6

Honda

Dream and it will happen*

HONDA

Teams of engineers merging cutting-edge combustion, hybrid propulsion, advanced materials, aerodynamic, and regenerative technology to design Earth-friendly products that deliver value to the triple bottom line.

Soichiro Honda as a young man

Honda's environmental leadership was born out of the strong personality of founder Soichiro Honda, his business partner Takeo Fujisawa, and the unique culture that emerged from a small struggling company fascinated with technology and performance. Mr. Honda started his motorcycle company in 1948 after working for two decades as a mechanic and engine parts supplier. With an investment of only $3,200, he bought surplus engines and attached them to bicycles to provide affordable transportation. In just 12 years, this middle-school dropout built the world's largest motorcycle company.[1]

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1 Readers who want to learn more about the history of Honda will want to start with Robert L. Shook's excellent book: *Honda, An American Success Story: Revolutionizing the Art of Management* (New York: Prentice Hall, 1988) and will also want to read *Dream: The Challenge of Creating and Progress*, published by the Honda History Project Group of Honda R&D in 1996. These books document extraordinary stories of leadership and risk taking that are so well known by employees that they were often told, with inventive variation, in our interviews.

> “I consider making motorcycles to be my mission in life, and this, if nothing else, I want to do by creating an absolute beauty of form that is not inferior to what comes out of any other country. I always feel the desire to make this happen, no matter what.”
>
> **Soichiro Honda**
> Quoted in interviews with Honda

Soichiro Honda was legendary for his quick temper when he demanded quality—he was sometimes called “Kaminari-san,” “Mr. Thunder,” after outbursts. He also was legendary for his ability to foster teamwork between workers and managers. He was a hands-on manager, rolling up his sleeves to solve problems at engineering centers and production plants. His business partner, Takeo Fujisawa, was the financial and marketing wizard who helped to create an organization where individuals could achieve their own ambitions by pursuing the goals of the team.

Japanese management encourages cooperation and consensus, perhaps because Japan’s historic rice cultivation could only have succeeded with teamwork and mutual respect. Japanese culture, developed in a land with limited fossil fuel resources, depends on efficiency for sustainability. *Cooperation*, *consensus*, and *conservation* have important roots in Japan’s respect for family values, art, culture, and nature. Soichiro Honda and Fujisawa Takeo declared in an early company principle: “Maintaining an international viewpoint, we are dedicated to supplying products of the highest performance.”

Ironically, the 1950 Honda philosophy was five decades ahead of its time. “First, each individual should work for himself—that’s important,” said Mr. Honda. “People will not sacrifice themselves for the company. They come to work at the company to enjoy themselves. That feeling will lead to innovation.” Honda welcomed new engineers to the company with a rousing speech telling them to “Think young and quest for the ‘three joys’: creating, buying, and selling.”[2]

Build it and they will drive

Five decades later, teams of Honda engineers are still merging cutting-edge combustion, electric, hybrid, fuel cell, advanced materials, aerodynamic, and regenerative technologies to produce Earth-friendly products that deliver value to the triple bottom line—people, planet, and profits. Honda is the only global company that produces so many forms of powered equipment: motorcycle, automobile, marine, and power products.[3] Honda is also the world’s largest enginemaker, producing more than 15.2 million annually.

2 Quoted in: Robert L. Shook, *Honda, An American Success Story: Revolutionizing the Art of Management* (New York: Prentice Hall, 1988).

3 Honda encourages the use of its engines in equipment made and marketed by other manufacturers. “Powered by Honda” means that a product has the fuel efficiency, low emissions, and reliability of Honda but other components made by cooperating companies. Honda engines power portable and standby electric generators, water pumps, air compressors, pressure washers, yard maintenance equipment, and farm equipment. Small Honda outboard marine engines are sold under several brands including Nissan.

HONDA PHILOSOPHY

Respect the individual

- Initiative, equality, and trust

Pursue the three joys

- Creating, buying, and selling

Work to win

- Have ambition and think young
- Value research and endeavor
- Respect theory with fresh ideas
- Enjoy work and communicate openly
- Strive for harmonious flow of work

At Honda, engineering ideas come from all product divisions, including many ideas with a big pay-off in environmental performance. For example, the Honda automobile engines that are among the cleanest in the world are reconfigured as outboard engines. The BF90/75 outboard motor is based on the Civic engine, the BF130/115 is based on the Accord engine, and the BF225/200/175 is based on the MDX engine. And Honda motorcycles, already the cleanest in the world, will further increase fuel efficiency. Honda engines provide quiet, reliable performance with lower fuel use and emissions. The cleanest Honda gasoline and natural gas prototype vehicles can reduce controlled emissions to almost unmeasurably low levels, and additional improvements will arrive soon.[4] This technical synergy of Honda engineers will be even more important as governments address problems of greenhouse gas emissions.

In Japan, companies are considered the "environmental top runner" when they set a new standard of excellence and stay well ahead of the competition in achieving the lowest emissions and highest fuel efficiency. Honda is recognized as the leader of almost every product category that it sells, almost every year.

HONDA ENVIRONMENTAL LEADERSHIP

- Faces environmental challenges head-on, with technical optimism and energy
- Announces daunting goals and provides finance necessary for R&D
- Meets and exceeds emission standards years before required
- Strives for incremental and evolutionary progress
- Remains poised for revolutionary technology leaps
- Markets vehicles meeting the most stringent environmental standards in all markets
- Achieves new emission standards while improving fuel efficiency and performance
- Serves customers with environmental technology at affordable cost; often offset by fuel savings and reliability

President and CEO Hiroyuki Yoshino says,

> Through self-innovation, we are challenging ourselves to make the power train of today and tomorrow cleaner and more efficient. This will give new meaning to the words "Powered by Honda"—a phrase so important to our past and one that, I believe, will have even more power in the future.[5]

That future power is currently epitomized by the 2003 Honda Civic Hybrid, one of the most fuel-efficient five-passenger sedans ever sold in the world, which is certified as a Super Ultra-Low-Emission Vehicle (SULEV). The Hybrid Civic achieves 48 mpg (20 km per liter) (city) and 47 mpg (19 km per liter) (highway)—a 24–55% city, highway, and combined mileage improvement compared to other Honda Civics—the previous "top runners" (see Table 6.1).

4 The Honda ZLEV is not available yet.
5 Quoted in interviews with Honda.

	03M Civic Hybrid*	03M Civic LX AT	Percentage improvement
EPA city fuel economy (m/g)	48	31	55%
EPA highway fuel economy (m/g)	47	38	24%
Combined (m/g)	48	34	41%

* The Civic Hybrid SULEV/Zero Evap engine upgrade has comparable mileage with even lower emissions.

Table 6.1 Comparison of Civic sedans with automatic transmissions

Daniel Becker, Director of the Global Warming and Energy Program at the Sierra Club, says, "With Honda's decision to add hybrid models to their line-up of ULEV sedans, Honda has pulled into the lead of car-makers making greener products."[6]

The Honda Civic Hybrid achieves more than 30% improvement in combined city and highway fuel efficiency in a standard Civic chassis with no compromise in performance, safety, or convenience (due to a computerized operating system that requires no special attention from the drivers). The only driving difference is the noticeable silence when the "idle stop" feature turns the engine off at intersections and then restarts the engine with the depression of the gas pedal. The most conspicuous differences between the hybrid and standard Honda Civic will be the time and convenience of fewer stops for refueling and perhaps the attention owners get from friends and strangers who notice their cars and want to know more about them.

"It is remarkably satisfying to be driving down the road at 65-plus miles [104 km] per hour in this very quiet car knowing that it is getting at least twice the miles per gallon of most of the cars that surround you, with no sacrifice in comfort or performance," say Lucy Hull and Bart Chapin.[7] "I'd claim it's better than a dog for making friends," says Nancy Drucker.[8] "The women think it's cute . . . the guys say, 'Yeah, man, but has it got any acceleration?' I say, 'It's not a Ferrari. If you have to press that accelerator to feel good about yourself, go somewhere else,' " says Brian Kent.[9]

The Honda Civic Hybrid is the newest member of a family of top-runner products. Honda has an environmental top runner in every product category it sells: cars, motorcycles, scooters, marine engines, electric generators, farm equipment, lawnmowers, and more.

