Office of Energy Efficiency
and Renewable Energy

An introduction by the U.S. Department of Energy to commercially available advanced vehicle technologies

Technology Snapshot

featuring the Honda Civic Hybrid

What's Inside...

Welcome to the Clean Cities Advanced Vehicle Information Series

Advanced transportation is not just a vision for the future — it's here today. Clean, fuel-efficient hybrid electric vehicles (HEVs) are now available, joining the alternative fuel vehicles already on the road. You may have seen the HEVs in the news, at your local dealership, and even in your neighborhood. This brochure is the third in a series produced by the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy, designed to introduce the latest commercially available vehicle technologies to consumers. Each Snapshot features a different vehicle and offers an objective, "plain English" explanation of how it works and how it differs from conventional vehicles. The web sites listed on the back cover of this brochure provide additional information about advanced transportation technology programs.

Although nothing can compare to sitting behind the wheel, each Snapshot gives you a feel for the featured vehicle by highlighting performance, vehicle features, and the benefits the new technology delivers to you and your community.

What Is a Hybrid Electric Vehicle?

A hybrid vehicle uses two or more sources of power — in today's HEVs, the two most common sources are electricity (from batteries) and mechanical power (from a small engine).

HEVs offer the low environmental impact of electric vehicles and yet provide the same power and driving range as gasoline vehicles. Compared with a conventional gasoline-powered car, HEVs offer better mileage, comparable performance, and equivalent safety — and they don't need to be plugged in for recharging. Widespread use of HEVs could help DOE meet its energy missions: reducing our nation's dependence on foreign oil, improving air quality, and cutting greenhouse gas emissions — which lead to global warming.

How Do HEVs Work?

Hybrids offer fuel economy and emissions benefits because they operate differently than conventional gasoline-fueled cars.

Gasoline Vehicle: The heat energy obtained by burning gasoline powers the engine, which drives the transmission that turns the wheels.

Electric Vehicle: A set of batteries provides electricity to a motor, which drives the wheels.

Hybrid Electric Vehicle: Not all hybrids are alike. There are many ways to combine the engine, motor/generator, and battery. Three basic hybrid configurations are the series, parallel, and split (or through-the-road) designs.

Series. The engine never directly powers the car. Instead, the engine drives the generator, and the generator can either charge the batteries or power an electric motor that drives the wheels.

Parallel (e.g., the Honda Civic Hybrid). The engine connects to the transmission, as do the batteries and the electric motor. So both the engine and the generator/motor can supply power to the wheels, switching back and forth as driving conditions vary.

Split. The engine drives one axle and the electric motor drives the other. There is no connection between the engine and the motor except "through the road."

Introducing the Honda Civic Hybrid

The Honda Insight (described in DOE's second Technology Snapshot) introduced car buyers to Honda's Integrated Motor Assist (IMA™) system, the motor generator system that powers the vehicle. Now, with the Civic Hybrid, Honda incorporates the lessons learned from the Insight in the Civic platform.

The Civic Hybrid, a parallel HEV, incorporates the second generation of the IMA system, combining a 1.3-liter, 4-cylinder i-DSI (intelligent Dual and Sequential Ignition) gasoline engine and a 10-kW ultra-thin permanent magnet electric motor to boost performance and fuel economy.

Like other HEVs, the Civic offers energy-efficient technologies:

- Computer control system that efficiently manages the power of the motor, charging system, and nickel metal hydride (NiMH) batteries.
- New i-DSI lean-burn combustion technology with two spark plugs per cylinder.
- A new cylinder idling system that improves regenerative braking — while stopping or decelerating, more energy is recaptured by the electric motor and stored in the battery for later use.
- An idle-stop feature that briefly shuts off the engine when the car is stopped to conserve fuel and reduce exhaust emissions.
- An electronic display that shows instantaneous trip and lifetime fuel economy.

