HONDA
The Power of Dreams

PRESS INFORMATION
2004.12

Honda Fuel Cell Power

FCX

Another Step Closer to the Mobility of the Future

On December 2, 2002, Honda delivered FCX fuel cell vehicles to customers in Japan and the US. The Honda FCX was the world's first fuel cell vehicle to be certified for commercial use, and its delivery to the Cabinet Office in Japan and the City of Los Angeles in the US marked the beginning of a new era.

Since then Honda has continued to work toward the large-scale commercialization of fuel cell vehicles, bringing this dream closer to reality. In 2003, implementing an innovative new approach, Honda created the new-generation Honda FC Stack. Realizing world-leading levels of compactness and output and the capability to start up in temperatures as low as –20° Celsius, the new Honda FC Stack represents a very significant breakthrough.

Now the cold-weather capable Honda FC Stack-equipped FCX has received certification for commercial use, the first fuel cell passenger vehicle to reach this milestone. Improved environmental adaptability significantly increases the commercial viability of the fuel cell vehicle, and Honda is now introducing the FCX in a broader range of markets worldwide.

Honda is working to ensure that the dream of the automobile will be passed on to future generations. The evolution of the world-leading Honda FCX is a statement of that commitment. Taking the fuel cell vehicle to a new level of environment-friendly high performance, Honda is taking another step closer to the mobility of the future, and another step toward the realization of our dreams.

For Honda, great challenges lie ahead.

Toward the Large-Scale Commercialization of Fuel Cell Vehicles

Honda is working to hasten the large-scale commercialization of the fuel cell vehicle, the zero emissions vehicle many see as the ultimate source of clean mobility for the future. To achieve this goal, we believe it is essential to maximize the performance of the fuel cell stack, making it more compact and more powerful, endowing it with greater environmental adaptability, and mass-production viability.

We have redesigned the composition and materials of our fuel cell stack, implementing innovative ideas and approaches to create the new Honda FC Stack. Overcoming technical challenges, we have made the fuel cell stack lighter and more compact, and achieved world-leading levels of output. At the same time, we have made the FCX the world's first fuel cell vehicle capable of starting in sub-freezing temperatures as low as –20º Celsius. We have also significantly reduced the number of components, improving the viability of future mass-production and recyclability. The Honda FC Stack has evolved.

In addition, the torque fuel efficiency of the fuel cell system is significantly improved, leading to a 22% increase in fuel efficiency, and the driving range of the new Honda FCX is some 20% greater. Further, improvements in the energy efficiency of the electric motor and ultra-capacitor, which stores and supplies electrical energy, have resulted in more responsive, powerful performance. The highly space-efficient cabin is built around a custom platform which offers superior drivability and collision safety. A motor-controlled Traction Control System, a quieter ride, and equipment enhancements throughout make the new FCX a more comfortable and relaxing place to be. The new Honda FCX takes the fuel cell vehicle to a new level, bringing large-scale commercialization that much closer. The Honda FCX is ready for the coming age of hydrogen.

World-leading output
Sub-freezing start up

Next-Generation Fuel Cell
Honda FC Stack
Compact · High Output
Environmental Adaptability
Mass-Production Viability

Improved Driving Performance
Improved Fuel Efficiency

Improved Comfort
Improved Ease of Use

Honda has taken the fuel cell vehicle to a new level

Honda Fuel Cell Power

FCX

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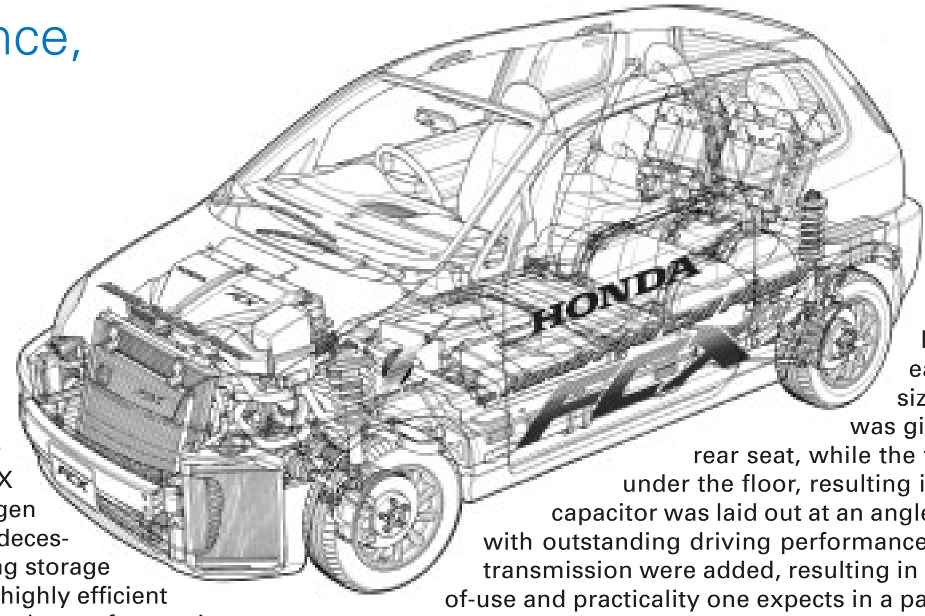
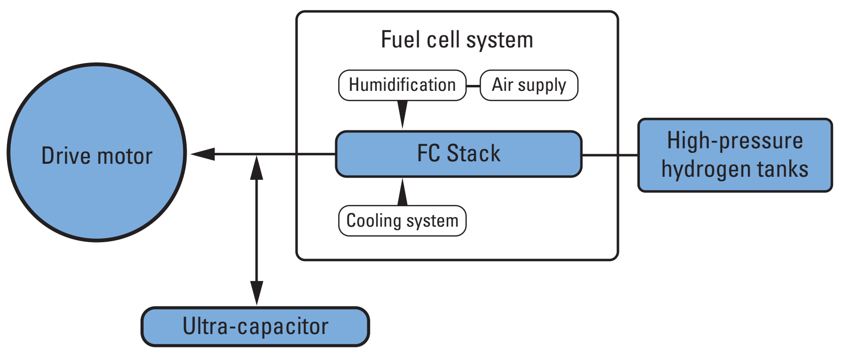
The Honda FCX—the ultimate in clean performance, now more powerful and practical



The newly developed Honda FC Stack and ultra-capacitor combine to power the motor, with onboard high-pressure hydrogen tanks for fuel storage.

A fuel cell vehicle is powered by an electric motor running on electricity generated by a fuel stack which uses hydrogen as its energy source. Considering factors such as energy efficiency during power generation and driving, overall system weight, and packaging efficiency, Honda has equipped the FCX with a system that combines a fuel cell stack and ultra-capacitor with onboard high-pressure hydrogen tanks. The newly developed Honda Fuel Cell Stack, which generates power more efficiently than its predecessor, serves as the main power source, while the independent ultra-capacitor contributes its outstanding storage capabilities as a supplementary power source to deliver ample drive power to the motor. The result is highly efficient driving performance: high-output, high-response driving and excellent fuel economy. And to ensure plenty of space in a compact body, the FCX employs high-pressure hydrogen fuel tanks capable of storing a large volume of hydrogen in a small space, along with a more compact fuel cell system and highly efficient packaging thanks to an optimum placement of the system components on a custom platform.

Main powertrain components



Main powertrain components

Honda FC Stack—PEMFC (Proton Exchange Membrane Fuel Cell) electrical generation device. Two lightweight, compact stacks with a total maximum output of 86kW.

Humidification system—The recycled water recovery (fully independent) humidification system recycles water generated in the FC Stack for use in air humidification.

PCU (Power Control Unit)—Controls electrical systems, including FC Stack output, capacitor output, drive motor output, air pump, and cooling pump.

Fuel cell cooling system—Equipped with one fuel cell system radiator (large) and two drive train radiators (small), specially developed for use in fuel cell vehicles for improved cooling performance.

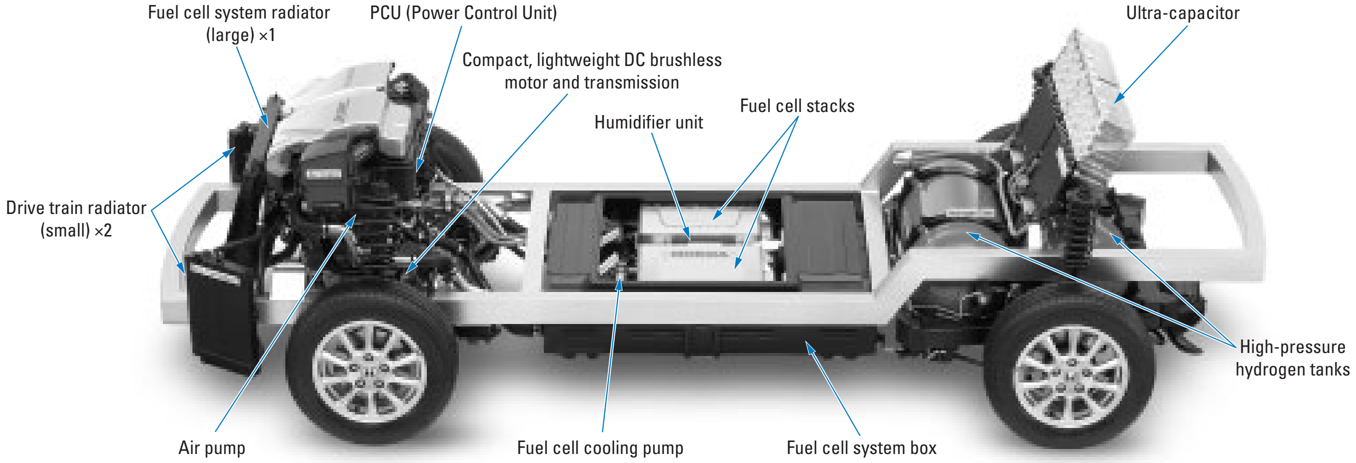
Drive train—Composed of a drive motor, transmission, and drive shaft. The drive motor combines high efficiency with high output and torque (maximum output: 80kW; maximum torque: 272N·m).