Although reducing emissions from automobiles is a global priority, motorcycles are emerging as the next generation of affordable and maneuverable transportation in developing countries—and prompt action now can prevent pollution and

6 Interview with Daniel Becker.

7 Quoted in: Natural Resources Council of Maine, *Hey, Cool Car! Hybrid Electric–Gasoline Vehicles in Maine* (Natural Resources Council of Maine): 3.

8 *Ibid.*: 8.

9 Jeffrey Ball, "For Mileage Fanatics, It's a Real Handicap to Have a Lead Foot," *Wall Street Journal*, June 5, 2002: front page.

actually increase the affordability of transportation in those countries. In 1999, 20 million motorcycles were sold worldwide, with about 80% sold in developing countries, and with China accounting for 45% of the market and India for 16% (see Figure 6.1). Honda is striving to produce "green" motorcycles that will provide mobility with the lowest possible environmental impact. Honda achieves high fuel efficiency and low emissions with the same strategy used for cars: lightweight material, fuel-injected 4-cycle and low-friction engines, and idle stop.

Honda can produce a motorcycle engine with half the pollution, and still improve the fuel efficiency of the typical product sold worldwide (see Figure 6.2). The savings in fuel with the Honda motorcycle actually pays for any increase in motorcycle price, and the owner saves even more with lower maintenance and higher resale value. For example, Honda has already achieved a 30% improvement in fuel efficiency by applying innovative environmental technologies developed for automobiles to the Wave-125 motorcycle. This was achieved by improving low- and mid-range torque, reducing engine friction with roller rocker arms and offset crankshaft, and computerizing ignition-timing control. A Honda prototype motorcycle, fuel-injected with an emission-control system, has emissions just $^1/_{12}$–$^1/_{20}$ of the "Euro 2" limits.

Larger motorcycles have achieved 20% higher fuel efficiency and low emissions with variable valve timing and lift electronic control (VTEC) engines incorporating

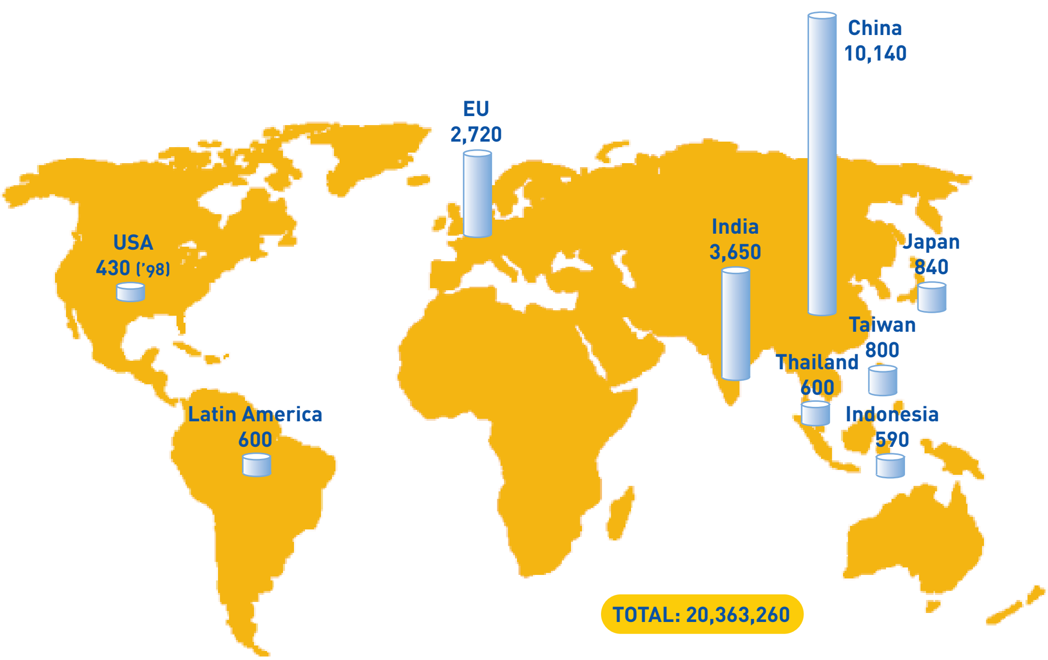

Figure 6.1 Annual motorcycle sales worldwide (1999) (× 1,000 units)

Source: Data from Honda

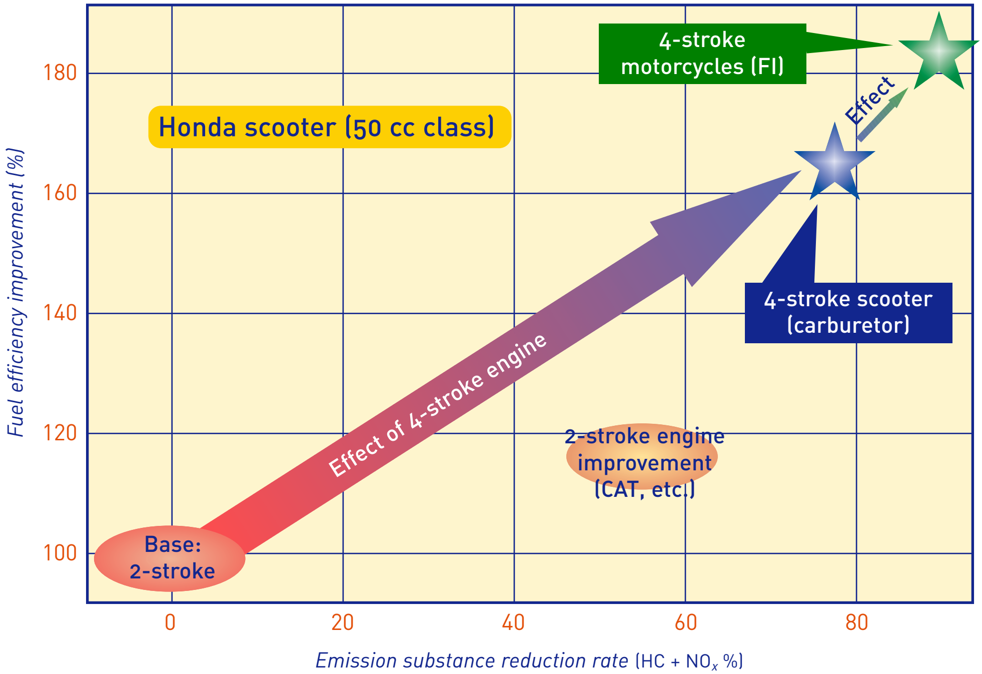

Figure 6.2 Emissions reductions from Honda fuel-injected (FI) small motorcycles

computer-controlled fuel injection, secondary air induction, and close-coupled three-way catalysts with dual oxygen sensors. Next-generation technology developed for motor sports will also be applied to basic motorcycles, including unicams, titanium valves, two-ring ultra-short pistons, and lightweighting and miniaturization.

Because Honda has a policy of producing its motorcycles in the countries where they are sold, a developing country can earn the same foreign exchange and create the same number of jobs that would be possible when producing inferior motorcycles. In addition, developing countries that choose to build environmentally superior technology will help protect the climate and will gain immediate health, economic, and safety benefits.

Honda satisfies the most stringent national environmental performance criteria in the markets where a vehicle model will be sold or manufactured; then the company supplies that environmentally superior vehicle to all of the markets where the model will be sold, including countries that do not require low emissions. This type of Honda leadership raises the bar on environmental competition, forcing competitors to try harder.

"Environmental leadership companies like Honda sometimes do more for the global environment than cumbersome regulations," says Yuichi Fujimoto of the JICOP. "In 1994, I served on a team of United Nations experts who discovered that


Helen Tope (EPA Victoria), Sally Rand (US EPA) and Yuichi Fujimoto (JICOP) with the green Honda Insight

a few German, Japanese, and Korean companies were still selling CFC-12 air conditioners in their cars assembled in Vietnam. Honda and three dozen other multinational companies solved the problem by pledging to use the same ozone-safe technology in Vietnam as they do at home."

