"Water is the coal of the future. The energy of tomorrow is water broken down into hydrogen and oxygen using electricity. These elements will secure the earth's power supply for an indefinite period."

Jules Verne,
The Mysterious Island, 1874

The idea of running a car on water is not far short of the ancient dream of the alchemists hoping to turn lead into gold. Achieving the former has never been more closely within our reach. In principle, the hydrogen engine is nothing other than a machine that uses water as a fuel. The only difference is that before it can be used the water must be separated into its two constituents hydrogen and oxygen. The energy used to accomplish the separation is transferred to these two elements. In combustion with oxygen from the atmosphere, the machine once more extracts this energy, and the outcome, consequently – is water.

Depending on the type of machine, the energy "parked" in the hydrogen can be exploited in two ways of interest in terms of vehicle power: either in a conventional combustion engine with direct transmission, or via so-called "cold" combustion in a fuel cell generating electricity. The BMW Group take advantage of both possibilities. In vehicle drive systems, BMW favours the combustion engine, since the sum of its properties brings greater advantage. The fuel cell is a valuable option, on the other hand, for supplying various other vehicle functions with electricity in place of the traditional battery; this opens up quite new possibilities, such as in air-conditioning.

Hydrogen in the car engine – lean mixtures avoid emissions

Hydrogen-powered BMW cars are already in existence. They have been so for a long time and are practically ready for series production. They are driven just like other series-produced BMWs and give equal driving pleasure. BMW began to address the question of hydrogen drive in the late seventies. Development has now reached the fifth generation of hydrogen-driven cars, presently on the basis of the latest 7-Series models.

Whereas the basic engine is series-produced, hydrogen drive as part of the fuel system calls for certain modifications in the mixture process. For this purpose, an electronic fuel-mixture system has been developed, which exactly regulates the hydrogen intake and the charge cycle. The combustion process generally involves a surplus of air. This absorbs heat in the combustion chamber and keeps flame temperature below the critical limit at which uncontrolled ignition can occur. At the same time, the substantial surplus of air and concomitantly reduced combustion temperature avoids the risk of generating oxides of nitrogen (NOx). In petrol engines without surplus air, these need to be neutralised by catalytic converters. Even without additional treatment of the exhaust, the BMW Group hydrogen engines run with virtually zero emissions. The only drawback resulting from this environment-oriented configuration of the engine is the decrease in specific output, which can, however, be overcome by increasing engine capacity.

Hydrogen in the tank – a range of 350 kilometres

Like all types of automotive fuel, hydrogen has to provide roughly the same cruising range as petrol in order to be acceptable in the market. Since hydrogen has a lower volume-related calorific value than petrol, a larger amount of hydrogen is needed to provide the same range. The solution, therefore, is to feed as much hydrogen as possible into the tank of a car, an objective best achieved by use of liquid hydrogen stored in a thermally insulated tank at a temperature of approximately -250°C.

In daily use, the highly effective insulation allows loss-free storage of hydrogen. The fleet of hydrogen-powered cars currently in use feature a highly insulated 140-litre tank positioned behind the rear seats of the car. The tank provides a cruising range of around 350 kilometres.

Safety first

In principle, hydrogen is no more dangerous as a motor fuel than petrol, but it needs to be handled differently. It is true that hydrogen – just like conventional petrol – can produce unstable reactions under certain conditions. So to achieve an equal standard of safety with the hydrogen tank, BMW has conducted comprehensive tests. In careful safety analyses, laboratory and field experiments, BMW engineers have established what can occur when hydrogen is one day regularly used as a source of energy.

Crash tests for hydrogen tanks and vehicles

The BMW Group has simulated and tested various types of severe accidents in a test programme over a number of years, thereby ascertaining how the tank for liquefied hydrogen behaves in the process. In one series of experiments, full tanks with their safety valves deliberately blocked were destroyed under high pressure. The predetermined fracture point in the inner tank designed for such an extreme case ensured a steady and smooth discharge of hydrogen without any major hazards.

Fire tests were also carried out in rigs with car tanks containing liquid hydrogen, whereby the tanks were completely covered in flames at a temperature of almost 1000°C for more than one hour. Again, the tanks took such extremes in their stride, the hydrogen evaporating at such temperatures escaped only slowly and virtually imperceptibly through the safety valves.

In the last series of worst-case tests, car tanks filled with liquid hydrogen were deformed and severely damaged through impact with massive objects. In no case did any tank explode.

However, not only the tanks but also complete vehicles had to prove themselves. For this purpose, BMW hydrogen cars were tested in accordance with the latest standards, for example: frontal collision at a speed of 56 km/h (US specification), rear collision with 100 and 40 percent contact ratio, as well as side-on collision at the most vulnerable point – the filler neck for the hydrogen tank. The car fully satisfied all criteria and confirmed that hydrogen is as safe as petrol.

