mazda

RX-8 HYDROGEN RE

Press Kit
Stavanger – Norway
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1. Mazda and Hydrogen powered vehicles

Fifteen years of Mazda research into hydrogen vehicles

Mazda's interest in hydrogen vehicles covers a span of 15 years: the first prototype, the HR-X, was presented at the 1991 Tokyo Motor Show. Even back then, the concept car had a hydrogen-powered rotary engine as its powerplant.

Mazda is strongly involved in the issue of sustainable development, and is highly committed to researching new energies to meet the mobility needs of future generations while at the same time looking after the environment. However, Mazda's goal is to solve such problems without sacrificing its 'zoom-zoom' values of dynamism and driving pleasure; hence the decision to choose the route of a hydrogen-powered rotary engine. The Renesis engine based on Wankel's patent is ingrained in Mazda's DNA, and was for good reason chosen as a partner for the company's new environmentally-friendly requirements.

Although the hydrogen rotary engine remains a key area of development for Mazda, this has not prevented the Hiroshima-based company from continuing development of fuel-cell vehicles at the same time.

The hydrogen-powered Mazda prototypes resulting from this intense research work have succeeded one another at a steady pace since the early 1990s, up to the latest Mazda RX-8 Hydrogen RE concept car presented at the Tokyo Motor Show in 2003.

The 2004 road homologated prototype formed the basis of the Mazda RX-8 Hydrogen RE which is now actually driven on public roads in Japan. Equipped with a 'dual-fuel' power system, it is capable of operating just as well on hydrogen as on petrol, making it easier to use in everyday life.

In 2006 the Mazda RX-8 Hydrogen RE vehicles are supplied on a lease arrangement to Japanese companies and local governments – a world first for a passenger car with a hydrogen internal combustion engine. This unique 'commercial' endeavour is providing Mazda with valuable experience for the future development of its hydrogen-powered vehicles.

"A hydrogen rotary engine only emits water. It is not as efficient as a fuel cell, but structurally it is closer to the petrol engine, hence its manufacturing cost is lower and it has fewer durability issues.
Compared to fuel cells, hydrogen engines with dual-fuel system are more likely to play a significant role in the initial phase of the hydrogen energy society in the future. That is why Mazda is currently focused on developing dual-fuel system hydrogen engine. Furthermore, under normal circumstances, a hydrogen vehicle is fueled by hydrogen gas for clean driving. But what if a hydrogen vehicle is also powered by petrol? It would mean greater convenience, because the driver does not have to worry about running out of hydrogen gas or about driving to a place where there are no hydrogen filling stations. Mazda has achieved such a system and calls it "dual-fuel system", a highly innovative function not achieved with fuel cell vehicles."

Akihiro Kashiwagi
Program Management Div.,
Hydrogen RE Program Manager

What is the difference between fuel-cell technology and a hydrogen internal combustion engine?

A fuel cell generates electricity by causing a chemical reaction between hydrogen and the oxygen contained in the air, with water as a by-product. A fuel-cell vehicle is powered by electricity generated by fuel cells.

A hydrogen internal combustion engine vehicle is powered by combusting hydrogen in a combustion chamber similar to today's petrol engines, which also produces water as emissions. The expansion of the gases caused by this combustion then turns the rotor (in the case of the RX-8 Hydrogen RE) to drive the vehicle.