The youthful courage to succeed

Even as a young company, Honda faced crises with undaunted courage and leadership. In 1954 Mr. Honda responded to the threat of bankruptcy with the public announcement of its ambition to win "tourist trophy" (TT) motorcycle racing competitions. TT races are held on closed public highways; the best known is probably the Isle of Man race, which has been held since 1907. At first, this bold statement shocked employees, but they were soon motivated to succeed. Publicity for racing revived sales and brought profits that were shared by all. Honda formalized the lessons of translating racing success to sales with a four-part code: (1) face ambitious targets with a challenging spirit; (2) pursue original technology; (3) make efficient use of time; and (4) have self-confidence and joy in inventing for performance.

"Thinking young" became a theme in all aspects of Honda operations—openness, optimism, energy, and excitement. Thinking young meant that Honda would also seek excellence in advertising from any source. The campaign theme ultimately immortalized by The Beach Boys, "You meet the nicest people on a Honda," was conceived by University of California at Los Angeles (UCLA) students as a class assignment and marketed to Honda by their professor.[10]

Both Soichiro Honda and Takeo Fujisawa recognized the importance of announcing impossible technical goals and backing those ambitions with highly financed research programs. Shortly after production of the company's first automobile, Mr. Honda announced a plan to dominate racing and to win the famed Le Mans Formula One race. He knew that he could attract exceptional engineers by telling the world that Honda would be the best and fastest in the world.

This set a precedent for Honda's subsequent public announcements of seemingly impossible plans, such as Honda's goal to help protect the planet. The

10 Robert L. Shook, *Honda, An American Success Story: Revolutionizing the Art of Management* (New York: Prentice Hall, 1988): 34.

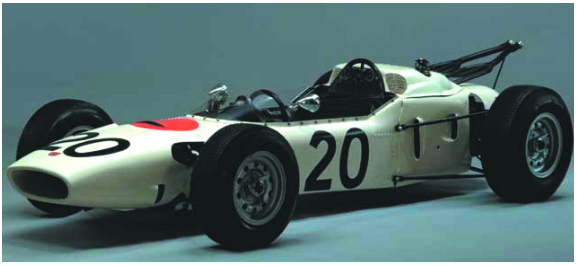

Figure 6.3 Honda Formula One racecar

obsession with racing reflected the ambitions of the company owners. Honda and Fujisawa used racing to attract and inspire engineers and to build teamwork and problem-solving. Racing involved clear results: win or lose; all or nothing; survival of the fittest. Winning engineers triumphed because they captured every technical advantage and extracted every last ounce of performance—where just two-hundredths of a second slower at the finish line could mean defeat. Winning required ambitious targets, passion, self-confidence, performance under pressure, courage, and stamina.

As a result of this process, Honda dominated class racing for many years. And, in 1965, the Honda team won its first Formula One victory at the Mexican Grand Prix, and a second in the 1966 Italian Formula One Grand Prix. In 1966, the Honda team became the first to capture all five solo World Motorcycle Championships (50 cc, 125 cc, 250 cc, 350 cc, and 500 cc classes). Also in 1966, Honda set a world record of 11 consecutive Formula Two victories. And in 1996 it also won the Indy/Championship Auto Racing Teams (CART) Series Championship.

Outside Honda, the racing program might have looked like advertising; but inside it was a carefully conceived strategy to push technology beyond its limits in ways that supported the goal of continuously improving consumer products. In 1968, Honda decided that his beloved automobile-racing program that had been devoted to power and speed could not produce an engine with low enough emissions to protect the planet. Characteristically, Soichiro Honda abruptly withdrew from Formula One competition, and publicly announced that Honda would now design the *cleanest engine* in the world.

The racing and business press could not believe what they were hearing. Some speculated that Honda was running out of money; others said it was quitting while it was ahead. Most claimed that the small Japanese company could not produce the low-emission engines that Detroit giants had announced were technically impossible. "Engineers were naturally disappointed when Honda withdrew from Formula One racing, but it wasn't long before we realized that we would be racing to protect the Earth for future generations. *And isn't that the ultimate race?*" remarked Hiroyuki Yoshino, President and CEO.[11]

11 Quoted in interviews with Honda

Winning the ultimate race

The best racing and research engineers at Honda devoted their full attention to a clean engine that would also achieve the goal of superior fuel economy. It was decided that the new engine would have the same power, equal or better fuel efficiency, and would operate on low-cost, globally available gasoline. Separate research teams competed and cooperated on developments. With each success, the teams were reorganized to pursue the most promising ideas, with experts forming the critical mass of necessary talent.

Honda was aware of the work by others on what became known as the "stratified-charge" engine, particularly the work by Russian L.A. Gussak on three-valve engines. This work demonstrated desirable fuel efficiency but with much higher emissions. "But, at least theoretically, we saw in the stratified-charge engine not only fuel economy, but the means for practical reliable emission control," says Tasuku Date of Honda Research and Development. "We then set out to achieve that controlled combustion, to convert a theoretical hope to a practical reality."[12]

A team of just eight engineers developed the revolutionary breakthrough technology, the Compound Vortex Controlled Combustion (CVCC) engine. The team included Tadashi Kume, who would later become CEO of Honda. The revolutionary CVCC was proven within a year, verifying Kume's genius.[13]

The original CVCC engine adds a small auxiliary combustion chamber located in the cylinder head (Figure 6.4). A rich fuel mixture is supplied to this auxiliary combustion chamber through its own intake passage and carburetor, and an extremely lean mixture is supplied to the main combustion chamber through its own intake passage and carburetor. The rich mixture is ignited by a spark plug in the auxiliary chamber, and the flame spreads through a torch opening to the lean mixture in the main chamber, ensuring reliable and complete combustion.[14] The geometry and timing is optimized to achieve a balance of power, fuel economy, emissions, durability, and reliability.[15]

The result was a stable, slow burn with a peak temperature low enough to minimize the formation of oxides of nitrogen, and a mean temperature held high enough and long enough to reduce carbon monoxide and hydrocarbon emissions.

12 T. Date, S. Yagi, A. Ishizuya, and I. Fujii, *Research and Development of the Honda CVCC Engine* (SAE Paper 740605; Washington, DC: Society of Automotive Engineers, February 1974): 1.

13 Robert L. Shook, *Honda, An American Success Story: Revolutionizing the Art of Management* (New York: Prentice Hall, 1988): 23.

14 A similar stratified-charge system with fuel injection had been developed in Germany but had not achieved the low emissions possible with the Honda design. See W.R. Brandstetter, G. Decker, H.J. Schafer, and D. Steinke, *The Volkswagen PCI Stratified Charge Concept-Results from 1.6-Liter Air Cooled Engine* (SAE Paper 741173; Washington, DC: Society of Automotive Engineers, February 1974).

15 T. Date, S. Yagi, A. Ishizuya, and I. Fujii, *Research and Development of the Honda CVCC Engine* (SAE Paper 740605; Washington, DC: Society of Automotive Engineers, February 1974); and S. Yagi, T. Date, and K. Inoue, *NO_x Emission and Fuel Economy of the Honda CVCC Engine* (SAE Paper 741158; Washington, DC: Society of Automotive Engineers, February 1974).