Familiar Car, Brand New Technology

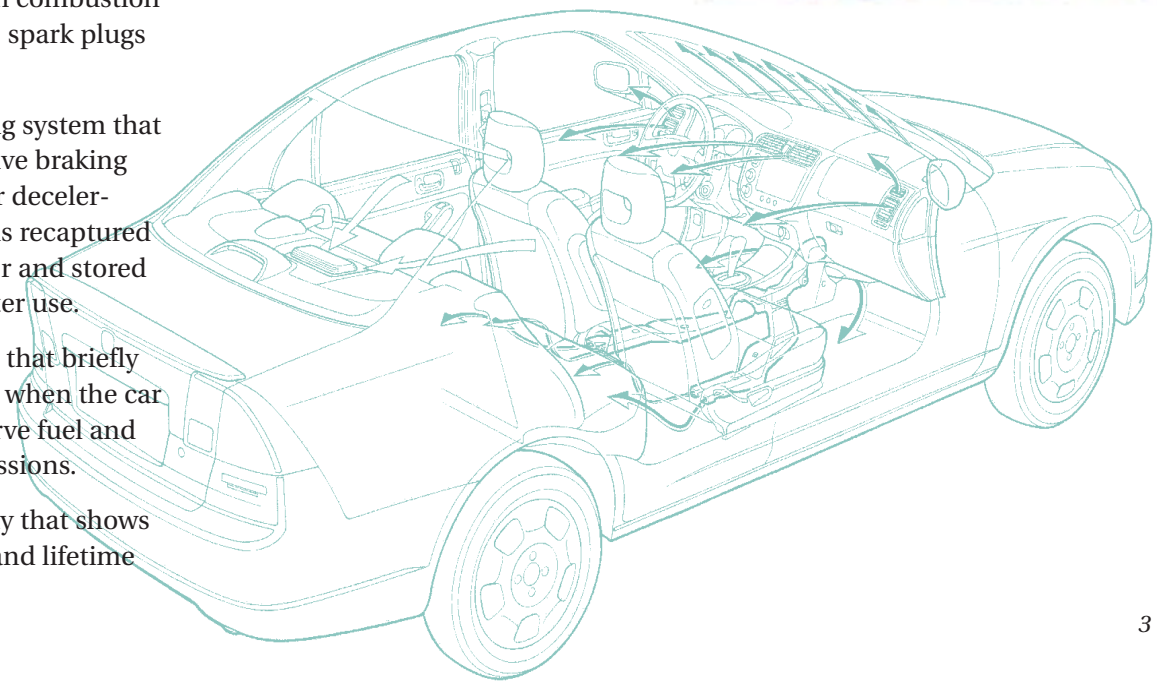
The Civic's hybrid system is completely transparent — you just fill the car with regular unleaded gasoline and drive it like any other car. It looks and feels very much like the Civics you see on the road every day, but it achieves up to 30% better fuel economy than a comparable conventional Civic, and it meets ultra-low emissions vehicle (ULEV) standards. (A super ultra low emissions [SULEV] version of the car will go on sale in California in 2003.) That means you can drive the Civic Hybrid up to 650 miles on a single tank of gas — from New York to Detroit — while generating 50–80% fewer emissions than a standard five-passenger car.

The next few pages offer more details on the technology used in these vehicles and illustrate how HEVs can deliver a cleaner, comfortable drive *today*.

Tax Deductions Available for HEVs

In recently issued guidance, the U.S. Internal Revenue Service (IRS) clarified that hybrid vehicles — defined as those powered both by a gasoline internal combustion engine and an electric motor that is recharged as the vehicle operates — are eligible for a federal "clean-fuel" tax deduction of up to $2,000. For hybrids purchased in past years, "the deduction would apply not only to returns being filed for tax year 2002, but also for the previous two years for which hybrid vehicles were available. The deduction could be claimed for a past year by a taxpayer filing an amended return."

www.irs.gov/pub/irs-news/ir-02-97.pdf



Focus on Technology

Performance

The Civic Hybrid is one solution to solving the challenging problem of combining fuel efficiency and performance. The IMA system allows for a smaller gasoline engine (compared with other Civics) without any significant loss of vehicle performance because the electric motor provides additional power when needed, such as when the car is accelerating from a stop. The motor, positioned between the engine and transmission, recaptures energy during deceleration and braking (regenerative braking).