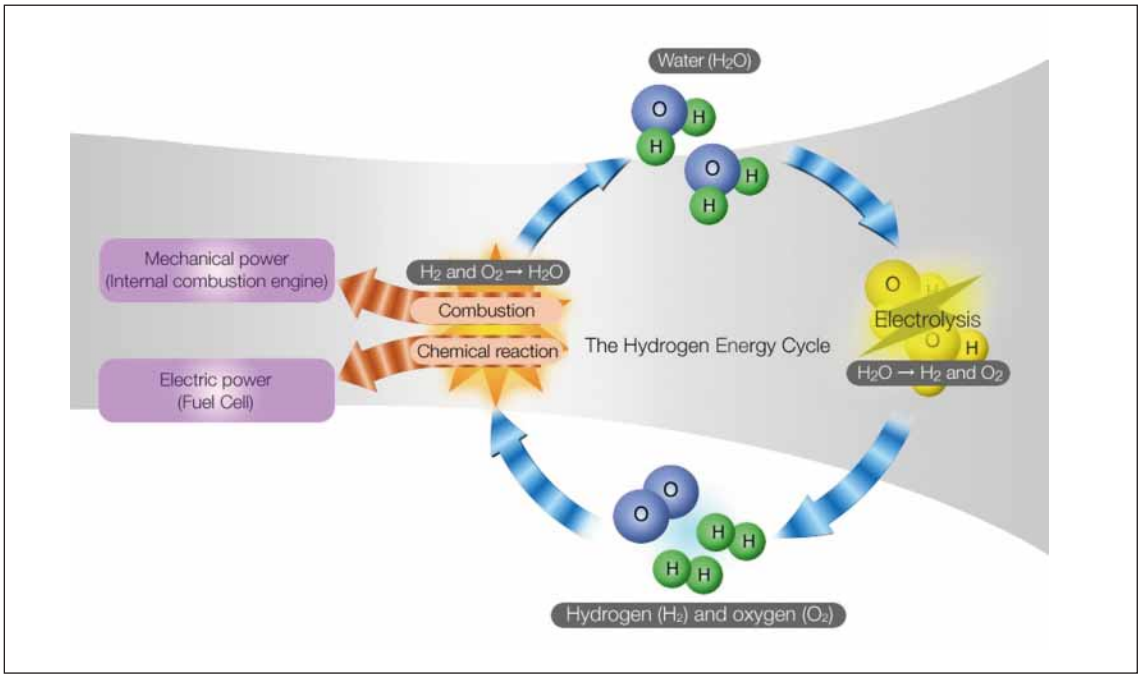
2. Hydrogen combustion: how does it work?

Hydrogen: a clean, recyclable and abundant fuel source

Hydrogen is one of the most widely available fuels: it accounts for 75% of the matter in the universe on its own. It is found in abundance in the stars and gassy giant planets.

On Earth, however, it is very rare in its natural state (its very low mass means that it escapes gravity's pull). It is, however, found in river and ocean water. Water electrolysis is needed to extract it, a process which splits the H20 water molecule in two: this produces dioxygen 02 on the one hand, and dihydrogen H2 on the other. This electrolysis uses electricity, which can be produced in a variety of ways (wind, solar, hydro-power, etc.).

Hydrogen can also be extracted from organic fossil matter (coal, petrol, natural gas), and is a by-product of a number of industrial processes (chemical, welding, etc.).



Hydrogen combustion follows the simplest of chemical formula: two H2 molecules combine with an 02 molecule to form two H20 molecules in vapour form, while at the same time releasing a very large quantity of energy. This reaction produces extremely few NOx nitrogen oxides and gives off no CO_2 (a greenhouse gas) whatsoever.

Hydrogen is considerably more combustible than conventional petrol. It can cope with very low concentrations (a mere 4% in air is sufficient for combustion to occur), and the flame front spreads much more quickly (approximately 265 cm/sec in stoechiometric conditions as opposed to 40 cm/sec for petrol). However, hydrogen does possess less energy at an equivalent volume. It is a fuel which is used widely in rockets, including the Space Shuttle. And it can be used as a fuel for an internal combustion engine as on the RX-8 Hydrogen RE.

Unlike fossil fuels, hydrogen forms part of a perfectly-balanced cycle: the hydrogen extracted from water by electrolysis is liberated after use in the form of vapour, which returns to the natural water cycle, while the CO2 given off by the combustion of fossil fuels is in excess of the quantity usually absorbed by plants.

Burning hydrogen is not the only way of releasing the energy required to power a vehicle: hydrogen can also power a fuel cell, inside which it reacts with oxygen to produce an electrical current. However, despite the fact that the fuel cell has advantages (high energy output, zero nitrogen oxide released), it is also complex and expensive to manufacture, and requires a total redesign of the powertrain and its incorporation into the vehicle. This technology is not yet sufficiently mature, therefore, for use in everyday life.

The rotary engine: ideally suited to hydrogen fuel

Mazda's decision to opt for the rotary engine rather than a piston engine as the basis for its hydrogen vehicle designs is not attributable solely to the brand's unique experience with this technology. The rotary engine is particularly suited to the specific requirements of hydrogen fuel.

