PSA PEUGEOT CITROËN

Fuel Cell:
energy for the future

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PSA Peugeot Citroën and Fuel Cells

A Long-Term Key to Protecting the Environment

A major component of **PSA Peugeot Citroën's environmental strategy**, fuel cells are a promising technology that is destined to play an important role in automotive development over the long term.

Fuel cells offer many benefits. Besides **curbing CO_2 emissions**, which is vital to **abating the greenhouse effect**, they **improve the quality of life in cities** by powering an electric motor, thereby reducing noise, and by **eliminating local pollution** caused by nitrogen oxide (NOx), particulates and other emissions. With an onboard hydrogen supply, fuel cell-powered cars are potentially the only truly zero emission vehicles (ZEVs).

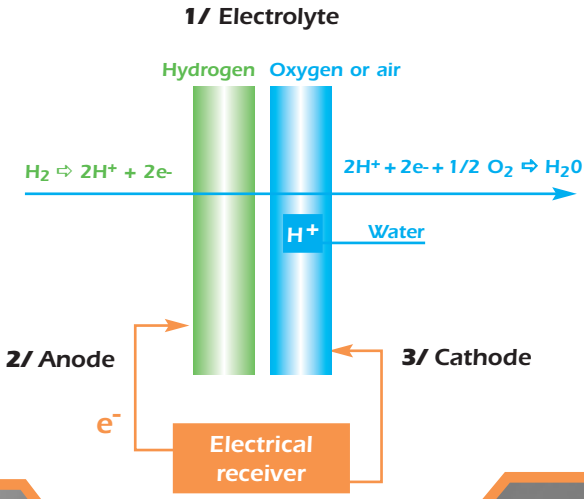
Fuel cells will help to break the dominance of hydrocarbons as automotive power sources, which will be a major advantage in the future energy environment. **They run on hydrogen**, a gas that can be produced from hydrocarbons such as oil and natural gas, although preferably from renewable sources such as wind, solar, water and biomass, or else from nuclear energy.

Although Fuel Cell technology has strong growth potential, a number of technical and financial **challenges have to be met** before it can be mass marketed. These hurdles include the cost of producing the cells, integrating them into vehicles, and storing hydrogen. In addition, **a new distribution system** will require substantial investment. PSA Peugeot Citroën therefore plans to introduce automotive fuel cell technology gradually, with the possibility of series production beginning around 2020.

How a Fuel Cell Works

- The principle of the fuel cell is generally described as being the reverse of water electrolysis. It is a controlled **electrochemical reaction between hydrogen and oxygen in the air, producing electricity, water and heat simultaneously**. Because the reaction uses catalysts, it takes place within a simple cell comprising two electrodes (a cathode and an anode) separated by an electrolyte.
- In practice, hydrogen gas (H_2) is released on the anode, where, in the presence of a catalyst, the hydrogen molecules release electrons ($H_2 \rightarrow 2H^+ + 2\ e^-$).
- The e- electrons migrate to the cathode through the electric circuit and, as a result of the catalyst, react with the oxygen.
- The H^+ protons migrate toward the cathode through the membrane. The subsequent oxidation-reduction reaction produces water ($2H^+ + 2\ e^- + 1/2\ O_2 \rightarrow H_2O$).
- The transfer of electrons generates an electric current.

Since the only byproduct of the reaction is water, there is no local pollution.



Support from Expert Networks

We are paving the way for this introduction with a process designed to explore today's technologies. With an in-house team of **dedicated specialists** and the support of networks of experts - **our targeted partners** - we are investigating various candidate fuel cells and prototypes to identify acceptable technical and financial conditions that will enable the development of automotive fuel cells.
In particular, the Group has signed **two strategic framework agreements**:

- The first is with the **French National Center for Scientific Research** (CNRS), to step up and direct basic research, for example to enhance the efficiency of components such as membranes and catalysts.
- The other is with France's **Atomic Energy Commission** (CEA), to establish a technical skills network to improve understanding of fuel cells and hydrogen storage.

This partnership has produced the GENEPAC, a world-class 80 kW fuel cell stack.

Technology Demonstrators

Findings from these programs have enabled the Group to build the Taxi PAC, the H_2O and the Quark **fuel cell demonstrators** to test the different technological solutions. In each case, the fuel cell serves as a range extender or auxiliary power unit (APU). It recharges the batteries, which deliver electricity to the traction motor as needed.

Fuel-cell vehicles are ideal for urban environments.

Their electric motors make them **quiet** running, an important quality for a city car, while their **range** is well-suited to urban and suburban use. The motor consumes power only when the car is moving, and **regenerates the batteries** during deceleration.

The Taxi PAC

Conceived as a **"London taxi for the 21st century"**, the Taxi PAC demonstrator is based on an electric Peugeot Partner powered by its original electric motor (rated at 22 kW) and **equipped with a small, 5.5 kW fuel cell**, nickel-metal hydride batteries and an interchangeable rack of hydrogen bottles.

The hydrogen is therefore stored on board in the form of **gas compressed at 300 bar**. An empty rack can be quickly replaced with a full one and the hydrogen bottles are easily refilled when off the vehicle.