Honda ultra-capacitor—Delivers instantaneous high-output assist during startup and acceleration, while efficiently recovering energy generated during braking. Combines high responsiveness with high efficiency.

High-pressure hydrogen supply system—Equipped with two tanks. Can be filled with up to 156.6L of hydrogen at approximately 350 atmospheres.

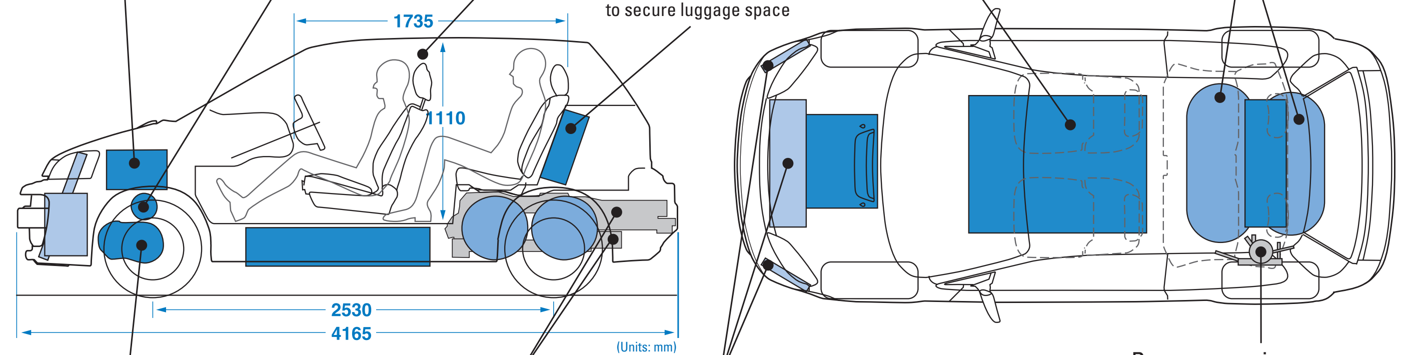
Air supply system—An air pump with a high-voltage electric drive motor supplies the FC Stack with air at the appropriate pressure and flow rate.

Powertrain layout

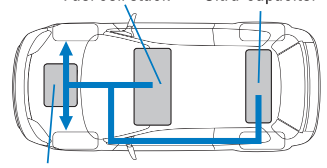


The highly compact fuel cell system is located under the floor and the high-pressure hydrogen fuel tanks are tucked under the rear seat, for a compact, easy-to-drive body with plenty of interior space and superior collision safety performance

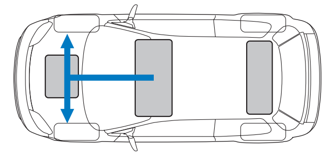
Honda custom-designed a platform for the FCX to ensure the high standards of ease-of-use and practicality required of a passenger vehicle by optimizing body size, spaciousness, and collision safety. The layout freedom allowed by the fuel cell was given full play. The high-pressure hydrogen storage tanks were located under the rear seat, while the fuel cell system was made more compact and lightweight and centrally located under the floor, resulting in a spacious cabin while maintaining a high level of collision safety. The ultra-capacitor was laid out at an angle behind the rear seat to secure luggage space. A space-efficient rear suspension with outstanding driving performance was also employed, freeing up even more space. Finally, a compact PCU and transmission were added, resulting in an easy-to-drive body. The FCX's highly efficient packaging gives it all the ease-of-use and practicality one expects in a passenger car.



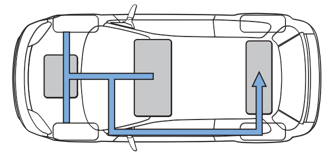
How power distribution works



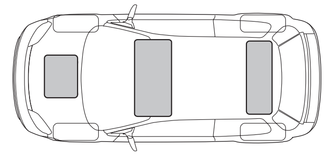
Startup and acceleration
(Output from fuel cell stack and ultra-capacitor)
The ultra-capacitor assists the fuel cell stack to achieve crisp, responsive performance.



Gentle acceleration and cruising
(Output from fuel cell stack)
The fuel cell stack supplies the motor with most of its electrical requirements, allowing unassisted, economical high-speed cruising.



Deceleration
(Power recovered and stored in ultra-capacitor)
The ultra-capacitor recovers the energy released during deceleration and stores it along with power from the fuel cell stack. This results in greater fuel efficiency and a natural feel on deceleration.



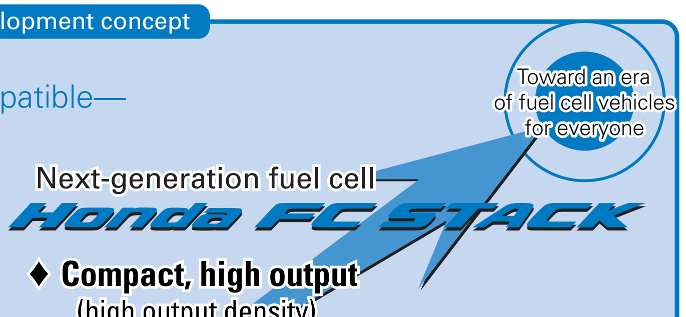
Stopped
(Idle stop)
The auto idle stop system shuts off output from the fuel cell stack to reduce fuel consumption. Electricity required to operate the air conditioner and other components is supplied by the ultra-capacitor. On startup, the system immediately supplies the necessary power for smooth, powerful acceleration. (Output of the fuel cell stack may not shut off under some conditions.)

Newly developed Honda FC Stack combines world-class levels of compactness and high output with operation at ambient temperatures as low as –20˚C

Honda FC Stack development concept

More compact, more powerful, more widely compatible—toward an era of fuel cell vehicles for everyone

Honda synergizes its research in a number of fields in its drive to commercialize fuel cell vehicles. Particularly with the fuel cell itself, the heart of a fuel cell vehicle, Honda is pursuing greater compactness and higher output to improve installability in vehicles and deliver better driving performance. At the same time, Honda is increasing the fuel cell's environmental adaptability to a wider range of climates, and mass production viability. Now, Honda has combined innovative thinking and groundbreaking new technologies to achieve a major breakthrough in fuel cell performance: the Honda FC Stack, the next generation in fuel cells.

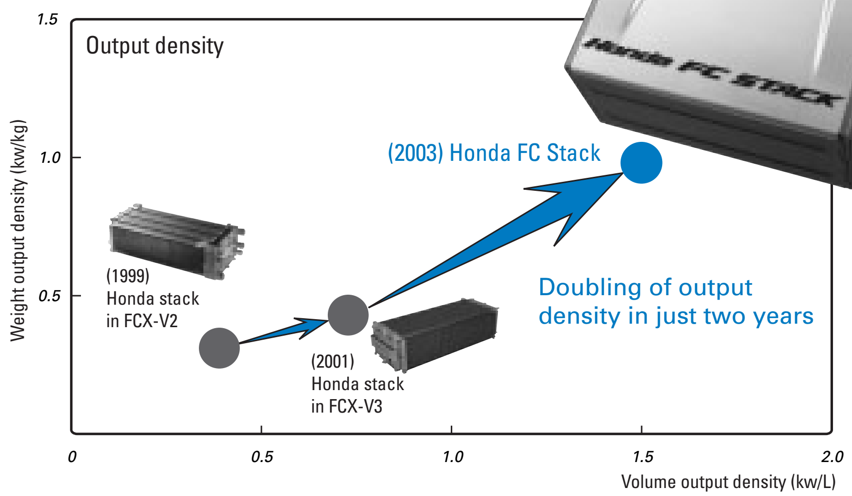


- ♦ **Compact, high output** (high output density)
- ♦ **Environmental adaptability** (high and low temperature performance)
- ♦ **Mass production viability**

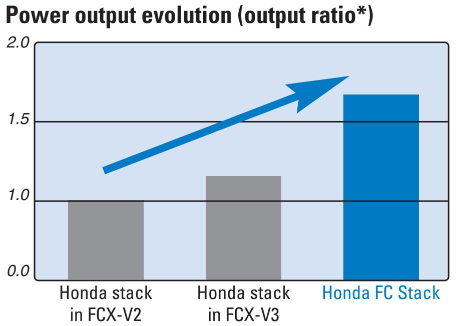
Aromatic electrolytic membrane and stamped metal separator used for the first time in an automotive application, for an evolutionary leap to the next generation in high-performance fuel cells

Honda has developed an aromatic electrolytic membrane, which offers outstanding hydrogen ion permeability, and a stamped metal separator, for superb electrical and thermal conductivity—a world's first in an automotive application. By improving electrical generating efficiency and through efforts to reduce stack size, the new stack has double the output and is half the size of its predecessor, achieving output density that ranks among the best in the world. What's more, this enables operation in temperatures from –20˚C to +95˚C, and enhances durability. Production and recycling are also easier. These breakthroughs herald a new generation in fuel cell performance.

