Hydrogen as an energy source: 45 years of research at the BMW Group

• The most abundant element promises sustainable mobility alternatives.
• BMW Group has 45 years of experience in developing hydrogen propulsion solutions.
• Records, pioneer series cars and fleets of vehicles with fuel cells in search of viable solutions.
• The history of hydrogen at the BMW Group in an Inside BMW Group Classic YouTube video: https://youtu.be/nSob-Jwij4U?si=Vl4ITacS7w3lmhaZ

Bucharest/Munich. Hydrogen is the most abundant element in the universe, and its use as a liquid or gaseous energy source in various types of vehicles has been the focus of research projects for many decades.

Obtained for example by electrolysis using green energy can be a clean energy source, thus supporting emission-free mobility. While BMW already started exploring local emission-free mobility solutions with electric prototypes already at the end of the 1960s, the hydrogen adventure started 45 years ago.

A presentation of BMW Group's historic hydrogen projects can also be watched here, in an Inside BMW Group Classic episode: https://youtu.be/nSob-Jwij4U?si=Vl4ITacS7w3lmhaZ

The first steps where using hydrogen in internal combustion engines, as an alternative to fossil fuels. In 1979, BMW partnered with DFVLR (German Institute for Aviation and Space Flight Test and Research, now known as DLR) to transform a first generation BMW 5 Series 520 (E12, produced in 1975) into a test car. From the outside, it didn't differ much from the gasoline versions, but

the four-cylinder engine burned hydrogen instead of unleaded gasoline. To take the first steps to demonstrate that the use of hydrogen as a fuel in heat engines was technically feasible.

In 1980, a first-generation BMW 7 Series (BMW E23) became the first car in Europe to be powered by liquid hydrogen hydrogen. Hydrogen was still obtained using natural gas from crude oil and not through cleaner solutions. In order to be in a liquid state, the refueling was made with Hydrogen at a temperature of -253°C (close to absolute zero, −273.15 °C). A 93-liter tank allowed an autonomy of about 300 kilometers.

Hydrogen contains less energy than gasoline, but the use of supercharging created the chance to develop strong performance. BMW was already the pioneer of turbo engines, with the introduction of the first model on the European market in 1972 and the first title obtained for a turbo in Formula 1 in 1983. The main competitive advantage of hydrogen was the environmentally friendly way in which it uses its energy: hydrogen burns with oxygen from the air to form water again.

A third project was developed in 1988 based on the second generation BMW 7 Series 735iA (BMW E32). For the first time, the 735iA with hydrogen was developed only by BMW. The BMW 7 Series test vehicle was to be powered by both gasoline and cryogenic liquid hydrogen in a combustion engine.

BMW research lays the groundwork for the future of hydrogen in cars

In 1987, BMW acquired 10% of the shares of Solar-Wasserstoff-Bayern GmbH (Hydrogen Solar Bavaria) based in Neunburg vorm Wald, Bavaria. The investment allowed SWB to investigate the production of hydrogen from solar energy, its storage and use as an energy source, all as part of BMW's research into hydrogen propulsion systems for cars. This offered a model for obtaning clean hydrogen in the future while using green energy.

Ready for production and a series of important world premieres.

In 1999, BMW presented the world's first hydrogen-powered 12-cylinder car at the Frankfurt International Motor Show: the BMW 750hL. On May 11, 2000, the first series-produced hydrogen car hit the streets of Berlin, with several examples used as a shuttle service during EXPO 2000.

The BMW 750hL develops a maximum power of 204 HP for an acceleration of 0-100 km/h in 9.6 seconds, and a maximum speed of 226 km/h. The 140-liter gas tank ensures a range of approximately 350 km after refueling from a special station in just 3 minutes.