The IMA System

In refining the IMA system for the Civic Hybrid, Honda had three main goals:

1. Increase the total power and efficiency of the system.
2. Increase the regenerative braking capacity.
3. Make the overall package smaller.

The following paragraphs describe the methods used to meet these goals.

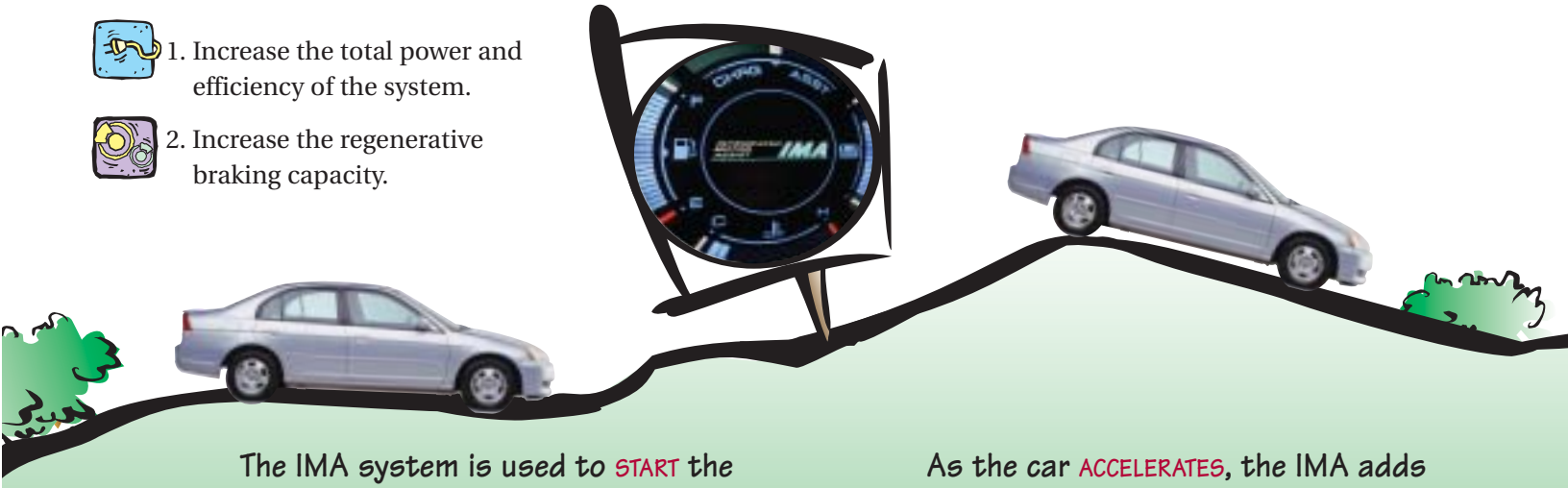
Maintaining Strict Control

The computer control system manages the power of the IMA system. The system "talks" to the car's key components and ensures that the car always operates in its most efficient mode — for lower fuel consumption and power output that instantly adjusts to driving conditions. Dashboard gauges like the one shown below display the amount of energy left in the battery pack and the rate of motor assist. A trip computer keeps track of the miles traveled and reports your current fuel economy.

Engineering a Smaller, More Powerful Engine

Combustion Chamber. A swirl effect, caused by the intake ports in the combustion chamber, provides a balanced air/fuel stream into the engine, which improves combustion efficiency.