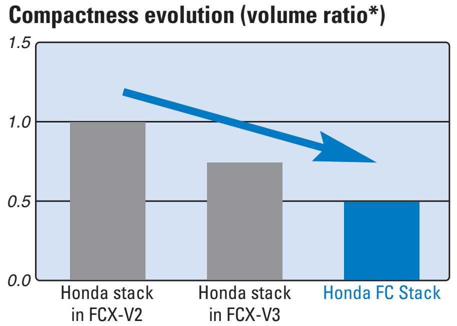
Honda stack evolution



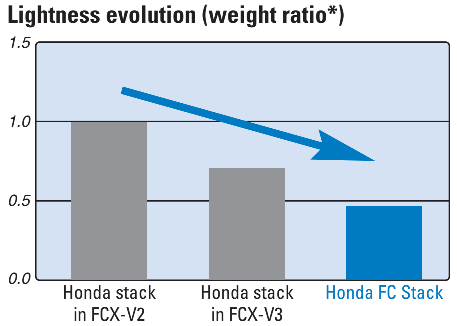
Power output evolution (output ratio*)



Compactness evolution (volume ratio*)



Lightness evolution (weight ratio*)

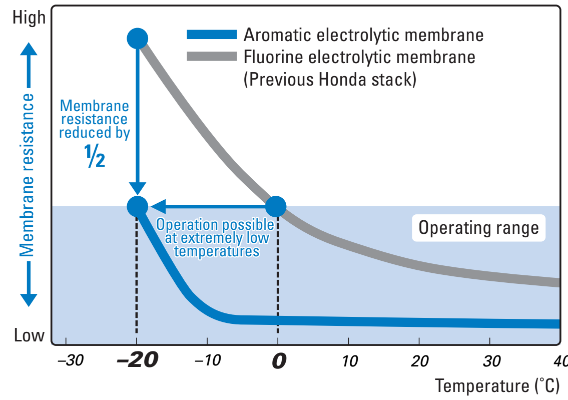


* Ratio: Honda stack used in FCX-V2 equals 1.0

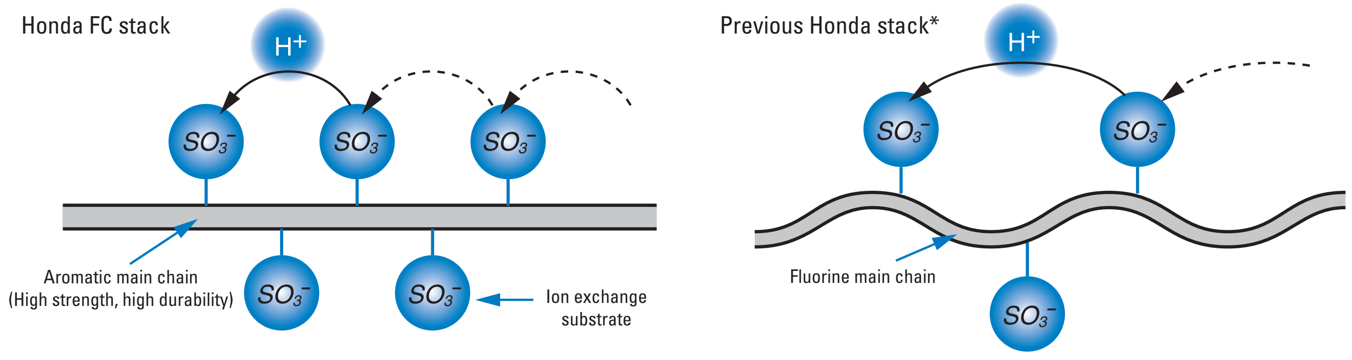
Newly developed aromatic electrolytic membrane delivers improved hydrogen ion conductivity even at extremely low temperatures

Whereas conventional fuel cells use fluorine electrolytic membranes, the Honda FC Stack employs a newly developed aromatic electrolytic membrane. This electrolytic membrane has been redesigned down to its molecular structure, combining main chains containing a highly stable aromatic structure with an ion exchange substrate (SO_3^-). This permits a major increase in ion-conducting substrate over that of a conventional fluorine electrolytic membrane, while exhibiting lower depletion. By increasing the ion exchange substrate, low-temperature hydrogen ion conductivity is increased twofold over that of a fluorine electrolytic membrane. As a result, membrane resistance can be reduced by around half and outstanding conductivity obtained even at sub-zero temperatures, to achieve operation at temperatures as low as –20˚C.

Improved hydrogen ion conductivity in electrolytic membrane



Comparison of electrolytic membrane structures



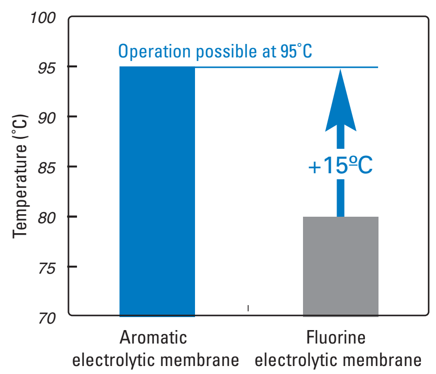
The aromatic electrolytic membrane contains more of the ion exchange substrate than the fluorine electrolytic membrane, resulting in lower membrane resistance over a broad temperature range.

*Honda stack installed in FCX-V3

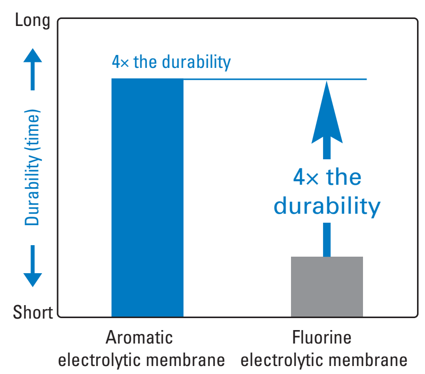
Improved high-temperature durability

In a conventional fuel cell using a fluorine electrolytic membrane, the materials suddenly soften and deform when the temperature climbs over 80˚C, making it inoperable at high temperatures. The aromatic electrolytic membrane used in the Honda FC Stack contains main chains employing a strong, durable aromatic structure that does not soften or deform even at high temperatures. However, even though the aromatic structure displays outstanding anti-deformity characteristics at high temperatures, Honda encountered adhesion problems between it and the electrode layer when using conventional membrane/electrode layer manufacturing processes. To overcome this problem, an original manufacturing process was developed. This resulted in outstanding adhesion between the electrolytic membrane and the electrode layer.

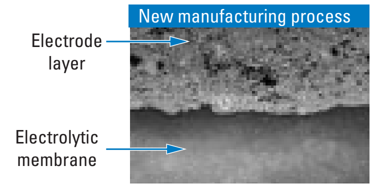
Improved high-temperature performance

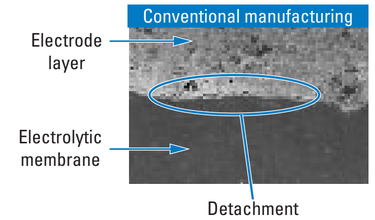


Improved high-temperature durability (80˚C)



Comparison of adhesion between aromatic electrolytic membrane and electrode layer





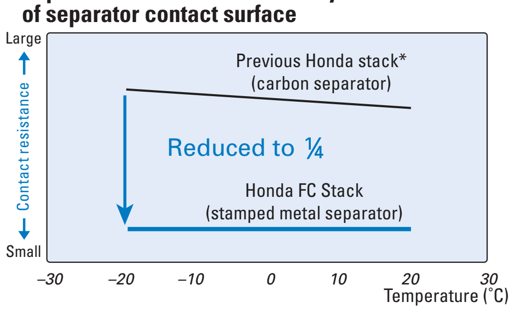
Newly developed stamped metal separator delivers outstanding electrical and thermal conductivity for improved low-temperature operation

The separator, which divides the serially connected fuel cells, acts as a pathway for the electrons and therefore demands outstanding conductivity. At the same time, thermal conductivity (rapid heating) is also important, to prevent the water produced as a byproduct of electrical generation from freezing. The Honda FC Stack employs stamped metal separators to obtain significant advances in both electrical and thermal conductivity. Metal's characteristic low electrical resistance and imperviousness to heat deformation result in a reduction in contact resistance to one quarter that of carbon separators at –20°C, for outstanding electrical conductivity. Metal separators are also just half the thickness of their carbon counterparts, resulting in a fivefold increase in thermal conductivity. The result: the entire stack can be heated quickly and evenly, for significant time savings from when power generation begins to when the stack is warmed up. This allows the aromatic electrolytic membrane's sub-zero generating capabilities to be used to their full potential.