Filling the tank in just three minutes

A further precondition for the introduction of hydrogen as a motor fuel is the availability of a tank-filling system that is no more complicated than the procedures employed today. The very low temperature of -250°C obviously calls for suitable technology.

In the latest version of tank developed by BMW, the liquid hydrogen is "rained in" from above. The droplets entering the tank ensure condensation of the hydrogen already evaporated, so none is lost in the process. This efficient method also allows the large tank to be filled in approximately three minutes – no more than is needed today with the conventional petrol pump.

The most recent practical step – the robot filling station at Munich airport

Using a manually operated pump, car tanks can be filled with liquid hydrogen rapidly, safely and without emissions. In collaboration with other companies, the BMW Group have also developed a fully automated robot filling system to ensure maximum convenience and even easier operation for customers. The state of the art is now in service at the world's first robot filling station for liquefied hydrogen at Munich airport – usable even by drivers with no specialist technical expertise.

The procedure is extremely simple. As at any other filling station, hydrogen-driven cars arriving at the filling station within the Munich airport complex stop in front of the pump where drivers initiate the filling process. They do not even need to leave the car, as each customer is identified by means of a chip card or electronic remote control; after three minutes the tank is full and closed once again, and the driver ready to go.

Coupling of the robot arm

A hydrogen filling station

BMW 750hl: The first hydrogen-powered series car in the world

In Berlin on 11 May 2000, the BMW Group presented the first series-built hydrogen car in the world – the 750hL. Used in a shuttle service during the entire duration of the international EXPO 2000 trade fair, the luxurious saloons, demonstrated to their passengers that they fulfil all the requirements related to comfort, dynamics and everyday suitability. The hydrogen-powered twelve-cylinder engine delivers 150kW/204hp, can accelerate from 0 to 100 km/h in 9.6 seconds and reach a maximum speed of 226 km/h. The 140-litre cryogenic tank provides the fully equipped 7-Series with a range of around 350 kilometres. This is complimented by a conventional petrol supply system, which has for the moment been retained to compensate for sparse distribution of hydrogen.

The first series car with fuel cell

BMW's most outstanding contribution will be a small series of exclusive 750hL saloons, power-

ed by hydrogen. The electrical functions on board these cars will not be powered by a conventional battery, but by a fuel cell. The BMW Group will be the first car manufacturer in the world to offer a series-produced fuel cell for generation of electricity on board the car. This "electrochemical battery" takes over the functions it performs best, supplying electricity for the various on-board systems – at a very high rate of efficiency of up to 50 percent. In the 7-Series saloon, the compact fuel cell takes up no more room than a conventional lead accumulator – but with five kilowatts of output outclasses it in performance and endurance by far.

The fuel cell – a well-known principle of power generation

The fuel cell battery employed by BMW is a unit consisting of Polymer Electrolyte Membrane (PEM) cells. Around one volt of electricity is generated through oxidation of hydrogen and oxygen from the air. The principle has been well known for many years, but its practical implementation still remains expensive. Connection of several cells in series allows any desired voltage to be generated.

BMW's system has two major advantages over others. First of all, it does not call for additional supplies of compressed air; the cell system employs a ventilator rather than a compressor. Its efficiency is greater, and at the same time it is simpler and less costly to construct. Additionally, it works with a closed, virtually loss-free water cycle. This makes the auxiliary water tank redundant, which is otherwise needed to provide the cells with moisture.

The supply of moisture is one of the shortcomings of the fuel cell for use in road vehicles. In cold weather, the water in an unused cell can freeze. For it to be operable at all times, the fuel cell must either be periodically pressurized on reaching a certain temperature limit, or else externally heated. Moreover, the fuel cell only achieves its high level of efficiency with ultra-pure hydrogen, which requires complicated purification; use of other sources of energy decisively reduces the system's level of efficiency. Work nonetheless proceeds on a further development allowing conventional petrol to be converted into electricity. Such a fuel cell would then be a conceivable alternative to the normal battery in today's cars.

BMW goes around the world on hydrogen

During the five months of the EXPO, the 15 cars of the BMW hydrogen fleet covered more than 100,000 kilometres in normal traffic without any breakdowns. The BMW Group also aims to demonstrate to the world the reliability and advantages of hydrogen technology by going on a world tour with its hydrogen fleet. " The World Tour 2001" gives BMW the opportunity to promote hydrogen on a global scale as the energy of the future hosting a series of events aimed at awakening the interest of political decision-makers, scientists and the media. The tour will visit industrial and technological centres for future energies between January and July 2001. On completion of the world tour, two of the saloons will remain in California and undergo a rigorous test programme at the BMW base at Oxnard. This is BMW's largest Californian location, around 90 kilometres north west of Los Angeles. Here, the BMW Group have built one of the most modern exhaust gas test centres in the world. Its laboratories are equipped to detect even the minutest quantities of toxic emission. With the aid of this technology, BMW is seeking to prove that its hydrogen vehicles can satisfy even the most stringent requirements for an environment-friendly car such as those valid in California.