As we have seen, hydrogen is astonishingly explosive, which can produce problems in the combustion chamber of a piston engine (abnormal combustion). In a traditional engine, the fuel-air mixture is injected directly into a high-temperature combustion chamber which is sealed by very hot exhaust valves. These are hardly favourable conditions, and make hydrogen less attractive as a fuel for a reciprocal engine.

By contrast, the rotary engine has separate intake, combustion and exhaust chambers. The hydrogen is thus injected at a lower temperature, and only comes into contact with the higher temperatures of the combustion chamber at the last moment.

The other key characteristic of hydrogen is that it produces less energy at equivalent volumes when combusted, because it has a lower density than petrol. The low density of hydrogen – injected in its gaseous state – means that at the quantity required for combustion, it would occupy 29.5 % of the volume of the combustion chamber, compared to a mere 1.7 % for petrol. The result would thus be a reduced quantity of injected air, resulting in incomplete combustion and reduced power.

A better approach, therefore, is to opt for direct injection into the combustion chamber to counteract this phenomenon. As it happens, it is easier to place an additional injector in the inlet chamber of a rotary engine than on the side of the narrow cylinder head of a piston engine.

Lastly, the rotary engine is better than a reciprocal engine at combining the air/hydrogen mix because of its longer cycle. The result is a more uniform mixture which consequently delivers better combustion.

3. Mazda RX-8 Hydrogen RE

From prototype to the road in just two and a half years

It was logical that the RENESIS rotary engine – winner of four "International Engine of the Year" awards in 2003 and 2004, and renowned for providing high levels of driving fun – should be used as the basis for the development of a hydrogen engine. At the Tokyo show in October 2003, Mazda presented the first prototype of the RENESIS hydrogen engine, which even then incorporated a dual-fuel system enabling it to run just as well on hydrogen as on petrol. The petrol injectors were located in the inlet pipes, as in the normal RENESIS engine, while two hydrogen injectors were added per rotor. The stated goal: to bring this brand-new technology to market within three years.

In 2004, a prototype Mazda RX-8 Hydrogen RE received approval from the Japanese Ministry of Land, Infrastructure and Transport to commence public road tests. Having received the appropriate authorisation, the RX-8 Hydrogen RE underwent an entire battery of tests which provided large quantities of information about the car's performance with the objective of providing a vehicle for leasing to government bodies and companies.

In March 2006 – six months ahead of the originally stated deadline – the first fleet clients received their Mazda RX-8 Hydrogen RE vehicles.

2003 RX-8 Hydrogen RE prototype

Mazda RX-8 Hydrogen RE: optimised for the best possible environmental performance

Apart from its individual badging, the RX-8 Hydrogen RE is virtually identical to a traditional RX-8. This belies the fact that the vehicle has been modified to reduce pollutant emissions to a minimum at all stages of the product's life.

The vehicle's tyres have been optimised to reduce fuel consumption and the RENESIS hydrogen engine has been fitted with an exhaust gas recirculation (EGR) system, offering a combination of high performance and reduced exhaust NOx when burning hydrogen.

Mazda RX-8 Hydrogen RE: designed for driving enjoyment and improved performance

Public road tests of the first 2004 RX-8 Hydrogen prototype have yielded a wealth of useful information for the current version. It differs from its predecessor in a number of respects:

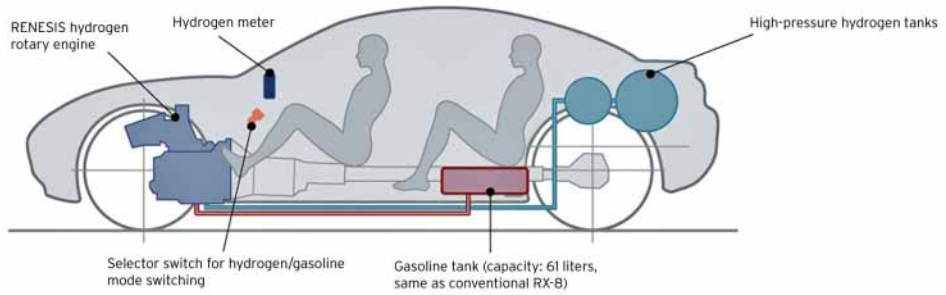
- Automatic gearbox: the prototype was equipped with a 5-speed manual gearbox. For even greater driving pleasure, particularly in urban traffic conditions, the new version of the RX-8 Hydrogen RE is fitted with a 4-speed automatic gearbox with steering wheel shift paddles.