Ignition System. The Civic Hybrid engine incorporates new i-DSI technology — which means it has two spark plugs per cylinder. The sequential or simultaneous ignition of the plugs is precisely controlled in order to ignite as much of the air/fuel mixture as possible. This accelerates the combustion process and results in more complete combustion — which means more power, less fuel burned, and fewer exhaust emissions.



The IMA system is used to START the gasoline engine. If the IMA battery pack charge is low, a separate 12-V battery and starter motor take over to start the car.

As the car ACCELERATES, the IMA adds its power to the output from the gasoline engine. The IMA assist indicator lights show the flow of current from the battery.

Cylinder Idling System. For the regenerative braking process, the engine needs to offer as little drag as possible during deceleration to allow the generator to produce more electricity to charge the batteries. A new idling system in the engine reduces engine drag by closing the intake and exhaust valves on up to three of the four cylinders and allowing the pistons to move more freely within the cylinders. The new system increases the power gained from regenerative braking.

Lightweight Engine Block. The engine's aluminum cylinder block uses a new structure, and the engine incorporates several lightweight plastic resin components that reduce its weight and allow greater packaging flexibility.

Saving Space with New Technologies

Several key technologies lead to more power from a smaller IMA package:

- New winding methods for the electric motor result in higher wire density within the same space.
- Within the computer control system, Honda combined key components to reduce the unit's weight by 28% and the volume by 39%.
- New high-density silicone wafers in the inverter reduce heat loss by 25%.
- A new cooling system combines two fans (for the battery and the computer control system) into one, consuming 85% less energy and resulting in a 32% weight reduction and a 20% volume reduction for the cooling system.

Using Chemistry to Cut Emissions

The lean air/fuel ratios that the engine achieves help improve fuel economy, and advanced catalyst technology reduces emissions. The catalysts used in conventional catalytic converters are not very effective in converting harmful nitrogen oxides (NO_x) to benign nitrogen in a lean engine exhaust stream. To keep NO_x emissions within ULEV levels, Honda developed a NO_x-absorptive catalytic converter that uses a mix of platinum and other metals to attract NO_x molecules to its surface during lean combustion. The catalyst is then regenerated regularly by changing the engine fuel strategy to run slightly rich (more fuel, less air) and convert the stored NO_x into harmless gases.

When the car is COASTING OR ITS BRAKES ARE APPLIED, the electric-assist motor becomes a generator, converting forward momentum (kinetic energy) into electrical energy, instead of wasting it as heat during braking. Energy is stored in the car's battery pack. If the battery charge is low, the IMA system will also recharge while the car is cruising.

The IDLE-STOP feature shuts off the gasoline engine when the Civic Hybrid is stopped in traffic to conserve fuel and further reduce exhaust emissions. The engine is instantly restarted when the driver depresses the accelerator.

Independently Tested by DOE and EPA

Starting in March 1999, DOE began independent testing of HEVs. The testing goals included assessing the operating performance of the hybrid technology and collecting data to determine the overall energy management performance. In July 2002, DOE tested the Civic Hybrid against a comparably equipped Civic EX. The results are shown in the chart (bottom right).

Why Drive a Hybrid Electric Vehicle?

HEVs can save drivers money on fuel, help reduce our nation's dependence on imported oil, improve air quality, and reduce greenhouse gases.

The Outlook on Oil

The United States imports more than 10 million barrels of oil a day — 54% of the oil we consume. Our imported petroleum costs $2 billion a week, and the cost is rising. Most of this oil — over two thirds of it — is used to satisfy our thirst for transportation fuel. And the demand for oil used for transportation will grow as the number of people and the number of miles they drive increase.

Air Pollution

EPA considers a number of pollutants in vehicle emissions to be harmful to the environment. Despite the substantial reductions in individual vehicle emissions over the last few decades, the millions of vehicles on our roads — which burn thousands of gallons of petroleum every second — account for a third of the country's air emissions.