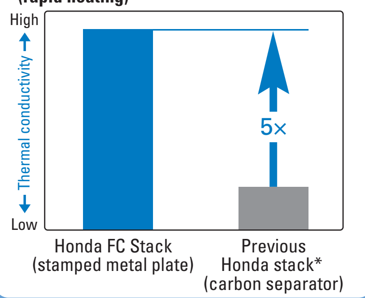
Separator performance comparison

	Honda FC Stack (stamped metal plate)	Previous Honda stack* (carbon separator)
Compactness	◎	×
Electrical conductivity	◎	△
Thermal conductivity	◎	△
Impact resistance	◎	×

Improved electrical conductivity of separator contact surface



Improved low-temperature startup (rapid heating)

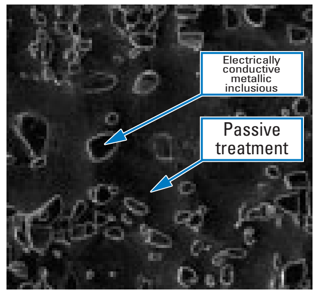


*Honda stack installed in FCX-V3

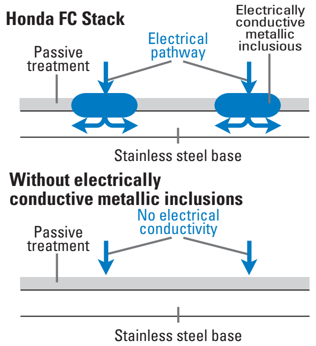
Newly developed stainless steel plate delivers both improved electrical/thermal conductivity and increased corrosion resistance

Use of metallic substances has long attracted attention as a means of effectively obtaining both electrical and thermal conductivity. However, up to now carbon separators have been employed, since the use of passive treatment to guard against rust and corrosion caused by electrical current in metal separators tended to increase resistance. In order to overcome this persistant problem, in the Honda FC Stack, highly electrically conductive metallic inclusions are dispersed on a stainless steel base, which is then given an oxidized coating. This prevents rust and corrosion while establishing a compulsory electrical pathway, to achieve outstanding electrical and thermal conductivity.

Newly developed stainless steel plate (expanded view)



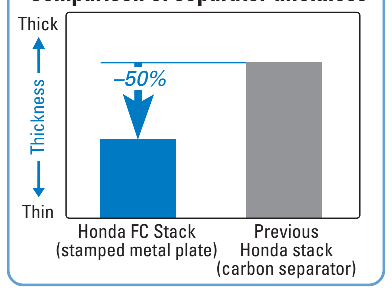
Cross section



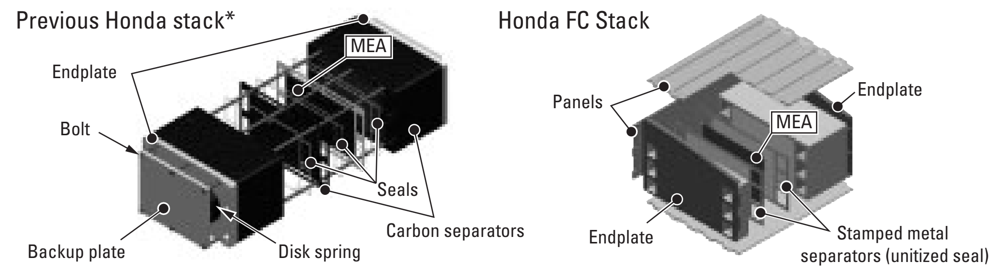
Use of stamped metal separators and a simplified construction make the Honda FC Stack lighter and more compact—for world-class output density

Conventional stacks using carbon separators require independent seals, along with disk springs and backup plates held together with large bolts in order to maintain a tight seal. In comparison, the Honda FC Stack utilizes high-strength stamped metal separators that are 50% thinner than their carbon counterparts, and employs a unitized seal that results in an even thinner cell unit and fewer parts. What's more, the design takes advantage of the springiness of the metal separators to create a simple structure in which the stack is simply encased in panels, reducing the number of parts by half. The result is a fuel cell stack that is lighter and more compact, for a high-output, high-efficiency unit that achieves world-class output density (ratio of output to volume and weight) more than twice that of previous fuel cell stacks.

Comparison of separator thickness



Comparison of Honda FC Stack construction

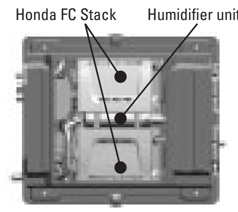


*Honda stack installed in FCX-V3

Modulization of the humidifier unit and unitization of other peripherals for a more compact fuel cell system

In order to maximize space efficiency in the fuel cell system box, the FCX uses two FC stacks that have been made lighter and more compact through the use of stamped metal separators. The resulting layout freedom is utilized to enable a unitized construction for the humidifier module. Structural components have also been combined and other peripherals unitized to create a highly efficient layout for the system, achieving a more compact fuel cell system box.

Fuel cell system box configuration



Improved productivity and recyclability

The stamped metal separators can be formed using ordinary metal stamping technology and feature unitized seals, resulting in major savings in production time. This results in improved productivity. And because metal is used, the unit is also easier to recycle, further improving the FC Stack's prospects for future large-scale commercialization.

What is a fuel cell?

Makes possible vehicles that generate no CO_2 or exhaust gas emissions: The fuel cell stack achieves the ultimate in clean performance

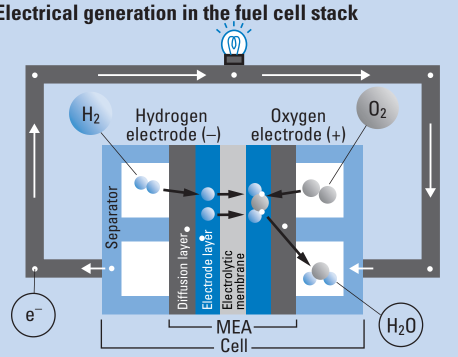
Electricity made from hydrogen and oxygen—the only emission is water

The FCX's fuel cell stack is a PEMFC (Proton Exchange Membrane Fuel Cell) electrical generation device that employs an electrochemical reaction between hydrogen (H_2) and oxygen (O_2) to directly convert chemical energy into electrical energy. This can be viewed as the reverse of the principle of electrolysis, in which an electrical current is used to separate water (H_2O) into hydrogen and oxygen. Honda has created a clean-running system that is capable of continuous electrical generation when supplied with hydrogen and oxygen, simultaneously generating electricity and water, with no CO_2 or other harmful emissions whatsoever.

How electricity is generated

- When hydrogen is delivered to the hydrogen electrode it is ionized by a catalytic reaction with the platinum electrode, emitting electrons.
- After emitting electrons, the hydrogen ions pass through an electrolytic membrane (ion exchange membrane), where they bond with oxygen ions from oxygen delivered to the oxygen electrode (+) and the previously emitted electrons arriving via an external circuit.
- This reaction creates a DC electrical current, generating electricity. Water is generated at the oxygen electrode as a byproduct, and some of this water is used for humidification.

Electrical generation in the fuel cell stack



Electrical generation in a cell unit

Hydrogen (–) electrode reaction	Oxygen (+) electrode reaction
$H_2 \rightarrow 2H^+ + 2e^-$ (catalyst) → Electrical energy	$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$ (catalyst)

Structure of the fuel cell stack and functions of its parts

The ion exchange membrane is composed of an extremely thin polymer layer (PEM, or proton exchange membrane, which exchanges positive ions). This membrane is sandwiched between two electrodes (the hydrogen electrode and the oxygen electrode), which in turn are sandwiched between separators to compose one cell. These cells are stacked, and when the electricity generated by each cell is combined, a large voltage is produced.

MEA (Membrane Electrode Assembly)
This is the area in the fuel cell where the reaction that generates the electricity takes place. Hydrogen (H_2) is separated into hydrogen ions (H^+) and electrons (e^-) at the hydrogen electrode. Only the hydrogen ions (H^+) are permitted to pass through the electrolytic membrane, where they react with the oxygen (O_2) at the oxygen electrode to form water (H_2O). Meanwhile, the separated electrons (e^-) pass through an external circuit, creating electrical energy.

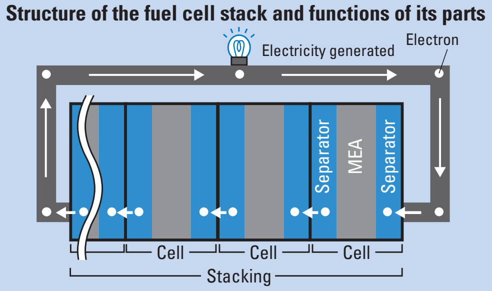
Electrolytic membrane (ion exchange membrane)
The membrane is composed of a polymer layer that is electrolyzed when impregnated with water, making it permeable only to positive ions (H^+). It also plays a role in gas separation and electrical insulation.

Electrode layer
This is the layer where the re-oxidization reaction between the hydrogen and oxygen occurs. It incorporates a catalyst to facilitate the reaction.

Diffusion layer
Located between the electrolytic membrane and the separator, this is where the reactive gas is evenly diffused over the electrode layer.

Separator
Inside the fuel cell, paths are required to supply the hydrogen and oxygen to the respective electrodes of the MEA. Also, heat is produced during the reaction that generates the electricity, necessitating a route for the coolant medium. The separator ensures that all these separate elements flow as required without being mixed together. On top of this, the separator also provides a direct path for the electrical current produced in the MEA.

