the wheels. HEVs can also be built to use the series configuration at low speeds and the parallel configuration for highway driving and acceleration.

In conventional vehicles, energy from deceleration is wasted as it dissipates. In some hybrid vehicles, regenerative braking systems capture that energy, store it, and convert it to electricity to help propel the vehicle—ultimately increasing overall efficiency. Some hybrids also use ultracapacitors to extend the life of a hybrid vehicle's on-board battery system because they are better suited to capturing high power from regenerative braking and releasing it for initial acceleration. Learn more about HEV technologies.

Hybrid passenger cars arrived in the United States in model year 2000, following their introduction in Japan a few years earlier. First came the two-seat Honda Insight, followed by the Toyota Prius in model year 2001. Honda then introduced a hybrid version of its Civic sedan, and Toyota offered a second-generation Prius. Ford plans to introduce its first hybrid, a version of the Escape sport utility vehicle, in model year 2005. Several other major automakers now either offer HEVs or plan to do so in the near future.

Hybrid systems have also proved effective in buses and heavy trucks. For example, Oshkosh Truck Corporation has demonstrated a diesel-electric system that may significantly improve the fuel economy and driving range of military vehicles. As a bonus, hybrids can be devised to generate alternating current electricity for other applications such as plug-in power tools. General Motors, through its Allison Transmission Division, produces a diesel-electric hybrid drivetrain for transit buses.