In total, 105 cars were built that gathered over 4 million km during the tests, equivalent to 5 times the distance from the Earth to the Moon and back. Produced in limited numbers for demonstration purposes, the BMW 750hL was the first series production car powered by hydrogen. Another absolute world first was the use of a fuel cell solution on a series production car. This worked as a power source as an alternative to the 12V battery. With an energy efficiency already of 50%, it provided a total power of 5kW in a compact

construction the size of a conventional led-acid battery. The high power ensured output not only allowed the needed energy of the electrical functions on the car, but also ensured the operation of the air conditioning during parking, without the operation of the internal combustion engine, a function currently provided by plug-in cars.

The car offered another innovation – the prototypes were permanently connected by radio to the technical team in Munich, as a functionality similar to telemetry in motorsport. Moreover, BMW was the pioneer of telemetry in Formula 1 at the beginning of the 1980s, and in 2001 it launched the BMW Teleservices function for the remote diagnosis of production cars and automatic communication with the service workshop.

The 2000 launch was followed in 2001 by the CleanEnergy World Tour, which had stops in five locations around the world. In parallel, as a demonstration of the versatility of hydrogen technology, the BMW Group also presented in 2001 a MINI (R60) model that featured a similar hydrogen propulsion solution, this time using a 1.6-liter engine that equipped the models Cooper.

Hydrogen records

BMW further used the hydrogen-powered V12 engine on a sports prototype. The BMW H2R set a total of nine records for hydrogen fuel cell cars. Its six-liter, 12-cylinder engine produced more than 210 kW/285 hp, enough to accelerate the prototype from 0 to 100 km/h in around six seconds and reach a top speed of 302.4 km/h.

These are the records set by the BMW H2R prototype:

- 1 kilometer, with a launched start: 11.993 seconds - 300.190 km/h
- 1 mile, launch: 19.912 seconds - 290.962 km/h
- ¼ kilometer, standing start: 9.921 seconds - 72.997 km/h
- ½ kilometer, standing start: 14.933 seconds - 96.994 km/h
- ½ mile, standing start: 17.269 seconds - 104.233 km/h
- 1 mile, standing start: 36.725 seconds - 157.757 km/h
- 10 miles, standing start: 221.052 seconds - 262.094 km/h
- 1 kilometer, starting from the spot: 26.557 seconds - 135.557 km/h
- 10 kilometers, starting from the spot: 146,406 seconds - 245,892 km/h

Hydrogen with star power

The Los Angeles Auto Show, which took place from December 1-10, 2006, was the scene for the world premiere of the BMW Hydrogen 7 codenamed BMW E68 (built on the basis of the fourth-generation BMW 7 Series BMW 750 iL with V12 engine).

The 7 Series sedan was powered by a 12-cylinder engine, which developed 191 kW/260 hp and accelerated from 0 to 100 km/h in 9.5 seconds. Top speed was electronically limited to 230 km/h. Uncertainty about the reliability of the hydrogen supply network was not a problem, as the BMW Hydrogen 7's dual-fuel engine could simply switch modes and use conventional unleaded petrol instead.

The project shone on the red carpets of several film festivals or premieres. Throughout the test program of the 100 cars produced, several personalities were able to directly test the car, including big names from Hollywood such as

Edward Norton or Brad Pitt, thus proving that hydrogen can be a viable propulsion solution in everyday life.

Hydrogen as art

Artist Olafur Eliasson was selected by an international group of curators who met in April 2004 to discuss the next step for the BMW Art Cars Collection. And in 2007, Eliasson, one of the most important representatives of the world of contemporary art and an active activist for environmental protection, created the 16th BMW Art Car. The artist's work was a technological landmark - BMW H2R Mobile Expectations. The artist chose to dress the car in an ice structure. If several viewers were present in the room where the work was presented, the heat released by the bodies of those present degraded the fragile work as a metaphor for human intervention on the environment through global warming.