Structure of the fuel cell stack and functions of its parts



Cells are stacked in series, like dry-cell batteries

{ Voltage: Determined by number of layers; unrelated to surface area of electrodes
Current: Determined by surface area of electrodes; unrelated to number of layers }

Voltage × Current = Output

To increase output: { Increase number of layers
Increase surface area of electrodes. }

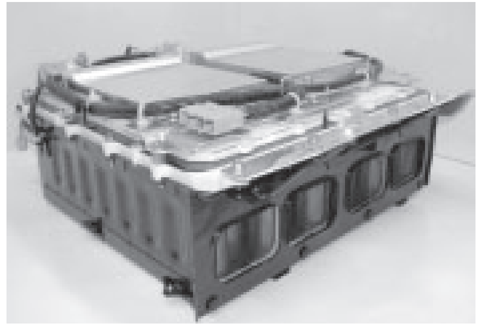
What is a fuel cell?

Honda's own originally developed ultra-capacitor—Higher output, higher efficiency, and increased storage capacity

More powerful drive assistance, more efficient energy recovery during braking

Honda has independently developed a high-performance ultra-capacitor (electrical two-layered condenser) to serve as a supplementary power source to the FCX's main power source—the fuel cell stack—for more powerful performance under various driving conditions. The ultra-capacitor combines the electrical storage capacity needed for high output and high responsiveness with solid reliability. It stores energy produced during deceleration and braking and provides powerful drive assist during startup, acceleration and at other times when an extra boost is required. The ultra-capacitor's internal resistance is lower than that of a battery, and moreover, because it stores and discharges electricity in response to fluctuations in the fuel cell stack, it doesn't require a converter for voltage regulation as in a battery system, so it delivers higher output. The result is improved drive-power performance and higher system efficiency.

Honda ultra-capacitor (system module)



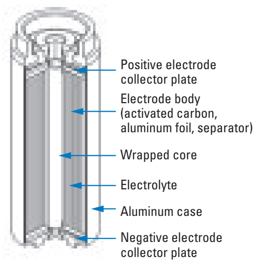
Outstanding charging and discharge functionality

The ultra-capacitor retains the same high-performance activated-carbon electrode that was used previously, while the configuration of the electrode wrapped-element construction has been reexamined to increase the number of wraps per electrode without increasing size. This increase in electrode charge density delivers a significantly higher energy storage capacity, resulting in a 10% improvement in energy storage and output compared to the previous ultra-capacitor. Its charging and discharge functionality is among the best in the world.

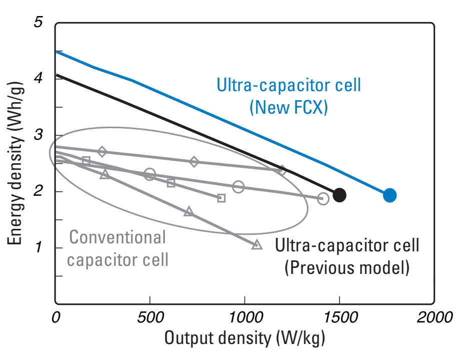
(Based on Honda in-house testing)

Cell construction

Capacitor cell

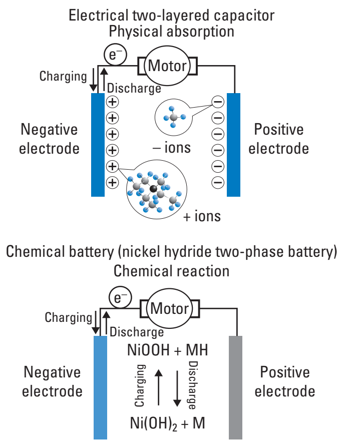


Capacitor charging and discharge performance (cell unit)



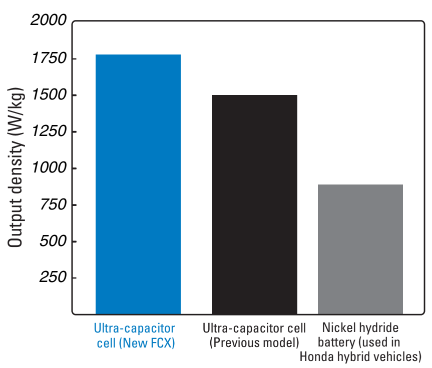
The Honda ultra-capacitor's high-performance electrodes and electrolyte deliver outstanding energy density and output density that surpass those of conventional capacitors. In particular, the low resistance reduction effect of the electrodes and collectors enable a high level of output normally considered difficult to obtain in a capacitor. The ultra-capacitor boasts a further 10% improvement in charging and discharge performance over the previous model.

Schematic of electrical charging and discharge in electrical two-layered capacitor



The capacitor does not rely on a chemical reaction during charging and discharge, therefore internal resistance is lower, enabling higher output.

Output density



The output of the nickel hydride battery is limited to around 900W/kg due to the effect of heat loss, but the ultra-capacitor's low resistance enables it to handle much higher output. The ultra-capacitor further improves on the performance of the previous model, achieving an output density of 1750W/kg or more.

Previous model: FCX released in 2002

Drive motor with increased power and torque—Realizing driving potential from low to high rpm

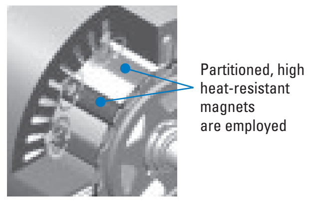
Energy loss reduction technology and a heat-management design, for high efficiency over a wide range and an expanded power band—plus increased power and torque

The FCX drive motor is a further development and refinement of the high-performance technology Honda developed for the EV-Plus electric vehicle. In the previous model, reluctance torque combined with a low-loss magnetic circuit and full-range, full-digital vector control were applied to secure high efficiency over a broad output range, along with an expanded power band. Heat generation in the rotor was also controlled to expand the power band in the high-rpm range. On top of this, the new model takes advantage of the Honda FC Stack's outstanding power generating capability and the increased ultra-capacitor storage capacity to attain a maximum output of over 80kW, stretching the motor's performance to its maximum potential.

Rotor heat generation control technology

To respond to increased magnetic flux variations in the rotor due to reluctance torque, magnetic partitioning was employed to greatly suppress the occurrence of eddy currents. High heat-resistant magnets and a magnetic circuit configuration appropriate for high output further achieved a high demagnetization suppression effect. This results in an expanded high-output range at high rpms.

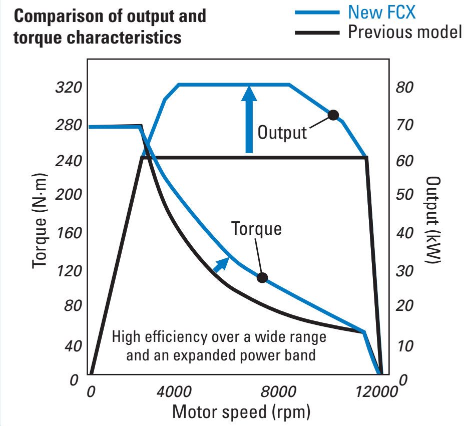
Partitioned high heat-resistant magnets



Comparison of drive motor performance

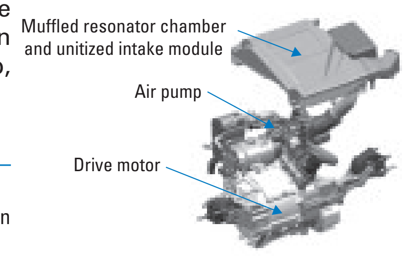
	New FCX	Previous model	EV-Plus
Max. output	80kW	60kW	49kW
Max. torque	272N·m	272N·m	275N·m
Max. rpms	11,000rpm	11,000rpm	8,750rpm
Max. efficiency	97%	97%	96%
Avg. efficiency (LA-4 mode)	93% or greater	93% or greater	90%

Comparison of output and torque characteristics



Noise-reduction measures in the powertrain enhance the fuel cell vehicle's already outstanding quietness

Powered by an electric motor, the fuel cell vehicle offers outstanding quietness, with none of the vibration or exhaust noise associated with the engine of a gasoline-engine car. In addition, the new FCX further reduces intake noise and noise and vibration in the air pump, to achieve even quieter, more comfortable driving than the previous model.



Powertrain noise-reduction measures

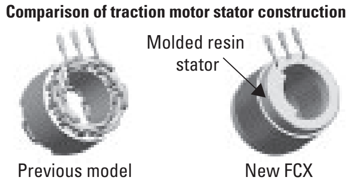
New technologies

- **Solid construction in the air pump rotor**
  By switching from a hollow to a solid construction in the air pump rotor, air column resonance is suppressed, resulting in decreased intake noise. Passenger compartment noise is reduced by 10dB over the previous model.
- **Resin molding in the traction motor stator**
  Resin molding is used for the wound portion of the motor stator to improve the stator's overall rigidity, reducing resonance vibration in the motor. Passenger compartment noise is reduced by 6dB over the previous model.

Technologies from the previous model

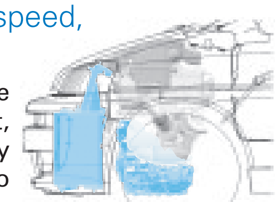
- **Muffled resonator chamber and unitized intake module**
  A compact, modular resonator chamber suppresses intake noise radiation over a broad frequency band.
- **Double floating mounts**
  The air pump and the air pump motor are secured to the motor and transmission with rubber mounts, which in turn are secured to the sub-frame with rubber mounts, resulting in a two-stage reduction of air pump rotational vibration to the body.