Greenhouse Gas Emissions

Growing scientific evidence suggests that greenhouse gas emissions contribute to a change in the earth's climate — and transportation, specifically the combustion of fossil fuels in our vehicles, accounts for a large portion of greenhouse gases.

At a glance, the Civic Hybrid looks a lot like its conventionally powered counterparts. Behind the wheel, the Civic Hybrid feels a lot like them, too, with comparable performance, space, and comfort, but with much better fuel economy, thanks to its HEV drivetrain.

What's the Difference?	Civic EX	Civic HEV
On-Road Fuel Economy (mpg)	40.1	47.8
EPA Fuel Economy (city/highway) (mpg)	31/38 (auto)	48/47 (CVT)*
Acceleration (s) 0–60 mph	10.84	12.88
Slalom (cones every 50 ft; average mph)	33.25	33.39
Skid Pad (average G clockwise)	0.69	0.66
Braking (ft from 60–0 mph)	140	136
Passenger/Luggage Volume (ft^3)	88.1/12.9	91.4/10.1
Curb Weight (lb)	2,615 (auto)	2,732 (CVT)

** Continuously Variable Transmission; mileage based on 2003 estimates.*

The U.S. Department of Energy's mission is to enhance our nation's energy security, national security, and environmental quality, and to contribute to a better quality of life for all Americans. The widespread availability and use of alternative fuels and clean, energy-efficient, advanced technology vehicles (like those profiled in the Technology Snapshots) will help reduce U.S. dependence on foreign petroleum and promote clean air and healthier living in communities nationwide.

Technical Specifications

Gasoline engine:	In-line 1.3-L, 4-cylinder, 8-valve SOHC, VTEC valve train, aluminum alloy engine with i-DSI ignition and lean-burn technology, 10.8:1 compression ratio, 85 hp at 5,700 rpm, 87 lb-ft of torque at 3,300 rpm
Electric motor:	Permanent-magnet with 13.4 hp at 4,000 rpm
Battery:	Sealed nickel-metal hydride (Ni-MH), 144 volts, 6.0 Ah
Transmission:	Front-wheel drive, manual (5-speed) or available automatic Continuously Variable Transmission (CVT)
Fuel efficiency:*	46 mpg city/51 mpg highway (manual transmission) 48 mpg city/47 mpg highway (CVT)
Emissions:	Meets California Ultra Low Emissions Vehicle (ULEV) standards
Fuel tank/fuel:	13.2 gallons/regular unleaded
Max. range:	607 mi (city)/673 mi (highway) (manual transmission)** 634 mi (city)/620 mi (highway) (CVT-automatic transmission)**
Passengers:	5
Length:	174.8 in.
Width:	56.3 in.
Height:	67.5 in.
Wheelbase:	103.1 in.
Weight:	2,661 lb (manual transmission) 2,732 (CVT)
Braking:	Power-assisted front disc/rear drum brakes with integrated regenerative system and 4-wheel ABS
Steering:	Variable-assist rack and pinion
Turning circle:	34.8 ft
Suspension:	Front: control-link MacPherson strut Rear: reactive-link double wishbone
Warranty:	3-yr/36,000 mi Battery Pack: 8-yr/80,000 mi

* Based on 2003 EPA mileage estimates

** Based on 13.2-gal fuel tank and 46 city/51 highway mpg or 48 city/47 highway mpg, depending on transmission

Related Web Sites

http://www.eren.doe.gov/

The official web site of DOE's Office of Energy Efficiency and Renewable Energy (EERE), with links to its programs and additional transportation-related information.

http://www.ccities.doe.gov

EERE's Clean Cities Program supports the deployment of alternative fuel vehicles and supporting infrastructure.

http://www.fueleconomy.gov

The web-based version of the DOE/EPA Fuel Economy Guide.

http://civichybrid.honda.com

Honda Motor Corporation web site.

Publishing services provided by Argonne National Laboratory