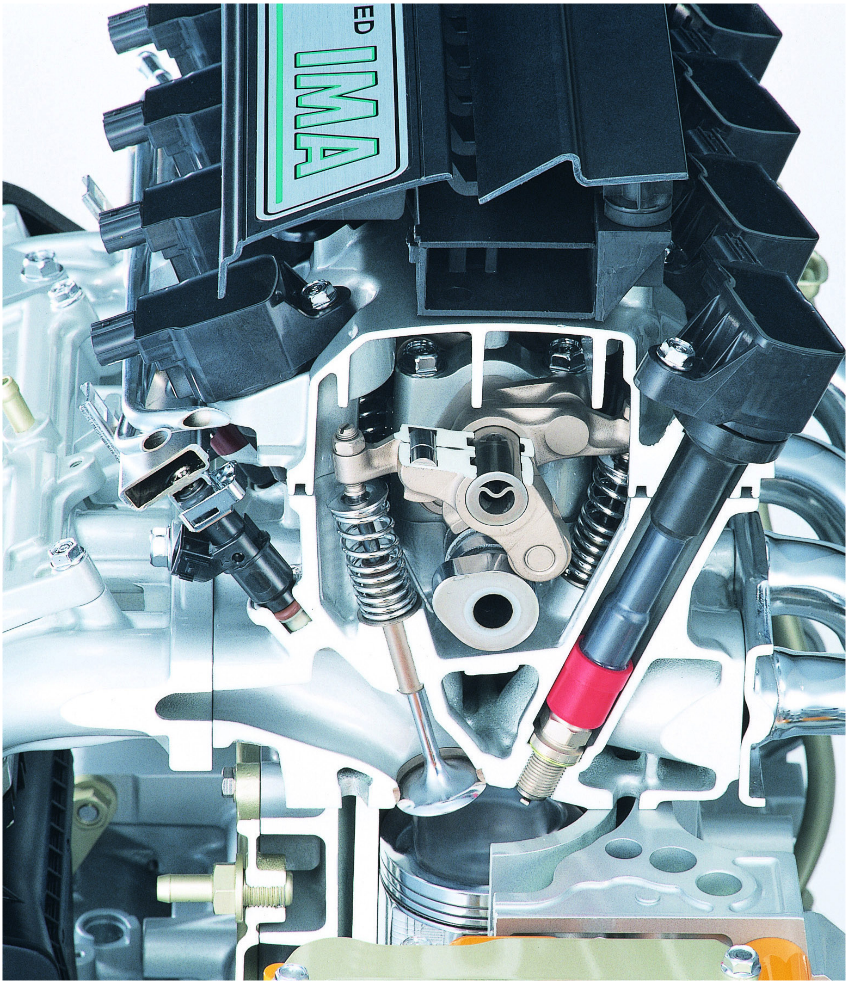

Figure 6.4 Latest valve mechanism showing auxiliary combustion chamber

Unlike emission controls based on chemical catalysts that deteriorate with use, the CVCC was designed to maintain low emissions for the life of the engine.

In 1973, Honda introduced the CVCC to the Honda Civic, the only car to satisfy the stringent 1975 emission standards under the 1970 US Clean Air Act and the 1975 Japanese standards.[16] It was the beginning of three decades of environmental progress leading to the current engines and hybrid systems that have almost

16 US and Japanese Standards 1975:

	CO	HC	NO_x
Japanese Standard (g/km)	210	0.25	120
Original Muskie Standard (g/km)	211	0.25	193

immeasurable emissions. Honda achieved the US standard—officially certified by the Environmental Protection Agency—with regular gas and with no catalytic converter. Grasping the significance, publications as diverse as *Reader's Digest* and the *Society of Automotive Engineers Journal* praised the achievement. The December 1975 *Reader's Digest* article "From Japan—A 'Clean Car' That Saves Gas" embarrassed Detroit with its strong words:

> Then came another surprise. Honda engineers installed their stratified-charge cylinder head and carburetor on the eight-cylinder engine of a 1973 Chevrolet Impala. When the Environmental Protection Agency tested this big-engine, full-size car, it found that Honda's modifications had reduced emissions substantially below the 1975 federal limits and that fuel economy was increased.[17]

Honda estimated that the new clean engine added about $170 to the cost of a conventional engine. This cost would be offset by fuel savings; and it avoided the typical $350 cost of catalytic converters, which decreased power, increased fuel costs, and would require more maintenance.

"The CVCC helped Honda earn its reputation for quality and engineering excellence. It is ironic that Detroit's claim that no one could meet that standard helped the public appreciate what had been accomplished," said Aki Nakamura, Technical Vice President (retired). Customers embraced the new Honda cars equipped with the 1,500 cc CVCC engine and purchased 800,000 by 1980.

Back to the finish line

Having achieved its clean engine goal, Honda returned to automobile racing—and at the same time expanded its race program to compete in environmental competitions such as the "World Solar Challenge," the world's top solar car race (Figure 6.5). "Racing solar cars is very competitive and pushes every technology to the limit," says Hiroyuki Ozawa of Honda R&D.[18] The balance between electric energy generated from solar cells and energy consumption dictated by the aerodynamics and rolling resistance determines the cruising speed of a solar car. "Solar car racing taught us to strive for the full potential of the car, in addition to boosting the efficiency of all individual components," says Ozawa. In 1999, Honda-powered drivers finished first, second, and third in the CART World Series for the third

17 EPA tested three Honda-powered vehicles and the 350 cubic inch Chevy Impala, confirming that the CVCC technology reduced emissions for both large and small engines to levels within the 1975 EPA limits. See US EPA, *An Evaluation of Three Honda CVCC Powered Vehicles* (Washington, DC: US EPA, December 1972); and US EPA, *An Evaluation of a 350 CID CVCC Powered Chevrolet Impala* (Washington, DC: US EPA, October 1973).

18 Y. Shimizu, Yasuyuki Komatsu, Minoru Torii, and Masato Takamuro, "Solar Car Cruising Strategy and its Supporting System," *Journal of the Society of Automotive Engineers Review* 19 (1998): 143-49; and H. Ozawa, S. Nishikawa, and D. Higashida, "Development of Aerodynamics for a Solar Race Car," *Journal of the Society of Automotive Engineers Review* 19 (1998): 343-49.

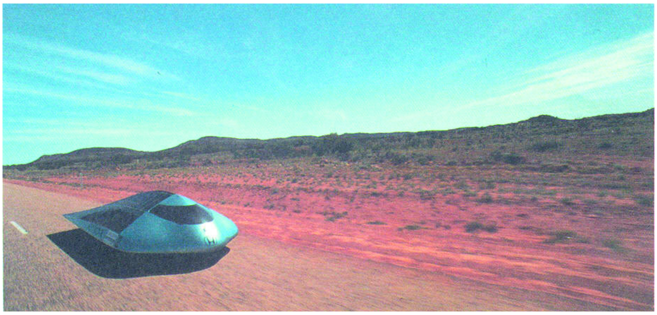

Figure 6.5 Honda solar racecar

> **HONDA INNOVATION AND INVENTION**
>
> - Soichiro Honda was awarded more than 470 patents.
> - Honda engineering firsts have come in combustion, anti-lock brakes, four-wheel steering, electronic fuel injection, continuously variable transmissions, aluminum die casting, and forming.
> - More than 300 patents are pending for innovation on the hybrid Insight and Civic.

consecutive year. In 2000, Honda returned to Formula One Grand Prix auto racing, the sport it had dominated in the 1980s.

Engineers were naturally disappointed when Honda withdrew from Formula One racing, but they soon realized his larger goal, that they were now racing to protect the Earth for future generations. They were now striving to win the ultimate race. For example, Honda marketed electric cars and vans under very favorable leasing terms that included complete maintenance and insurance, but was still unable to satisfy customers. It then switched to the hybrid car, because it could achieve comparable environmental performance as well as satisfy consumer demands for vehicle range, comfort, and simplicity of operation.

Honda's top managers and CEOs have always been engineers. "It is not that we ever decided to have a president with an engineering background, but an underlying concept of this firm is that rather than being driven to realize profits, we want to make superior engines. When a company thinks in these terms, its customers will be satisfied, and the profits will eventually be there too," says Tadashi Kume.[19]

Honda products have been first to achieve the vast majority of the most daunting European Union, Japanese, and North American emissions standards; and Honda offers these clean and fuel-efficient products in every market—even markets without stringent environmental requirements.

This environmental superiority is achieved at Honda as a result of the strong ethic of innovation and inspiration developed by its founders, and by setting

19 Quoted in: Robert L. Shook, *Honda, An American Success Story: Revolutionizing the Art of Management* (New York: Prentice Hall, 1988): 189.

challenging goals and financing research and development heavily. This "ethic" has created a synergy of imagination and technical know-how between engineers from all its product divisions. Environmental excellence from each division is shared company-wide, and the best environmental performance engineers are rotated throughout the racing programs to reward and inspire even more extraordinary inventions.