Comparison of traction motor stator construction



A lightweight, compact motor and transmission with unitized construction—single-speed, fixed reduction ratio utilizes the motor's output characteristics to maximum effect

The simple, high-efficiency transmission delivers power to the differential through a two-stage reduction from main (primary) to counter (secondary) to final. Built for high rpms and high output, the unit has also been made more lightweight and compact. This allows the FCX to offer distinctively smooth, powerful performance, while offering the packaging merit of permitting a large radiator to be installed, contributing to improved cooling performance.



Positioning of the motor, transmission, and radiator

Operational capabilities

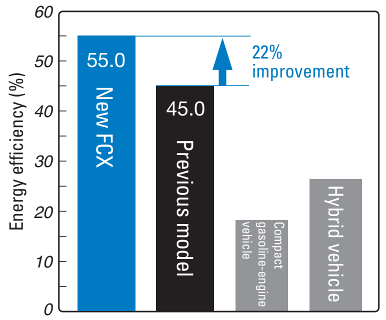
The new FCX delivers much more powerful performance, a stable, reassuring ride, and a significant improvement in fuel efficiency that extends the vehicle's driving range. And with the newly developed Traction Control System (TCS) the stability of the new FCX is evident even on snowy roads.

The combination of the superior power generation efficiency of the Honda FC Stack and the further enhanced efficiency of the fuel cell system elevate torque energy efficiency. With its outstanding fuel efficiency, the FCX now has a driving range of some 430 km.

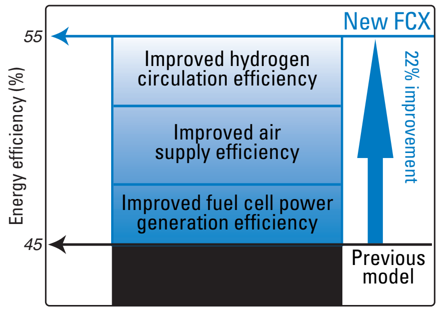
The newly developed Honda FC Stack features significantly improved operational capabilities. The improved efficiency of power generation by the stack, the air supply system to the stack, and the hydrogen circulation system results in a 22% increase over the previous model in torque energy efficiency. Further, highly efficient energy management ensures efficient use of the power generated, while minimal fuel consumption is achieved through energy recovery during deceleration, storage of electricity from the fuel cell stack, and the auto idle stop system for cutting power to the motor during idling. The FCX thus achieves an energy efficiency of 55%—approximately twice that of a hybrid car and three times that of a gasoline-engine vehicle. Consequently, fuel efficiency has improved 22% compared to the previous model, extending the driving range from 355 km to approximately 430 km.

(Honda internal calculations, LA-4 Mode)

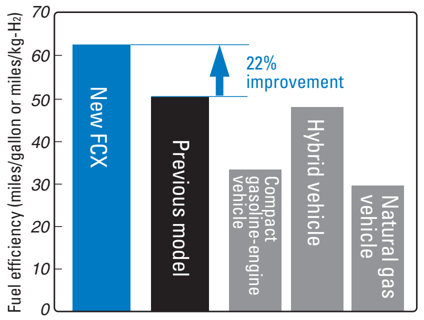
Comparison of torque energy efficiency*



Breakdown of improved torque energy efficiency*



Comparison of fuel efficiency*

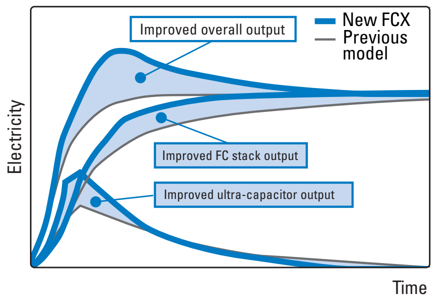


* Honda internal calculations, LA-4 Mode

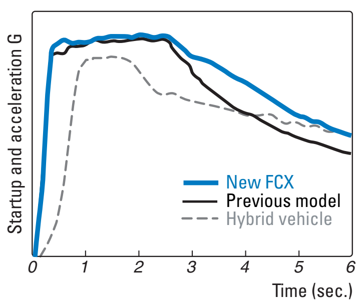
The high output of the Honda FC Stack and the increased energy capacity of the ultra-capacitor greatly improve the overall output. The new FCX delivers torquey startup and smooth acceleration.

The Honda FC Stack delivers world-leading output density and the ultra-capacitor provides more powerful drive assist because of its increased energy storage capacity. As a result, the new FCX delivers prompt, powerful response to the driver's accelerator inputs. And thanks to a 20kW increase in motor output, it offers quick startup and acceleration that can surpass that of a gasoline-engine car. Powerful, smooth acceleration at all speeds is achieved by maintaining torquey motor output, even during acceleration from mid- or high-speed range.

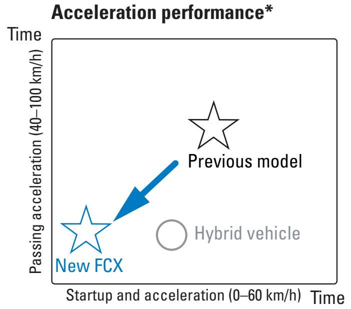
Improved FC stack responsiveness and ultra-capacitor output



Startup and acceleration G*



Acceleration performance*



* Honda internal calculations, LA-4 Mode

Previous model: 2002 FCX

The FCX delivers powerful performance, and superb maneuverability and handling stability.

To complement the smooth, powerful performance of the highly energy-efficient powertrain, the chassis and other components have been engineered for an improved ride, stability, and comfort. From city to highway driving, the FCX offers easy handling and a comfortable ride.

5-link double-wishbone rear suspension
An Accord-type rear suspension is used to provide superb handling stability and ride comfort. The suspension mounts have also been unitized with the high-pressure hydrogen tanks and the sub-frame, contributing to greater space-utilization efficiency and easier installation.

EPS (Electronic Power Steering)
Specially designed rack-assist EPS combines light, natural handling at low speeds with solid stability at higher speeds.

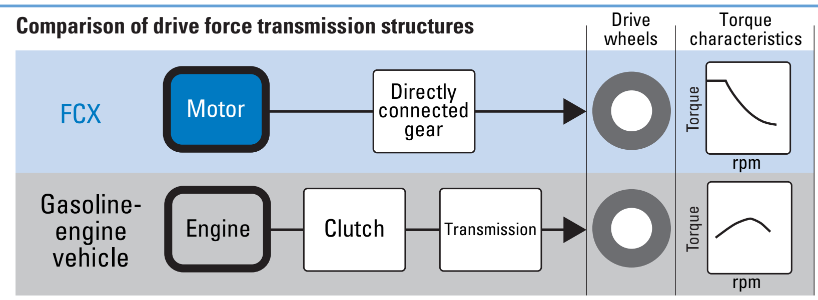
Electronic vacuum pump brakes
An electronic vacuum pump and master power provide the right amount of braking assistance. ABS with EBD (Electronic Brake-force Distribution) is standard equipment.

55:45 front-rear weight distribution
The fuel cell system and other major components have been optimally positioned to provide the ideal front-rear weight distribution for a front-wheel drive car. This results in highly stable handling characteristics.

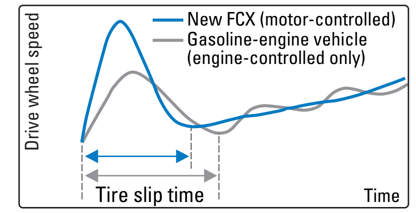
The newly developed motor-controlled traction control system (TCS) is specially designed for the FCX to deliver a stable, reassuring ride even on snowy roads and other slippery surfaces.

Capable of starting at sub-freezing temperatures, the new FCX also features a newly developed TCS. This helps ensure ideal torque transmission even on snowy roads and other slippery surfaces. The wheel sensors for monitoring the rotational speed of each wheel detect wheel spin, and the ECU promptly controls the motor torque. Thanks to its simple structure, the motor-integrated transmission has minimal mechanical loss. Its superior responsiveness made possible the FCX's quick, linear motor control. What's more, its smooth acceleration with accurate wheel speed control and minimal differences in wheel rotational speed suppresses tire slip and delivers a stable, reassuring ride.

Comparison of drive force transmission structures



Comparison of TCS performance on a low μ road

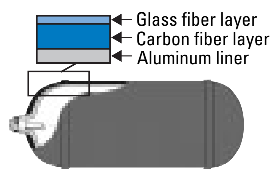


Since the responsiveness of motor torque is optimal, wheel rotational speed is promptly controlled despite high drive-wheel slip.

High-pressure hydrogen tanks

Two 350-atmosphere high-pressure hydrogen tanks provide ample storage capacity.

Given that the hydrogen used as fuel has a low energy density per volume, as much hydrogen as possible must be available to ensure maximal driving range. For optimal packaging, however, the fuel tanks must take up as little space as possible. The FCX's 350-atmosphere, corrosion-resistant, high-pressure hydrogen tanks are constructed of three layers: an aluminum liner, a carbon fiber layer, and a glass fiber layer. The two tanks provide the FCX with a 156.6L fuel capacity. This large capacity combined with improved fuel consumption contributes to the car's 430km* driving range. Fueling time at a high-pressure fueling station is only three minutes, for a level of convenience comparable to that of a gasoline-engine vehicle.



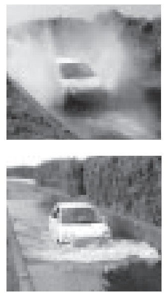
The Honda FC Stack-equipped FCX, which is capable of starting at sub-freezing temperatures,is the world's first fuel cell vehicle to be certified for use on public roads by the US Environmental Protection Agency (EPA) and the California Air Resources Board (CARB).