- Larger hydrogen tanks for longer driving range: with their higher capacity (110 litres), the vehicle's range in hydrogen mode has been increased to approx. 100 km, despite the added fuel consumption introduced by the automatic gearbox.

- Fuel switching 'on the fly': a (rotor-shaped) switch on the dashboard enables the driver to switch from hydrogen to petrol while driving. The switch illuminates in blue when the car is running on hydrogen.

- New instrument layout: in the first version of the RX-8 Hydrogen RE, the hydrogen gauge, fuel mode indicator and warning lights were located in the centre of the dashboard. They have now been incorporated into the instrument panel.

Vehicle layout



Here are the main technical specifications of the RX-8 Hydrogen lease car:

Vehicle	Type	Mazda ABA-SE3P 'Kai' (modified model)
	Overall length/width/height	4.435 mm / 1.770 mm / 1.340 mm
	Wheelbase	2,700 mm
	Curb weight	1,460 kg
	Seating capacity	4 adults
Engine	Class	RENESIS hydrogen rotary engine with dual-fuel system
	Type	13B
	Displacement	0.654 L x 2
	Maximum output	Hydrogen 80 kW / 109 PS Petrol 154 kW / 210 PS
	Maximum torque	Hydrogen 140 Nm (14.3 kgm) Petrol 222 Nm (22.6 kgm)
Fuel	Type	Hydrogen/petrol switch
	Fuel tank	Hydrogen 110 L at 35 MPa (350 bar) in high pressure hydrogen tanks Petrol 61 L
Performance	Cruising distance (Japan 10-15 mode)	Hydrogen 100 km Petrol 550 km

Mazda RX-8 Hydrogen RE: uncompromising safety

The hydrogen tanks are located in the boot. The fuel is kept at a pressure of around 350 bar (35 MPa). The petrol tank, carried over from the standard RX-8 model, is under the rear seats.

For maximum safety, hydrogen detectors have been fitted in the cabin to sense any intrusion of gas into the passenger area.

Mazda RX-8 Hydrogen RE: dual-fuel technology for maximum peace of mind

Until a genuine hydrogen distribution network is established (it exists in embryonic form at present), it is hard to imagine how a vehicle running exclusively on hydrogen could be used on a daily basis anywhere in Europe. The Mazda RX-8 Hydrogen RE provides the perfect solution to this problem: its RENESIS engine runs using either petrol or hydrogen.

Switching from hydrogen gas to petrol can be done using the switch next to the driver's seat. The car must be stationary to switch from petrol to hydrogen. In addition, when the hydrogen tank is empty, the RX-8 Hydrogen RE switches automatically to petrol power.

This dual-fuel technology is made possible by the use of traditional petrol injectors in the inlet pipes, complementing the hydrogen injector located in the rotary housing for direct injection, and an additional hydrogen injector located in the intake pipe. Engine control activates one fuel source or the other depending on the position of the switch in the cabin or the level of fuel in the hydrogen tank.