- The interior of the Taxi PAC has been redesigned in two sections separated by a glass panel: an area for the driver and a **spacious compartment** with a wide seat for three passengers, located over the rack and rear drive train.
- Space is provided next to the driver for storing baggage, with a seat that can fold up from under the floor to accommodate a fourth passenger facing the rear.

The H_2O Demonstrator

The **H_2O demonstrator** is a battery-powered fire truck equipped with an electric generator comprising a 5.5 kW fuel cell.

A cross between a child's dream and an engineer's vision, the H_2O represents a new application for fuel cells.

In this case, hydrogen is **produced on board** using an aqueous sodium borohydride solution and a catalyst. The vehicle therefore never carries more than **2.5 grams of hydrogen** on board, the energy equivalent of a glass of gasoline.

- Representing a **major innovation** compared with a conventional fire truck, H_2O retains all its capabilities in an anaerobic (oxygen-free) environment, such as a fire in a tunnel or an underground parking lot. In this case, the oxygen required to power the vehicle is supplied from two onboard bottles. Ultracompact breathing systems are also included in the passenger compartment.
- **Built in collaboration with firefighters**, the H_2O demonstrator includes a water tank supporting a telescopic ladder at the rear, and two connectors, one for water supply and one for the fire hose.

The Quark

Like its two predecessors, **the Quark** is a technology demonstrator that uses a fuel cell as a range extender. The clean, two-seat ATV-style concept is a futuristic vehicle offering the promise of fun and freedom, yet with the technological content to be a credible candidate for production.

Its **1.5 kW fuel cell** supplements the electrical energy supplied by a nickel-metal hydride battery consisting of 40 individual cells.

With the Quark, PSA Peugeot Citroën is also offering an **air-cooled fuel cell**, a new solution specific to "two-wheeler" applications.

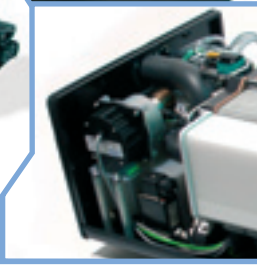
- In addition, the demonstrator uses a 9-liter hydrogen tank at **a pressure of 700 bar** that is the same size as a 350-bar tank, thereby increasing the amount of onboard hydrogen and extending vehicle range to around 100 kilometers. **The plug & drive system** makes it easy to change the tank.
- The most innovative feature is the powertrain. Instead of a single motor, the Quark has four electric motors, one in each of the wheels.

The GENEPAC

- **Developed in partnership with the French Atomic Energy Commission, the GENEPAC is a proton exchange membrane fuel cell** (PEMFC) stack with a maximum rating of 80 kW for automotive applications. The project is financed by the French government through the PACo network.
- The new stack consists of **thin, stamped stainless steel plates**, which **reduces cost and size** in comparison to conventional plates.
- Each of the four modules comprises thin plates and an electrode membrane assembly.

The innovative technical concept ensures simultaneous supply of gas (air/H_2) and liquid coolant, while making it easier to develop fuel cells with a lower rating. Fully charged, the **simple stack** delivers an efficiency of more than 45%; when partially charged, efficiency is greater than 50%.

> INTELLIGENT ENERGY



A New Partnership with Intelligent Energy

- In November 2005, PSA Peugeot Citroën formed a **research partnership with Intelligent Energy**, a U.K. company specialized in clean energy technology, especially fuel cells.
- In line with the Group's other fuel cell research initiatives, **the project aims to integrate a low-power fuel cell into a vehicle as a range extender**. Subsidized by the U.K. Department of Trade and Industry, the project will focus in particular on enhancing fuel cell cold start.

Alternative energies

PSA Peugeot Citroën is committed to developing alternative energies, a key avenue for **reducing CO_2 emissions** and **combating the greenhouse effect**. We are exploring a wide variety of solutions, each meeting specific requirements. The main avenues of our strategy in this area are:

> Diesel

PSA Peugeot Citroën has developed a **family of HDi diesel engines** whose exceptional emission performance **reduces CO_2 emissions by around 20%** compared to a diesel engine with a precombustion chamber. Close to **11.5 million HDi engines have been marketed since 1998**.

In combination with the HDi engine, the particulate filter pollution control system effectively eliminates particulate emissions, reducing them to below measurable thresholds. **Since their introduction in 2000, more than 1.3 million particulate filters have been marketed.**

> Combating the Greenhouse Effect
> Increasing Fuel Economy

> Stop & Start Technology
Launched in 2004, the intelligent Stop & Start system reduces consumption and **lowers CO_2 emissions by 5 to 8%** depending on use, and up to 16% in city driving. It also significantly reduces noise related to driving in urban environments.

> Biofuels, such as ethanol from cereals or sugar beets and diester from oilseeds such as colza and soybeans, are by nature **renewable energies**. In addition to their exceptional impact in abating the greenhouse effect, they make a substantial contribution to **environmental performance** by reducing particulate emissions.

> Compressed natural gas (CNG) reduces CO_2 emissions by 20% compared to a gasoline engine.

And, of course, **fuel cells**...

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Direction de la Communication
75, avenue de la Grande-Armée - 75016 Paris
Press contact: (33) 01 40 66 38 86
www.psa-peugeot-citroen.com