Certified by the EPA and the CARB

Safety measures for hydrogen and high-voltage electricity handling throughout the vehicle

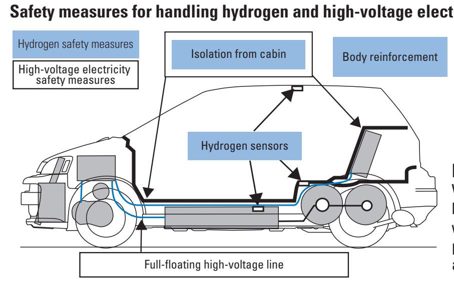
The new FCX offers superior safety measures for handling hydrogen and high-voltage electricity.

The FCX layout positions the fuel cell system box under the floor and the high-pressure hydrogen tanks under the rear seat, completely isolating the cabin from all hydrogen and high-voltage lines. Hydrogen sensors are located throughout the vehicle to provide a warning in the unlikely event of a hydrogen leak. Should a hydrogen leak occur inside the fuel cell system box, a forced ventilation system is activated and an automatic cut-off system closes the main stop valves on the hydrogen tanks or appropriately located cut-off valves on the supply lines as necessary. The high-voltage lines are electronically full-floating. If grounding occurs, a sensor sends a warning, and in the event of a collision a contact mechanism shuts down the source power line. Repeated floodwater testing and fire tests have confirmed a high level of safety and reliability.

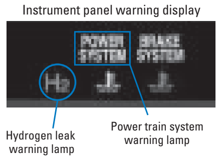


Floodwater testing

Safety measures for handling hydrogen and high-voltage electricity



Instrument panel warning display



Hydrogen leak warning system
When hydrogen sensors detect hydrogen leakage over a predetermined amount, a warning lamp lights up on the instrument panel. If necessary, the fuel line is automatically shut off.

Hydrogen fueling safety measures

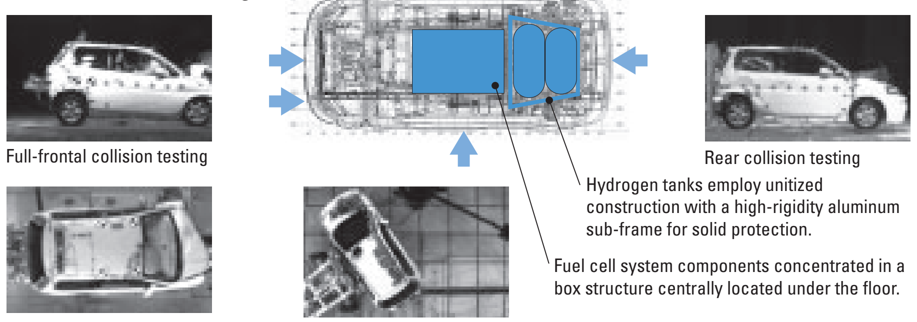
The hydrogen filler mouth provides firm contact with the filler nozzle, is equipped with a highly reliable filter, and employs a check valve of unitized construction for an excellent hydrogen seal. This design prevents the mixing in of other gases or the connection of filler nozzles with the wrong fill pressure. Further, a grounding system rids the vehicle of static electricity before fueling. The safety design positions the hydrogen filler mouth opener inside the grounding lid, requiring that the grounding lid be opened before the opener can be operated. There is also a system that prevents driving during fueling to further ensure safety.

Hydrogen filler mouth　Grounding system

Frame designed to withstand collisions from any direction

In addition to incorporating the advanced technologies developed by Honda for all its automobiles, the fuel cell vehicle employs a special platform to achieve superior collision safety performance. Besides protecting vehicle occupants from collisions from the front, sides, and rear, the FCX also exhibits an outstanding level of safety performance to protect the fuel cell system and high-pressure hydrogen tanks from impact and the effects of body deformation in a crash.

Collision tests from all angles



Full-frontal collision testing　Rear collision testing　Off-set frontal collision testing　Side collision testing

Hydrogen tanks employ unitized construction with a high-rigidity aluminum sub-frame for solid protection.

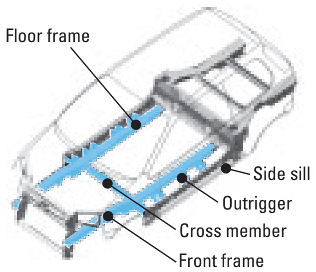
Fuel cell system components concentrated in a box structure centrally located under the floor.

Photos depict US crash testing.

Straight frame for superior safety performance

Front frame and floor frame straight construction

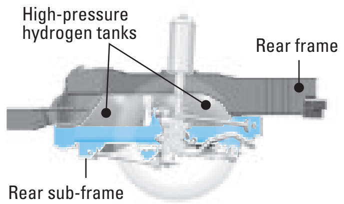
A large-cross-section, straight configuration from the front frame to the floor frame is bolstered by outriggers and a cross-member that extends to the side sills. The front frame has an impact-absorbing construction to reduce the force of impact on the cabin area in a frontal collision. The outriggers effectively absorb the impact of a side collision to minimize the effect on the cabin and fuel cell system.



Two-stage construction of the high-strength rear aluminum sub-frame and the rear frame

Rear frame and rear sub-frame two-stage construction

The lightweight, rigid rear sub-frame with extruded aluminum members is attached to the rear frame in a vertical two-stage construction. In a rear collision the back part of the rear frame first effectively absorbs the impact. Then the two-stage construction of the sub-frame and rear frame restrains the impact force to protect the high-pressure hydrogen tanks.



Comfort and amenities specially designed for the new FCX in pursuit of an advanced yet highly practical fuel cell vehicle

The exterior design is a reflection of the vehicle's advanced features and promotes a 'clean' image.

New body colors
The new FCX body colors convey a 'clean' image and suggest high quality.

Fuel cell vehicle symbol mark
The fuel cell vehicle symbol mark indicates that fuel cell stacks make electricity out of hydrogen. The globe motif is an expression of the system's environment-friendliness.

Aluminum-alloy wheels

Equipped with the Honda HDD Navigation System, featuring voice recognition and a hydrogen station locator function

The new FCX is equipped with the advanced, multi-functional Honda HDD Navigation System, featuring voice recognition, and programmed to indicate the locations of hydrogen stations. Inter-Navi Premium Club services are also available. Further, the new FCX is equipped with an electronic toll collection (ETC) system for highway driving. Information on ETC toll gates is displayed with the HDD Navigation System.

Hydrogen stations

ETC toll gates

Vehicle-mounted ETC system

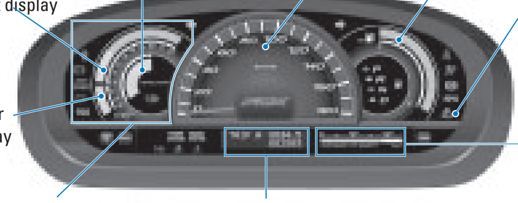
Superb heating and cooling for the ultimate in comfort

The new automated heater/air conditioner maintains the FCX interior at an ideal temperature whether the outside temperature is –20ºC or extremely high. The heater has a hot-water heating system that uses electricity supplied by the fuel cell system, while the air conditioner employs a cooling cycle with an inverter-controlled compressor.

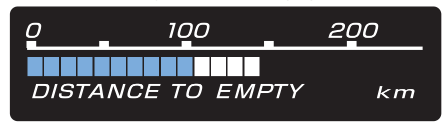
Advanced instrument design for superb readability and a clear understanding of energy management conditions

Energy management conditions are conveyed to the driver on an easy-to-understand display showing fuel stack output under different driving conditions, ultra-capacitor assist output and recharge status, and more. Along with a hydrogen fuel gauge, there is also a Distance to Empty gauge that indicates the remaining driving distance in accordance with fuel consumption. The bottom-center part of the display has an odometer, tripometer, and a multi-information display that can be adjusted to display various changes in vehicle status.

FCX instrument display



Distance to Empty display
An estimate of the minimum remaining driving distance under current driving conditions is displayed in blue. The maximum remaining driving distance possible under more fuel-efficient driving conditions is displayed in white.