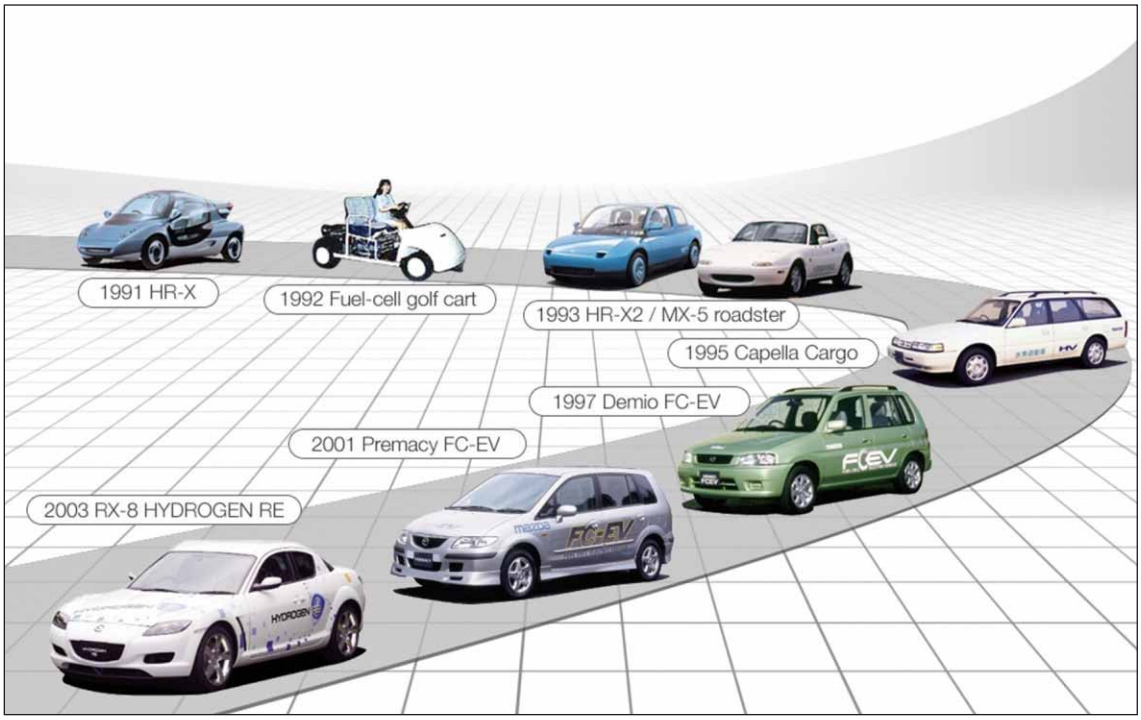
Thanks to this technology, a hydrogen vehicle can now be used for any type of journey. It makes it possible to travel without any worries to areas without hydrogen fuel stations, particularly since the vehicle's range is increased to 550 km with the RENESIS engine operating in petrol mode (650 km in total with both energies).

Mazda RX-8 Hydrogen RE: already in service with corporate and local governmental vehicle fleets in Japan

A world first: the Mazda RX-8 Hydrogen RE is the first hydrogen internal combustion passenger car supplied for lease. Idemitsu Kosan Co. Ltd. in Tokyo and Iwatani International Corporation in Osaka were the first two companies to take this pioneering step, following Hiroshima City and Prefecture.

The lease price for these Mazda RX-8 Hydrogen RE vehicles is set at a mere 420,000 yen per month (around 2,860 euros per month); that is, just over half the lease price of an equivalent model with a fuel cell system. This represents a strong basic competitive advantage to ensure the long-term development of a hydrogen network.

4. Appendix : Mazda hydrogen vehicle history



• 1991 – Mazda HR-X

First vehicle with a hydrogen-powered rotary engine.

• 1992 – Mazda golf cart

First Mazda prototype to be fitted with a fuel cell.

• 1993 – Mazda HR-X2

Second hydrogen-powered rotary-engined vehicle.

• 1993 – Mazda MX-5

Test prototype of Mazda MX-5 fitted with a rotary hydrogen engine.

• 1995 – Mazda Capella Cargo

First test on Japanese roads of a hydrogen-powered rotary-engined vehicle.

• 1997 – Mazda Demio FC-EV

Prototype small people carrier fitted with a fuel cell battery.

• 2001 – Mazda Premacy FC-EV

Compact people carrier with a methanol fuel cell battery. Full-scale test on Japanese roads.

• 2003 – Mazda RX-8 Hydrogen RE

First prototype of RX-8 with rotary hydrogen engine.

• 2004 – Mazda RX-8 Hydrogen RE

First road tests of hydrogen-powered RX-8 with dual-fuel technology, allowing the vehicle to operate in petrol or hydrogen mode according to driver's wishes.

• 2005 – Premacy/Mazda5 Hydrogen RE Hybrid

Mazda presents the Premacy/Mazda5 Hydrogen RE Hybrid concept at the Tokyo Motor Show. It is a front-engine, front wheel drive MAV combining rotary engine dual-fuel (hydrogen-petrol) with an electric motor and idle stop.

• 2006 Mazda RX-8 Hydrogen RE

Mazda Motor Corporation delivers RX-8 Hydrogen RE vehicles to its first two corporate customers – the world's first leasing of an internal combustion engine passenger car that can use both hydrogen and petrol as fuel.