The synergy of engineering

Honda encourages "synergy of engineering" between product areas through its centralized research centers with "crossover meetings" of engineers, and by encouraging every employee (called "associates" at Honda) to make suggestions about the company. Consider how the company's patented variable valve timing and lift electronic control (VTEC) evolved over time. VTEC engines essentially take one intake valve per cylinder out of operation at low engine speeds to produce a precise and very lean air–fuel ratio. Operating with just one intake valve induces a high degree of swirl in the combustion chamber, leading to faster and more complete combustion. At higher engine speeds, both intake valves operate to increase engine-breathing capacity. This results in double the intake-valve area, achieving higher power output.[20]

VTEC was first developed for racing motorcycles to achieve higher power at every engine speed, and to allow operation at very high revolutions per minute (rpm). After VTEC had proven itself at the races, it was first commercialized in the 1983 CBR400F motorcycle and then withdrawn when other engine designs provided needed performance. In 1989, VTEC was introduced in the Acura NSX sports car and Integra, in configurations designed to deliver high-power performance. Later it was reapplied to motorcycles as HYPER VTEC (CB400SF: 1999; VFR800FI: 2002YM).

> In the early eighties, our motorcycle racing team was desperate to wring out every bit of horsepower. The intricate mechanisms of VTEC were less daunting to motorcycle engineers because everything on a motorcycle is miniaturized to fit between the rider's legs. The demands of racing inspired the engineers to push the technology to its limits, and in the end that won road races—*and is helping win the race for sustainable development*. At that time, no one could have imagined that variable valve timing could reduce emissions, and no environmental regulatory authority was demanding the low emission levels that are now proven to be necessary for air quality and climate protection.[21]

Honda perfected VTEC to provide faster and more complete combustion, resulting in very high fuel efficiency and reduced hydrocarbon and carbon monoxide

20 K. Horie, K. Nishizawa, T. Ogawa, S. Akazaki, and K. Miura, *The Development of a High Fuel Economy and High Performance Four-Valve Lean Burn Engine* (SAE Paper 920455; Washington, DC: Society of Automotive Engineers, February 1992).

21 Personal interview with Osamu Kuroiwa, Deputy General Manager of Environment and Safety Planning Office, Honda, February 2002.

emissions necessary to satisfy increasingly stringent California and global emission standards. Honda engineers were among the first to realize that the people of California would demand increasingly stringent standards, that national standards would quickly match any more-stringent state standards, and that vehicle manufacturers would want the manufacturing and marketing convenience of supplying the same car to all states.

The holistic "grail" of efficiency

The fuel-efficient version of the VTEC engine, called the VTEC-E ("E" for economy), was introduced in the 1992 Honda Civic HX Coupe and soon became the foundation for many of Honda's breakthroughs in environmental technology. Honda added three-stage, four-valve-per-cylinder timing, incorporating an engine management system that can assure highly accurate air–fuel ratios controlled by an air–fuel ratio sensor using zirconia (ZrO_2) for the 1995 Civic and Acura.[22]

Traditionally, engineering goals such as fuel economy, low emissions, performance, and safety were viewed as mutually exclusive. For example, early engineering approaches to safety often made cars heavier, which compromised both performance and fuel economy. "The old thinking was that power would always be sacrificed for fuel efficiency and even that fuel efficiency would be sacrificed to reduce emissions. This was true when engine designers just bolted on exhaust gas recirculation pumps, reduced compression ratios with shorter piston stroke, or made other crude compromises."[23] Honda engineers made it their goal to demonstrate unequivocally that fuel efficiency and engine performance could be achieved simultaneously. "We went back to the basics of physics and chemistry to learn that there were no limits. We embraced complex mechanisms and controls, and we experimented bravely until we succeeded. Today it is obvious that the goal is to turn all the fuel into power, with no toxic or greenhouse gas emissions."[24]

In 1998, Honda's revolutionary designs achieved the first gasoline engine certified by California and the US EPA as meeting the Ultra-Low-Emission Vehicle (ULEV) standard—which was previously deemed impossible. In the same year, Honda introduced its Natural Gas Vehicle (NGV), achieving even lower emissions—"almost zero"—for most pollutants and a 20% reduction in greenhouse gas emissions. Remarkably, Honda achieved ULEV- and NGV-level emissions while actually improving engine output and fuel efficiency—proof again that environmental protection can be "no compromise."[25]

22 *Ibid.*

23 Kazushige Toshimitsu, Senior Chief Engineer, Advanced Product Planning Division, interview, February 2002.

24 Hidekazu Kanou, Chief Engineer, Advanced Product Planning Division, interview, February 2002.

25 N. Kishi, S. Kikuchi, Y. Seki, A. Kato, and K. Fujimori, *Development of the High Performance L4 Engine ULEV System* (SAE Paper 980415; Washington, DC: Society of Automotive Engineers, February 23, 1998).

In 1999, Honda announced the ultimate combustion engine—the Zero-Level Emission Vehicle (ZLEV) based on the 2.3 liter, 4 cylinder engine found in 1998 and later Honda Accords. This vehicle has just one-tenth of the emissions of California's ULEV standard, the most stringent standard in the world both then and now (see Table 6.2). The name "ZLEV" is a term created by Honda. Honda defines the ZLEV as achieving one-tenth the ULEV standard, with nearly immeasurable emissions that are lower than the air the vehicle drives in ("negative emissions effect").[26]

	Non-methane organic gas (NMOG)	Carbon monoxide (CO)	Nitrogen oxides (NO_x)
Tier 0 Standard	0.41 total hydrocarbons (THC)	3.4	1.0
Tier 1 Standard	0.25 non-methane hydrocarbon (NMHC)	3.4	0.4
LEV Standard	0.075 @ 50k miles 0.90 @ 120k miles	3.4 @ 50k miles 4.2 @ 120k miles	0.05 @ 50k miles 0.07 @ 120k miles
ULEV Standard	0.040 @ 50k miles 0.055 @ 120k miles	1.7 @ 50k miles 2.1 @ 120k miles	0.05 @ 50k miles 0.07 @ 120k miles
SULEV Standard	0.010 @ 120k miles	1.0 @ 120k miles	0.02 @120k miles
01 Civic GX (NGV) test results	0.0084 @ 120k miles	0.1 @ 150k miles	0.01 @ 150k miles
Honda SULEV test results	0.0084 @ 120k miles	0.0155 @ 120k miles	0.0161 @ 120k miles
Honda ZLEV test results	< 0.004 (w/100k-mile aged catalyst)	< 0.17 (w/100k-mile aged catalyst)	< 0.02 (w/100k-mile aged catalyst)

Table 6.2 California LEV II Standards and Honda SULEV and ZLEV test results

The "next-generation" 2 liter, 4 cylinder Honda engines, which have debuted in Japan and the USA and will be offered worldwide by 2005, achieve ULEV emissions and a 10–20% boost in fuel efficiency as well as a reduction in greenhouse gas emissions plus higher performance including low-speed torque. Honda ZLEV and NGV vehicles achieve emission levels that are almost the same per kilometer as emissions produced by a clean mix of the power plants necessary to power electric vehicles (see Figure 6.6).

"A car equipped with this engine could drive through a high smog area, and the smog-producing emissions coming out of the tailpipe would actually be lower than in the surrounding air," said Nobuhiko Kawamoto, Honda's former President and CEO. "This engine represents a feasible approach, one we believe can be

26 N. Kishi, S, Kikuchi, N. Suzuki, and T. Hayashi, *Technology for Reducing Exhaust Gas Emissions in Zero Level Emission Vehicles (ZLEV)* (1999-01-0772; Washington, DC: Society of Automotive Engineers, January 3, 1999).