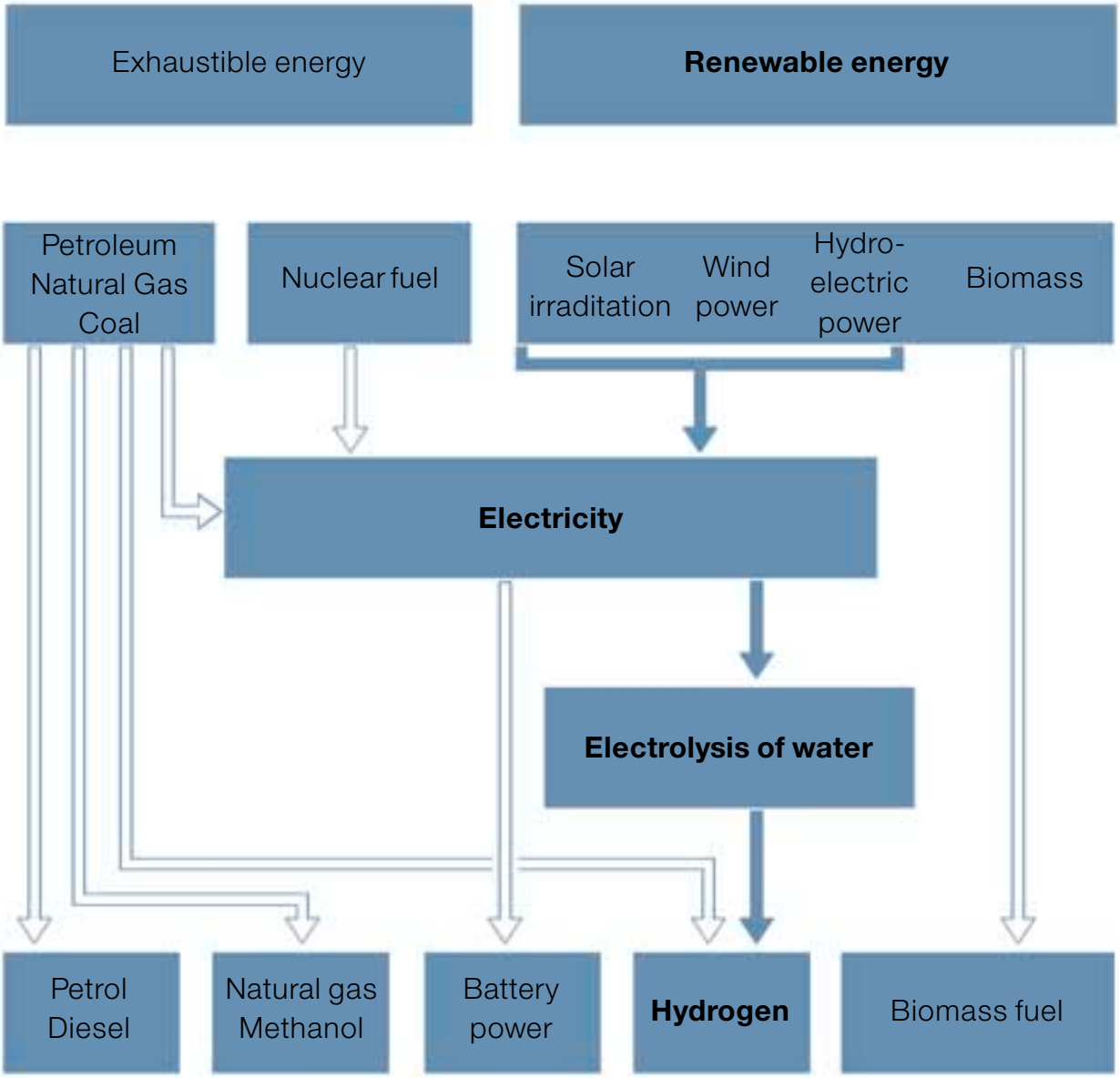
Applications of the fuel cell

All lighting

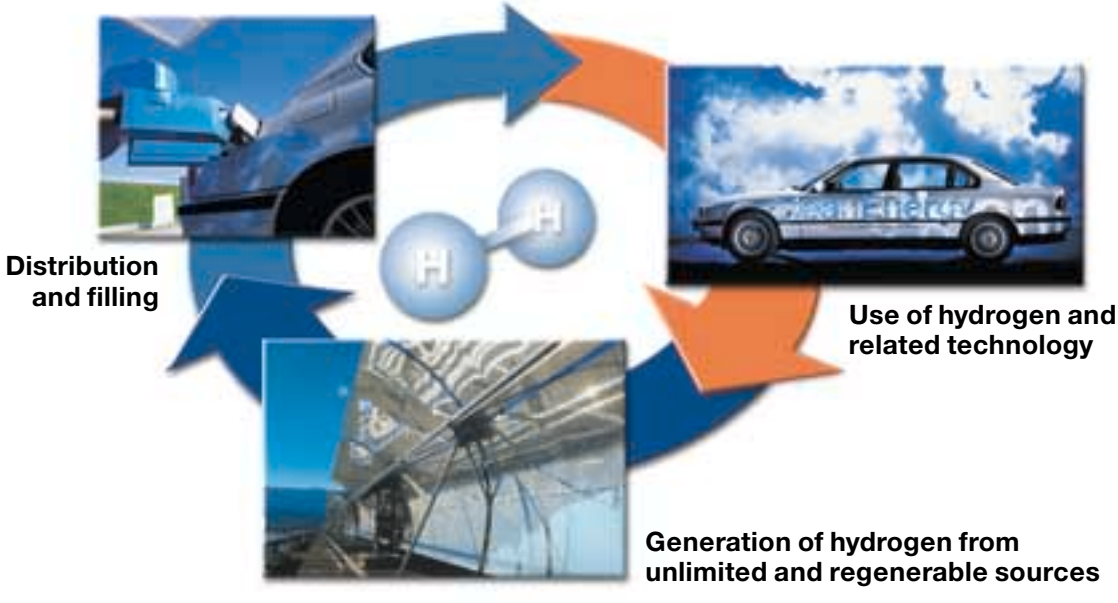
Air-conditioning with car stationary

Heater with car stationary

Possible types of energy for driving road vehicles



CleanEnergy - Hydrogen Cycle



Future plans: Hydrogen from solar energy

Before hydrogen drive systems can be implemented on a sufficiently wide scale, a number of hurdles must still be overcome, particularly with regard to infrastructure. Hydrogen will only become a viable alternative to fossil fuels when it can be produced using sustainable sources of energy.

One alternative is solar energy. To test scenarios its suitability in practice, the BMW Group decided at an early stage to join the Solar Hydrogen Project in the German town of Neunburg vorm Wald where, in collaboration with other companies, BMW tested the photovoltaic generation of hydrogen and the application of this method for various purposes.The objective is to produce sufficient quantities of hydrogen using electrolysis with the aid of solar power. In addition to solar-generated electricity, wind and hydrodynamic power also come into consideration; however, their capacity is limited.

The implementation of solar power stations employing trough-shaped parabolic mirrors of the type used in the Californian Mojave desert present another promising alternative. Solar thermionics provides a viable solution for generating hydrogen on an industrial scale.

From natural gas to hydrogen

As long as hydrogen is unavailable in sufficient volume as a practicable source of energy, non-toxic natural gas represents an ecological and resource-saving alternative to conventional fuels. Engines powered by natural gas emit around 20 percent less carbon dioxide (CO2), which contributes to the greenhouse effect, and an 80 percent lower volume of hydrocarbons (HC), which increase the formation of ozone. At the same time, engine technology which requires the burning of gas, is similar to the principle of hydrogen technology. The BMW Group therefore entered the market with series-produced natural gas cars in 1995, and thus became the first manufacturer in Europe to take the first determined step towards the hydrogen-driven car.