Development of the Honda FCX, a pioneer fuel cell vehicle for the future

Honda strives to develop even better fuel cell vehicles

1999

September · Prototype fuel cell vehicles FCX-V1 and FCX-V2 introduced


FCX-V1


FCX-V2

2000

September · Prototype fuel cell vehicle FCX-V3 introduced


FCX-V3

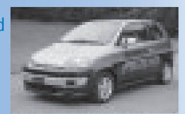
2001

February · Prototype fuel cell vehicle FCX-V3 equipped with a Honda FC Stack demonstrated at the California Fuel Cell Partnership in Sacramento, California

July · Public road testing of the FCX-V3 begins in Japan

July · Experiments with hydrogen production and fueling for fuel cell vehicles begin at Honda R&D Americas in California

September · Prototype fuel cell vehicle FCX-V4 introduced


FCX-V4

2002

March 1 · Honda FCX-V4 granted certification by the Japanese Ministry of Land, Infrastructure and Transport

March 3 · Honda FCX-V4 serves as pace car for Los Angeles Marathon

July 25 · Honda FCX first fuel cell vehicle to receive US government certification for commercial use

October 8 · Agreement concluded with the City of Los Angeles to make Los Angeles the first US customer for a fuel cell car

October 22 · Introduction of the FCX prototype planned for commercial release within the year

November 22 · FCX granted certification by the Japanese Ministry of Land, Infrastructure and Transport

December 2 · FCX fuel cell vehicles delivered on the same day in Japan and the US


Vehicle delivery ceremony at the official residence of the prime minister of Japan


Vehicle delivery to the mayor of Los Angeles

2003

July 15 · Honda becomes world's first automaker to supply a fuel cell vehicle to a private corporation


FCX delivered to Iwatani International Corporation

September 25 · FCX vehicles delivered to the City of San Francisco

October 2 · Experiments begin in the US with a hydrogen Home Energy Station (HES), providing hydrogen fuel supply and cogeneration functions

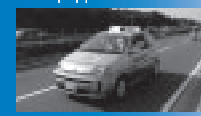
October 10 · Release of the Honda FC Stack, a next-generation fuel cell stack capable of power generation at temperatures as low as –20ºC

Honda FC Stack

Honda FC Stack-equipped FCX

2004

January 2–3 · Honda FC Stack-equipped FCX serves as lead car at the 80th Tokyo-Hakone Ekiden Road Relay Race


FCX lead car at Tokyo-Hakone Ekiden

February 26 · Public road testing in Hokkaido, Japan of Honda FC Stack-equipped FCX, proving the vehicle's cold-start and driving performance capabilities


Public road testing in Furano, Hokkaido

March 19 · FCX first fuel cell vehicle test-driven at the office of the prime minister of Thailand

April 5 · Test drives of Honda FC Stack-equipped FCX begin on Yakushima Island (Japan) as part of the Yakushima Zero Emissions Project


Public road testing on Yakushima Island

April · Honda FC Stack-equipped FCX test drives begin in the US

July · Honda FC Stack-equipped FCX receives US government certification for commercial use

November 16 · Honda FC Stack-equipped FCX leased to New York State

Lease agreement ceremony in New York State

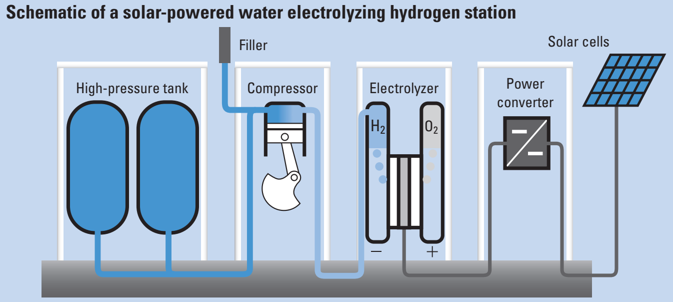
	FCX-V1	FCX-V2	FCX-V3	FCX-V4	FCX	New FCX
Hydrogen supply	Hydrogen-absorbing metal alloy tank	Methanol reformer	High-pressure hydrogen tank (250 atm)	High-pressure hydrogen tanks (350 atm)	High-pressure hydrogen tank (350 atm)	High-pressure hydrogen tank (350 atm)
Hydrogen storage capacity	———	———	100L	137L	156.6L	156.6L
Fuel cell stack	Ballard-manufactured	Honda-manufactured	Ballard-manufactured/Honda-manufactured	Ballard-manufactured	Ballard-manufactured	Honda-manufactured
Power assist	Battery	Battery	Ultra-capacitor	Ultra-capacitor	Ultra-capacitor	Ultra-capacitor
Motor max. output	49kW (67PS)	49kW (67PS)	60kW (82PS)	60kW (82PS)	60kW (82PS)	80kW (109PS)
Motor max. torque	———	———	238N·m (24.3kg·m)	238N·m (24.3kg·m)	272N·m (27.7kg·m)	272N·m (27.7kg·m)
Max. speed	———	———	130 km/h	140 km/h	150 km/h	150 km/h
Vehicle range	———	———	180 km	315 km	355 km	430 km
Number of occupants	2	2	4	4	4	4
Cargo space (VDA system)	———	———	———	98L	102L	102L

Figures are Honda internal calculations.

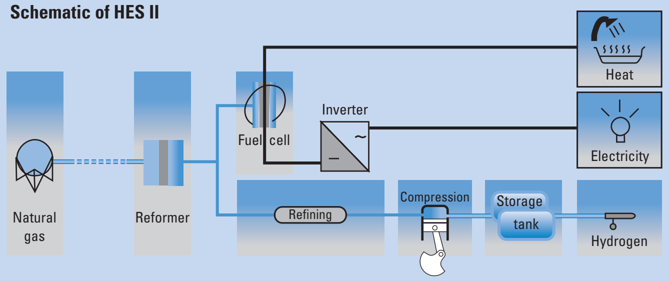
In addition to a solar cell-powered hydrogen refueling station, Honda is operating an experimental Home Energy Station (HES) that generates hydrogen from natural gas for use in fuel cell vehicles while supplying electricity and hot water to the home as part of its ongoing research into development of hydrogen production and supply systems for a hydrogen-based society of the future.

Honda has long been conducting research into hydrogen production and supply systems for a hydrogen-based society of the future. At the solar-powered water electrolyzing hydrogen station that has been operating on an experimental basis since 2001 at Honda R&D Americas in Torrance, California, employment of Honda's water electrolyzing module, which boasts world-leading efficiency, as well as next-generation solar cell panels made by Honda Engineering, has further improved hydrogen production efficiency and greatly reduced CO_2 emissions during system manufacturing. In 2003 Honda established an experimental HES (Home Energy Station) that generates hydrogen from natural gas for use in fuel cell vehicles, while supplying electricity and hot water to the home through fuel cell cogeneration functions. In November 2004, in collaboration with Plug Power Inc. of the US, Honda began operating a second-generation Home Energy Station (HES II), which unifies natural gas reformer and pressurizing units into one compact component to reduce the overall volume by approximately 50%. Honda is continuing its efforts to develop systems required for a hydrogen-based society of the future through experiments with various hydrogen production and usage systems.

Schematic of a solar-powered water electrolyzing hydrogen station



Schematic of HES II



Outline of a solar-powered water electrolyzing hydrogen station

Location: Honda R&D Americas research facility in Los Angeles
System configuration: Solar battery, electric converter, electrolyzing system, compressor, pressurized hydrogen tank
Hydrogen production capacity: In conjunction with commercial electric power: Max. 2Nm^3/h*; Solar power only: Max. 1.2Nm^3/h*
Hydrogen storage capacity: 400L (350 atm)

Outline of HES II

Location: Plug Power Inc. headquarters (New York)
System configuration: Reformer, refiner, fuel cells, compressor, high-pressure storage tank
Hydrogen production capacity: Maximum 2Nm^3/h*
Hydrogen storage capacity: 132L
Power generation capacity: Over 4kW

* N = standard conditions at 0ºC, 1 atm

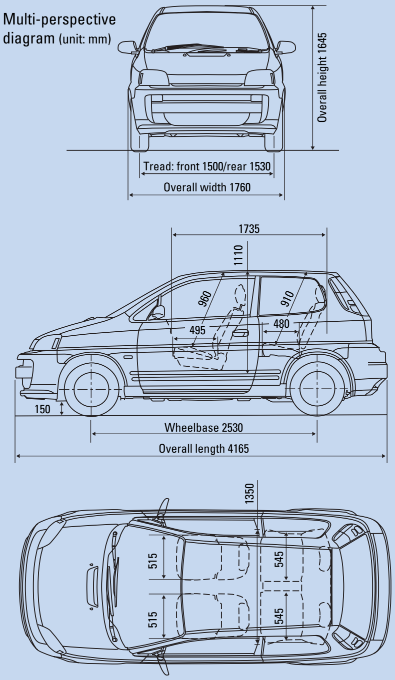
Honda FCX Main Specifications

Model type			Honda ZC2
Name			FCX
Dimensions, weight, occupancy	Overall length (mm)		4,165
	Overall width (mm)		1,760
	Overall height (mm)		1,645
	Wheelbase (mm)		2,530
	Tread (front/rear, mm)		1,500/1,530
	Vehicle weight (kg)		1,670
	Number of occupants		4
Performance	Maximum speed (km/h)		150
	Vehicle range (km, LA-4 mode)*		430
Powertrain	Drive method		Front-wheel drive
	Motor	Type	AC synchronous electric motor (permanent magnet)
		Max. output (kW [PS])	80 [109]
		Max. torque (N·m [kg·m])	272 [27.7]
	Fuel cell stack	Type	Honda PEMFC (Proton Exchange Membrane Fuel Cell)
		Max. output (kW)*	86
	Ultra-capacitor	Electrostatic capacity (F)*	9.2
Fuel	Type		Compressed hydrogen gas
	Storage		High-pressure hydrogen tank
	Tank capacity (L)		66+88 (156.6)
	Gas volume when full (Nm3)*		42 (3.75kg)
	Max. pressure when full (MPa)		34.40 (approx 350 atm)

● Specifications are determined in accordance with procedures proscribed in Road Transportation Motor Vehicle Law, except where marked by an asterisk (*) indicating Honda in-house test values. ● FCX is a registered trademark of Honda Motor Co., Ltd. ● Manufacturer: Honda Motor Co., Ltd.

★The FCX is available only on lease to certain government and corporate organizations.

Multi-perspective diagram (unit: mm)



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