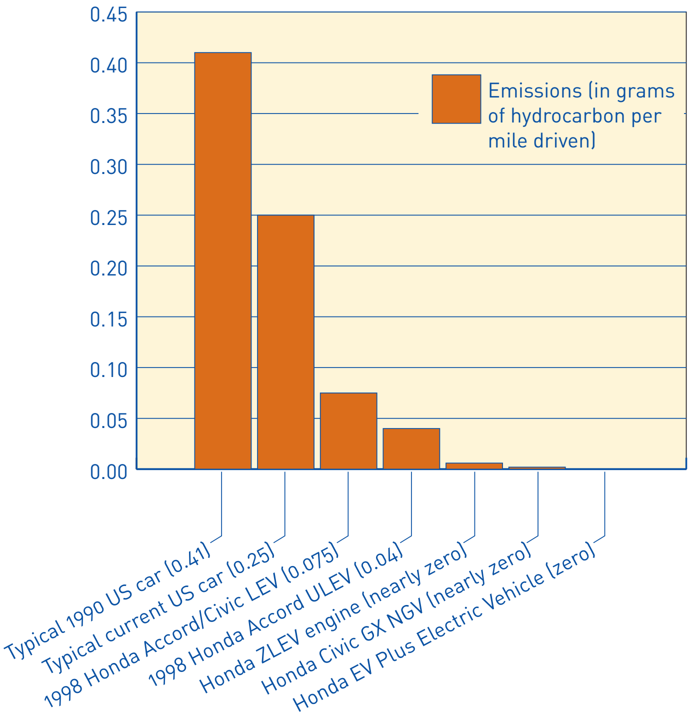

Figure 6.6 Clean, cleaner, cleanest engine

applied to Honda products."[27] The Honda ZLEV does depend, however, on low-sulfur reformulated fuel currently available only in California, Japan, and some European countries.

At Honda, the future is now

"Today everyone is excited about the fuel cell cars that will dominate markets after 2010, but we have not forgotten the importance of making next year's cars more friendly to the environment. We will continue to use synergy between our projects," says Tomohiko Kawanabe, Managing Director of Honda R&D. "For example, our hydrogen fuel cell vehicle uses the electric motor drive system developed for the EV Plus electric car, the energy management systems used in the Insight and Civic gasoline–electric hybrid car, and the high-pressure gas storage tank technologies developed for the natural gas-powered Civic GX."

27 Quoted in interviews with Honda.

OUTRUNNING THE VOCABULARY OF REDUCED VEHICLE EMISSIONS

Emission standards can be defined by scope (the list of chemicals controlled), stringency (the grams per mile allowed), and life-cycle (as new and at designated vehicle mileage). Until 2002, the standards covered toxic chemicals and chemical precursors to smog but not carbon dioxide or greenhouse gases. The US EPA sets national vehicle emission standards, but in some circumstances allows states to set more stringent standards. California has historically been the only state to exercise this right consistently. These standards are expressed in emissions per mile and, beginning in the 1990s, were translated by EPA into acronyms for convenience.

At first, it was easy to describe improvements, but now regulators are reaching a vocabulary dead end, and California is defining its own acronyms. The first EPA name was "Low-Emission Vehicle" (LEV). The next was logically named "Ultra-Low-Emission Vehicle" (ULEV), followed by the "Super-Ultra-Low-Emission vehicle" (SULEV) and then a designation of "Inherently Low-Emission vehicles" (ILEV). Sensing that adverbs were running out, the EPA just recently defined the "National Low-Emission Vehicle" (NLEV) with subcategories of "tiers" and "bins." California chose instead the designation of "Zero-Emission Vehicle" (ZEV). For example, the California ZEV is currently equivalent to the EPA's Tier 2 Bin 1 NLEV. In July 2002, California announced plans to control carbon dioxide from cars—no doubt starting a new round of cleaner-vehicle acronyms.

In 2001, the Civic featured a safety chassis and a new power train incorporating a further modified 1.5 liter VTEC lean-burn engine, with a continuously variable transmission. Fuel economy was improved by 10% in North American markets and by an additional 8% in Japan and other countries that have embraced low-sulfur fuel that allows direct injection.[28] Emissions were reduced dramatically to satisfy the most stringent standard in the world—the US ULEV standard.

Relentless pursuit of life-cycle climate performance (LCCP)

Since 1966, Honda has used LCCP to measure the total CO_2 emissions from every aspect of vehicle material supply, manufacturing, use, and disposal/recycling. A typical vehicle produces 80% of CO_2 emissions from fuel use; 18% from materials, manufacturing, and transport; and 4% in maintenance and disposal. Honda is working to reduce all of these emissions by increasing the use of recycled materials, by eliminating unnecessary weight and content, by making manufacturing more efficient, and by transporting parts and vehicles by the most energy-efficient option. The highest priority is to reduce the 80% of emissions from fuel consumption.

A conventional vehicle must have an engine large enough to provide acceptable power under the most demanding circumstances—fully loaded, high altitude,

28 M. Matsuki, H. Ohura, K. Watanabe, and Y. Kinoshita, "Development of a 1.5 l Lean-burn Engine for the 2001 Civic," *Honda R&D Technical Review* 12.2 (October 2000).

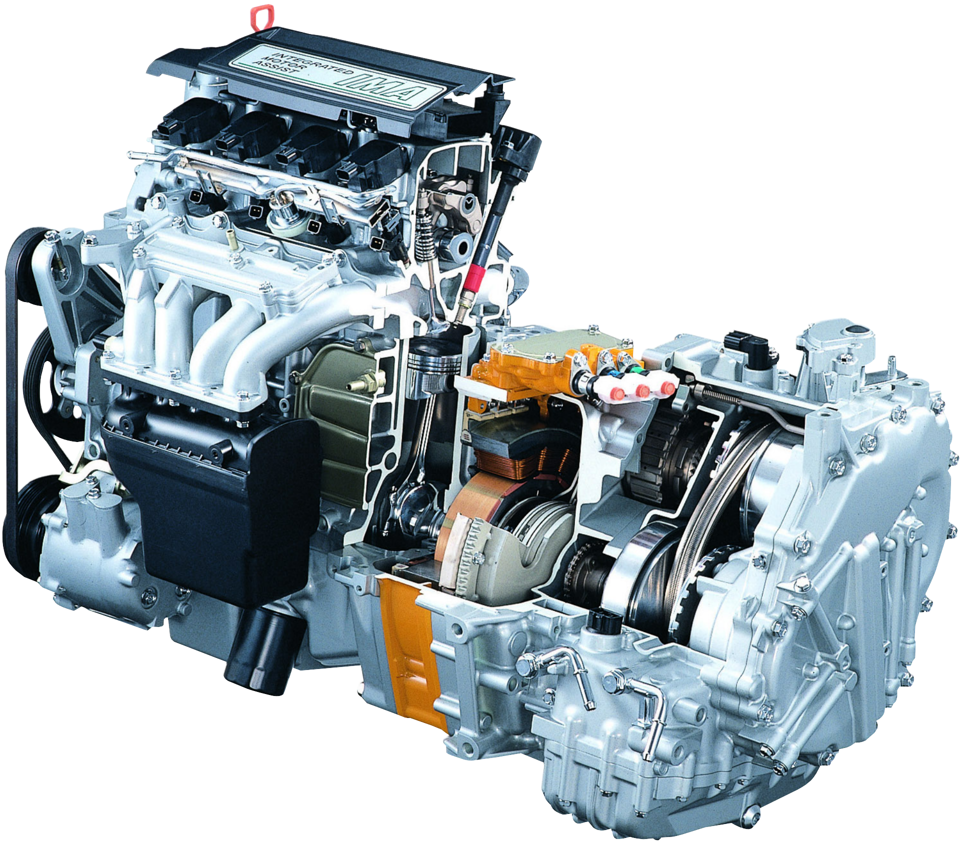

Figure 6.7 Honda hybrid engine, motor drive and automatic transmission

steep hills, and strong acceleration. During braking, a conventional vehicle wastes the kinetic energy of motion by converting it to heat energy via the brakes. Fuel is also wasted when engines idle. A hybrid takes advantage of the best traits of each power system—the clean nature of electricity and the high performance, range, and infrastructure of internal combustion engines.

Honda places its low-emission, clean-burn gasoline engines in hybrid electric–gas Insight and Civic models (Figure 6.7). Hybrid propulsion essentially recycles energy that would otherwise be lost during braking, and uses that power for acceleration at a later time. During acceleration and other times of heavy engine load, the electric motor assists the gasoline engine by providing additional power, resulting in improved acceleration without compromising fuel economy. This allows a significant reduction in engine displacement and higher engine efficiency.