TES, EIHP and ”HYFORUM 2000” – an alliance to promote hydrogen

Naturally, the BMW Group cannot initiate the hydrogen economy entirely on its own. A breakthrough onto the market can only be accomplished by an alliance of powerful partners with shared interests who pool their resources. The "Forum for Future Energies“ , the International Bankers Forum (IBF) and the BMW Group have founded a platform for such an alliance under the name of ”HYFORUM 2000".

This international conference on hydrogen was held in Munich in September 2000. It brought together high-ranking decision-makers from industry, finance and insurance, as well as from government and the scientific community. Further practical measures have also been adopted: The partners of the government-represented "Transport Energy Strategy” (TES) – an organisation for commercial transport energy strategy, of which the BMW Group is a co-founder, have already started planning detailed strategies to launch hydrogen onto the market. And the European Integrated Hydrogen Project (EIHP II) is working on proposals on the development and harmonisation of regulations and laws on the storage, transport and application of liquefied hydrogen.

The hydrogen age has begun.

Informationen der
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CleanEnergy - hydrogen drive

The fuel of the future is hydrogen. In a completely closed cycle, it is extracted from water, and in combustion it becomes water once again. Produced with the help of solar power, hydrogen is the cleanest fuel of all. The BMW Group therefore regards the hydrogen-powered engine as the most important development programme in the longer term. The future has long since begun. Clean energy is the future.

BMW Group