Hydrogen and fuel cells

When it comes to pure automobiles, hydrogen as an energy source has advantages over a solid-state battery in terms of mass and, above all, charging time. A car can be fueled with liquid hydrogen just like gasoline or diesel. Since the late 1990s, BMW has been working hard on fuel cell research, using them to power a BMW 750iL (E32) and for cargo handling equipment at the BMW Group plants in Spartanburg and Leipzig since 2010. With over 800 machines, BMW operates the largest fleet in the world in Spartanburg, and in Leipzig one of the largest fleets in Europe.

In 2013, the BMW Group and Toyota launched a development collaboration for a fuel cell system to power automobiles. A small BMW 5 Series Gran Turismo

equipped with the fuel cell supplied by Toyota was later presented at the 2017 Hannover Motor Show under the slogan "NewEnergy-4-Mobility2050".

Manufacturing of the fuel cell system started in August 2022 at the hydrogen competence center in Garching. Shortly after, the production of the cars that make up the BMW iX5 Hydrogen pilot fleet started, which in 2023 went into action around the world for testing and demonstration purposes. The combination of a powerful battery and a fuel cell opens up new possibilities and perspectives.

The hydrogen required to power the fuel cell is stored in two 700 bar carbon fiber reinforced polymer (CFRP) tanks. Together they contain 6 kg of hydrogen, enough to give the BMW iX5 Hydrogen a range of up to 504 km in the WLTP cycle. Filling the hydrogen tanks takes just three to four minutes, so the BMW iX5 Hydrogen can also offer the driving pleasure for which BMW is famous, over long distances with only a few short stops along the way.

The fuel cell system develops a maximum power of 125 kW, the surplus power for the electric motor is provided by a lithium-ion battery. This unique combination a maximum power of the electric motor of 295 kW/401 hp for the most powerful production car powered by hydrogen. Acceleration from 0-100 km/h is achieved in less than 6 seconds and the maximum speed is electronically limited to 180 km/h.

The future

The BMW Group is the first German car manufacturer to join the "Business Ambition for 1.5°C" campaign led by the Science-Based Targets initiative and

is committed to achieving the goal of full climate neutrality along the value chain.

The next step in this process involves the BMW Group's plan to reduce CO2 emissions per car over its entire life cycle - i.e. the supply chain, production and use phase - by at least 40% by 2030 compared to 2019.

By 2030 at the latest, the BMW Group aims to reach a situation where electric cars claim a share of more than 50% of its total sales.

The BMW Group sees FCEV (Fuel Cell Energy Vehicle) technology as a potential complement to the propulsion technology used by battery electric cars.

Hydrogen as part of global activities for CO2-free mobility. Hydrogen can be a clean source of energy. Equally, there are several hydrogen production technology solutions (differentiated by the so-called colors of hydrogen).

According to a report by the International Energy Agency (IEA), hydrogen offers considerable potential as a future energy source to support global energy transition activities. Due to its storage and transport capabilities, hydrogen can be used for a wide variety of applications.

Therefore, most industrialized countries adopt hydrogen strategies and support them with concrete strategies and projects. In the transport sector, hydrogen can become another technological option, alongside battery-powered electric mobility, for shaping long-term sustainable individual mobility.

However, this will depend on the competitive production of sufficient amounts of hydrogen from green energy, as well as the expansion of the corresponding supply infrastructure, which is already being pursued intensively in many countries.
(A map of the main filling stations in Europe can be found here: https://h2.live/)

The BMW Group welcomes and supports innovation promotion activities in Germany and Europe that will contribute to building a hydrogen economy and accelerating hydrogen production using renewable energy. These specifically include large-scale hydrogen projects classified as Important Projects of Common European Interest (IPCEI).

The projects comprising this European Union initiative, supported in Germany by the Federal Ministry of Economic Affairs and the Federal Ministry of Transport, cover the entire value chain - from hydrogen production, through transport, to applications in industry.

Under the right conditions, hydrogen fuel cell technology has the potential to become another pillar in the BMW Group's powertrain portfolio for local CO2-free mobility.