At cruising speeds when the engine load is lower, the computerized motor assist system lets the ultra-efficient gasoline engine maintain the vehicle's speed. During deceleration, the electric motor becomes a generator and converts the energy into electricity. When the car comes to a temporary stop, at a traffic light for example, the engine shuts off automatically. Then it restarts immediately when the driver lets off the brake pedal and depresses the gas pedal on automatic transmission vehicles, or depresses the clutch and puts the car into first gear on manual transmission vehicles.[29] The Insight Hybrid is a two-passenger car built from the ground up for fuel efficiency and low emissions. The Civic Hybrid is a five-passenger, four-door sedan.

The Insight achieves its top-runner fuel economy through three technical breakthroughs. The integrated motor assist (IMA) system (with idle stop and regenerative breaking) contributes 30% to fuel efficiency; the advanced engine contributes 35%; and the lightweight aluminum body, low rolling-resistance tires, and aerodynamic body design contribute 35%. The integrated electric motor system is sized precisely to operate without surplus or deficit, and to minimize the size and weight of batteries to improve fuel economy without sacrificing vehicle performance.

The hybrid propulsion system achieves a 94% fuel economy advantage with no sacrifices in dynamic performance when tested on equivalent 500 kg vehicles.[30] The aluminum Insight body is 40–50% lighter than a comparably sized steel body using a combination of both Monique and space frame structure.[31] The use of aluminum also reduces the total greenhouse gas emissions from the manufacturing of the vehicle, with the highest reductions achieved with recycled aluminum. Chapter 1 of this book, on Alcoa, elaborates the importance of aluminum to climate protection. Here Honda's experience building the Acura NSX sports car paid off, because Honda engineers were able to apply new construction techniques, such as the use of extrusions and castings in the body.

The Insight is the world's most aerodynamic mass-produced automobile, with a

"Hybrid technology is ready to transform markets, demonstrating an extraordinary 30% improvement in fuel efficiency while maintaining the acceleration and speed of conventional Civics," says Honda. "The Honda Civic is the best-selling compact car in America and one of the pillars of the Honda brand worldwide. To add hybrid power to the Civic line-up is an example of the faith and confidence we have in our hybrid technology."* Hybrid vehicles are currently available only from Honda and Toyota, but DaimlerChrysler, Ford, and General Motors (GM) have announced plans to introduce hybrid vehicles: Ford Escape SUV (sport utility vehicle) in December 2003; GM in large pickup trucks in 2004; and DaimlerChrysler in future SUVs.

* Source: Honda press releases.

29 K. Nakano, K. Aoki, B. Knight, S. Kajiwara, H. Sato, and Y. Yamamoto, *An Integrated Motor Assist Hybrid System* (2216; Washington, DC: Society of Automotive Engineers, 2001); and S. Ochiai, K. Uchibori, K. Hara, T. Tsurumi, and M. Suzuki, "Development of a Motor Assist System for a Hybrid Car—Insight," *Honda R&D Technical Review* 12.1 (April 2000): 7-14.

30 Y. Hasegawa, S. Aoyagi, T. Yonekura, and H. Abe, "Energy Efficiency Improvement for a Series Hybrid Vehicle," *Honda R&D Technical Review* 12.1 (April 2000): 79-84.

31 A Monique frame structure replaces traditional rigid frame rails by engineering the sheet metal to provided the necessary strength. The space frame structure is a further refinement of the Monique structure that collapses in a collision in a manner that protects the occupant areas.

0.25 coefficient of drag and a weight of only 1,856 lb (841 kg). The aluminum body achieves high standards of safety, performance, stiffness, and cost savings relative to previous aluminum bodies. For example, to minimize head-on collision damage, the front and rear frame parts are made of extruded aluminum with different cross-sections in such a way that the front part will be compressed and collapsed and the rear part will bend and alleviate any penetration and impact on the body. The energy absorption rate is improved and the weight is reduced significantly. Lower weight improves fuel efficiency and improves braking and handling—possibly avoiding collisions that would occur with heavier steel bodies. The Insight aluminum body meets all US, European, and Japanese safety standards, including the 2003 safety standards for side impact and head injury protection.[32]

The 2003 ULEV Hybrid Civic achieves top-runner fuel economy with a 30% mileage improvement compared to the 2003 Civic with only a gasoline engine, but in some respects is the same as the traditional Civic.[33] It sells for about $18,000—only $3,000 more than a comparably equipped standard Civic. The final cost of the hybrid feature is reduced by credits available in Europe, Japan, and the USA and offset by fuel savings. About 95% of that extraordinary improvement is the result of an integrated gasoline engine/electric motor system, with about 5% coming from inconspicuous improvements in aerodynamics (front air dam and rear spoiler, revised underbody panels) and highly efficient power steering and special wheels and tires to reduce rolling resistance and inertia.

The engine in the Civic Hybrid has several breakthrough technologies including dual and sequential ignition, and VTEC variable-valve control with cylinder deactivation. Dual and sequential ignition features two separately controlled spark plugs per cylinder to maximize combustion. VTEC cylinder deactivation shuts down three of the four

If all cars in the Honda Civic size class were replaced by a Honda Civic Hybrid, 448 million gallons (1,702 million l) of gasoline would be conserved, keeping 4 MMt CO_2 out of the air. This would reduce atmospheric CO_2 levels by the same amount as a 1.2 million-acre (485,000 ha) forest, roughly the size of Glacier National Park, Montana.

AWARDS FOR HONDA HYBRID CARS

- *Popular Mechanics* Design and Engineering Award
- *Automobile Magazine* "2000 Technology of the Year"
- *Popular Science* Best of What's New Award
- *American Woman Motorscene* "Most Likely to Change the World"
- Clean Car Coalition "Clean Car Salute"
- Edmunds.com "Most Significant New Vehicle"
- Sierra Club Environmental Engineering Award
- US EPA 2000 Climate Protection Award
- US EPA "Most Fuel-Efficient Car in America" 2000, 2001, 2002, and 2003
- American Council for an Energy Efficient Economy (ACEEE) "Best Vehicle in Class"

32 M. Saito, S. Iwatsuki, K. Yasunaga, and K. Andoh, "Development of Aluminum Body for the Most Fuel Efficient Vehicle," *Japan Society of Automotive Engineers Review* 21 (2000): 511-16.

33 The Civic Hybrid has improved aerodynamics around the wheel wells, alloy wheels as a standard feature, and leaves out the fold-down rear seat to accommodate the batteries.

cylinders during deceleration to significantly increase the amount of electrical energy that can be recovered.

"Think of this integrated motor assist (IMA) system as an electric supercharger that provides additional performance without using much energy because it recovers the Civic's momentum to recharge itself," suggests Csaba Csere of *Car and Driver Magazine*.[34]

In 2002, Honda announced another revolutionary goal for environmental protection: to market a fuel-cell vehicle, operating on renewable energy, that achieves zero toxic emissions and zero greenhouse gas emissions from its propulsion system.[35] The company also intends to achieve two or three times the energy conversion efficiency of the most efficient gasoline engine and to attract customers with a vehicle that is easy to use, has the same dynamic performance, safety, durability and reliability of today's passenger cars. "Of course this is daunting and almost impossible," said Honda Research and Development Managing Director Tomohiko Kawanabe, "But it is clearly necessary for future generations. It is our duty and our challenge."

Looking back, it is possible to define some Honda environmental technologies as *evolutionary* and others as *revolutionary* as shown in Table 6.3. Revolutionary technology is entirely new and represents a breakthrough in environmental performance. Evolutionary technology fine-tunes existing technology to further increase power and fuel efficiency and to reduce emissions.

Tomohiko Kawanabe expands on the evolutionary and revolutionary processes of technology innovation at Honda:

> Each breakthrough in environmental technology required self-confident engineers who were willing to dismiss engineering skepticism and tackle problems again and again as environmental regulations matured. Revolutionary breakthroughs like the CVCC were continuously improved until we reached the limits of emission reduction. When we couldn't go any further, we jumped to a new revolutionary technology and then continuously improved that. I am very proud that Honda combustion engines with hybrid drive can environmentally outperform current electric and fuel cell propulsion, but I will celebrate when new technology has even less impact on humans and nature.

Honda, like all vehicle manufacturers, faces daunting challenges in improving the environmental performance of vehicles while satisfying safety performance. Intuitively, most people believe that increased weight and size improves safety, but this is not true. Heavy vehicles protect the occupants against being crushed in an accident, but heavy vehicles take longer to stop, are less maneuverable at high speeds, may roll over more easily, and can cause tire failure leading to complete loss of control.

Furthermore, any advantage in size is offset in accidents with other large vehicles. Fortunately, Honda engineers are making breakthroughs in safety. Car bodies are now shaped and formed to be stronger without increasing weight.

34 Csaba Csere quoted in *Car and Driver Magazine*, May 2002.

35 Greenhouse gas emissions will occur from vehicle manufacturing, transport, and disposal, and from fuel refining.

Revolutionary improvements	Evolutionary improvements
Compound Vortex Controlled Combustion (CVCC) 1973	Branched circuit CVCC 1976 (longer torch passage oriented toward approximate center)
	Multi-opening torch 1979 (five-opening torch spreads flame all over the higher-compression main combustion chamber with exhaust gas catalyst for CO and HC)
Variable valve timing and lift electronic control system (VTEC) 1983 motorcycles, 1990 cars	1.5 liter lean-burn engine 1992 (for the Civic)
Variable valve timing and lift electronic control system (VTEC) 1983 motorcycles, 1990 cars	1.5 liter 3 stage VTEC combined with the continuously variable transmission (CVT) 1996 (4 valve, variable swirl, valve timing and lift managed by 3 stage control—inactive, medium-speed, and high-speed cams).
	1.8 liter VTEC lean-burn 1998 (for the Accord)
	Evolved VTEC lean-burn with CVT 2000
	Evolved 1.5 liter lean-burn 2001 (reduced engine friction, newly designed intake port and combustion chamber, direct injection three-way NO_x adsorption reduction type catalyst)
	2.0 liter lean-burn i-VTEC 2000 (resin intake manifold, improved cylinder head, optimized valve timing, friction reduction, advanced exhaust, quick catalyst heating)
Ultra-Low-Emission Vehicle (ULEV) VTEC	ULEV VTEC 1997 (adaptive "self-tuning" precise cylinder-specific combustion control, air-gap exhaust for rapid heating of new three-way catalyst with precious metal layering and increased surface area)
Super-Ultra-Low-Emission Vehicle (SULEV)	SULEV 2000 (ULEV VTEC technology with predictive fuel control)
Hybrid gas–electric	World's lightest 1.0 liter gasoline engine merged with ultra-thin electric motor and regenerative braking for improved efficiency and added power when needed, earning the best EPA mileage ratings in history.

Table 6.3 Honda's revolutionary and evolutionary environmental technologies

This is all part of Honda's effort to strive for both revolutionary and evolutionary product improvement. Given its history of successful innovation, it is clear that Honda's dream for better environmental products will continue to come true.

Honda time-line

- **1935** Soichiro Honda races at the All-Japan Speed Rally, setting a speed record before being injured seriously.
- **1948** Soichiro Honda founds his company with only ¥1 million (< $10,000) investment.
- **1949** Co-founder Takeo Fujisawa joins the company.
- **1954** Honda factory motorcycles enter their first race in São Paulo, Brazil.
- **1955** Honda wins All-Japan Motorcycle Endurance Road Race in 350 cc.
- **1958** Super Cub motorcycle released.
- **1961** Honda wins top five positions in both 125 cc and 250 cc classes at Isle of Man Race.
- **1964** Honda announces participation in Formula One car racing.
  - The GB30 with 4-stroke engine was released in the marine engine category, which generates less noise and vibration than 2-stroke models, and consumes less fuel and produces cleaner emissions.
- **1965** Honda Formula One car wins the Mexico Grand Prix Race.
- **1966** Honda wins five classes in the World Motorcycle Championship Grand Prix Race.
- **1967** Production of automobiles started at Suzuka, Japan.
- **1970** US Clean Air Act and Japanese regulators set first stringent vehicle emission standards.
  - Honda N600 car sold in the USA (air-cooled, chain drive).
- **1971** Honda invents Compound Vortex Controlled Combustion (CVCC) engine.
- **1972** Details of CVCC low-emission engine system announced; CVCC engine complies with the US Muskie Act of 1975.
- **1973** Honda achieves 1975 Japanese and US emissions standard without catalysts.
  - Ford, Chrysler, Isuzu, and Toyota sign licensing agreement with Honda for CVCC technology.
- **1974** CVCC engine development group awarded "Society Prize" by the Society of Automotive Engineers.
- **1977** Civic CVCC ranked first in US EPA Fuel Economy Test.
- **1983** CVCC Chief Engineer Tadashi Kume becomes president, replacing retiring Kiyoshi Kawashima.
  - VTEC first developed and implemented for CBR400F motorcycle (reapplied to motorcycles as HYPER VTEC in the 1999 CB400SF and the 2002 VFR800FI).
- **1985** Honda CRX-HF is the first mass-produced 4 cylinder car to break the 50 mpg (21 km per liter) barrier.

1986 • Honda rated number one in J.D. Power Consumer Satisfaction Index.
• Honda captures Formula One Constructors' Championship.
1987 • Acura rated number one and Honda number two in J.D. Power Consumer Satisfaction Index.
1990 • VTEC engine first introduced on Acura NSX sports car, later to become the foundation for many of Honda's breakthroughs in environmental technology.
1992 • Honda captures sixth consecutive Formula One Constructors' Championship.
• First outboard motor to comply fully with the European Lake Borden emission-control regulations.
1993 • Honda wins the World Solar Challenge with the "Honda Dream" (held every three years).
1994 • Electric scooter introduced.
1995 • Civic becomes the first gasoline-powered vehicle to meet the California LEV standard; Honda achieves 2000 California standards requiring fleet average emissions at LEV—70% lower than the toughest federal standards for reducing emissions.
1996 • Honda wins the World Solar Challenge.
1997 • The BF130, a low-pollution marine engine, developed by Honda; all models are already well below the 2006 marine engine emission limits set by the US EPA.
• Honda Accord EX with automatic transmission first to achieve 2000 California standards for ULEV engines.
• Honda becomes first auto manufacturer to sell LEVs voluntarily in all states, with both Accord and Civic models.
• Honda EV Plus is first application of advanced nickel-metal hydride batteries in an electric vehicle.
• Honda announces a gasoline-powered internal combustion engine that is virtually pollution-free.
• Honda announces that it will gradually abandon manufacture of 2-cycle motorcycle engines and switch to more environmentally friendly 4-cycle engines.
1998 • Honda distributes "Best-In-Class" ULEV Accord in California, Connecticut, Massachusetts, and New York—with "no-compromise" engineering that achieves the lowest emissions while boosting power by 15% and increasing fuel economy and decreasing emissions of greenhouse gases.
• Honda GX SULEV Accord is first SULEV sold in the USA and was certified as the cleanest internal combustion vehicle ever tested, with a 20% reduction in greenhouse gas emissions.
1999 • Honda Insight is first gasoline–electric hybrid vehicle for sale in the US.
2000 • Honda Accord Super-Ultra-Low-Emission Vehicle (SULEV) is first vehicle certified to meet California's 2004 standard and was the cleanest gasoline-powered vehicle tested.
• Honda Accord SULEV awarded the California South Coast Air Quality Management District's 2000 Clean Air Award for Advancement of Air Pollution Technology.

2000
- Honda distributes Civic and MDX vehicles meeting California ULEV standards to all US states.

2001
- Honda MY Civic is the first car to meet California's ULEV standard in all states.
- Honda improves Insight's fuel efficiency by 5% to 9% and also improves power, performance, and safety.
- Honda announces Hybrid snowblower HS1390I; the snowblower is equipped with a Honda e-SPEC engine, an environment-friendly powerplant that surpasses the latest EPA regulations; and fuel economy improves 10% against same-type snowblower.

2002
- Honda hydrogen-powered fuel-cell vehicle (FCX) first to be certified by the California Air Resources Board as a Zero-Emission Vehicle (ZEV) and by the US EPA as a Tier 2 Bin 1, National Low-Emission Vehicle (NLEV), the lowest national emission rating.
- All Honda and Acura models sold in US meet or exceed Low-Emission Vehicle (LEV) levels.