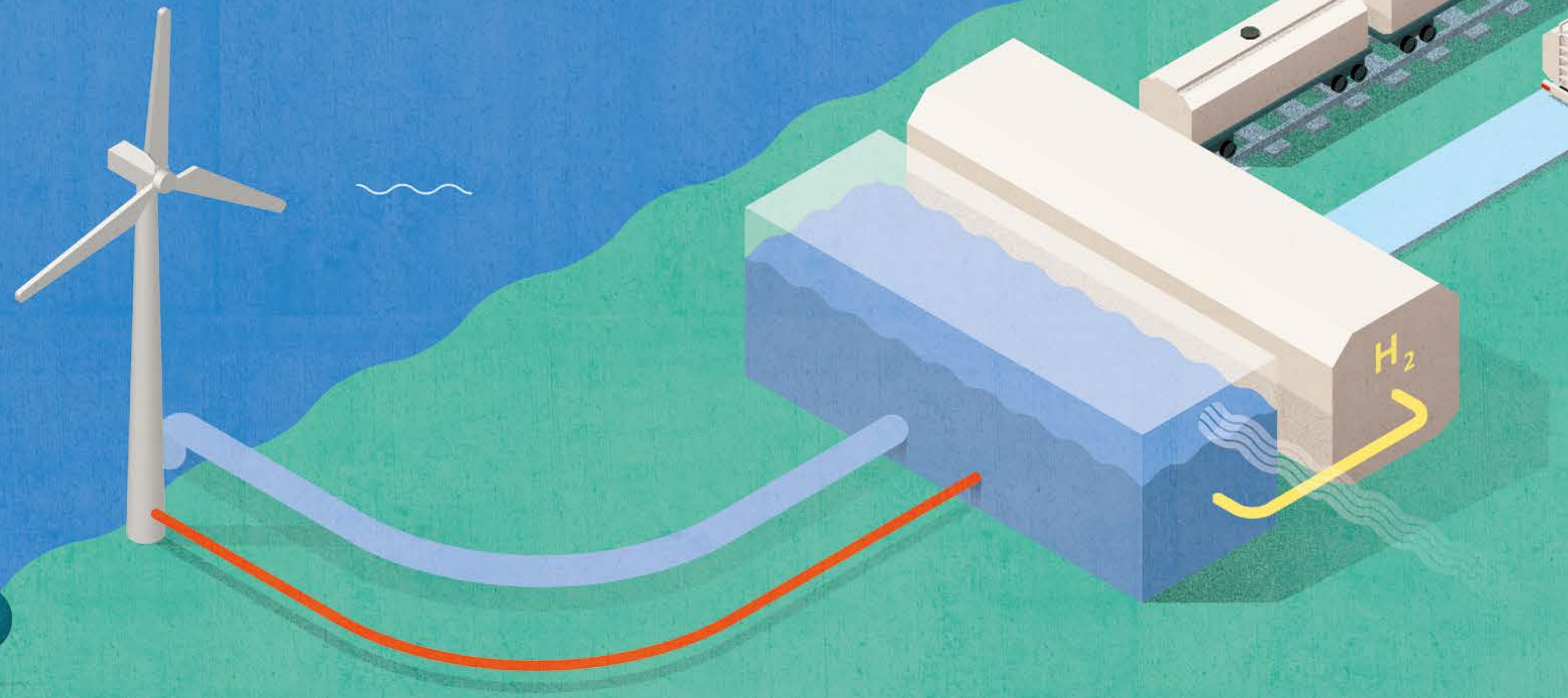
THE WAY OF HYDROGEN

When couples marry in Korea, they often receive wooden ducks from their relatives. The tight bond attributed to these waterfowl is supposed to rub off on the newlyweds. This kind of bond can also be found in the realm of elements – between hydrogen and oxygen, for example. Together they form water and can only be torn apart with great effort and energy. On its own, hydrogen is a volatile character. Under normal conditions, it is a colorless, odorless gaseous molecule consisting of two atoms. It must be stored under high pressure in well-sealed gas tanks or cylinders. It actually only wants one thing: to get back to its beloved oxygen and become water again. As an expression of gratitude, it releases some of the energy expended at its separation. That is the cycle that people can utilize as they move toward a climate-neutral world.

STATION 1
WATER

Water is a chemical compound consisting of two elements, hydrogen and oxygen. Each water molecule is made of two hydrogen atoms and one oxygen atom. In nature, water usually contains dissolved quantities of salts, gases and organic compounds. It covers 71 percent of the earth's surface and has a total volume of 1.4 billion cubic kilometers; 3.5 percent of the total is freshwater, which still amounts to 48 million cubic kilometers, the equivalent of a cube 363 kilometers (225 miles) high. Water is basically abundant but unevenly distributed on the planet.



STATION 2
CLIMATE-NEUTRAL PRODUCTION OF ELECTRICITY

Electric current generated by the wind, the sun or hydropower is made available to consumers and industry. But in certain weather conditions – for example, when there is plenty of wind and sunshine – wind turbines and solar facilities are increasingly producing too much electricity. The more a country expands its renewable facilities to produce electricity, the more often the supply exceeds the demand. Since the surplus electricity travels at nearly the speed of light through the lines as an electromagnetic wave, it has to be used or stored immediately. One possibility: It could be fed into an electrolysis facility to produce hydrogen.

STATION 3
ELECTROLYSIS FACILITY

In the electrolysis facility, electric current is introduced into water: The application of electrical energy separates it into hydrogen and oxygen. While freshwater is primarily used here, scientists are also working on catalysts for hydrogen electrolysis directly from seawater. Today's facilities use a process in which a membrane that is solely permeable to protons serves as a separator between the anode and the cathode, virtually a fuel cell in reverse. If external voltage is applied, the water breaks down at the anode. The result is oxygen, hydrogen ions and free electrons. The membrane only allows the hydrogen ions through to the cathode, where they encounter free electrons and combine with them to become hydrogen.

STATION 4
HYDROGEN DISTRIBUTION

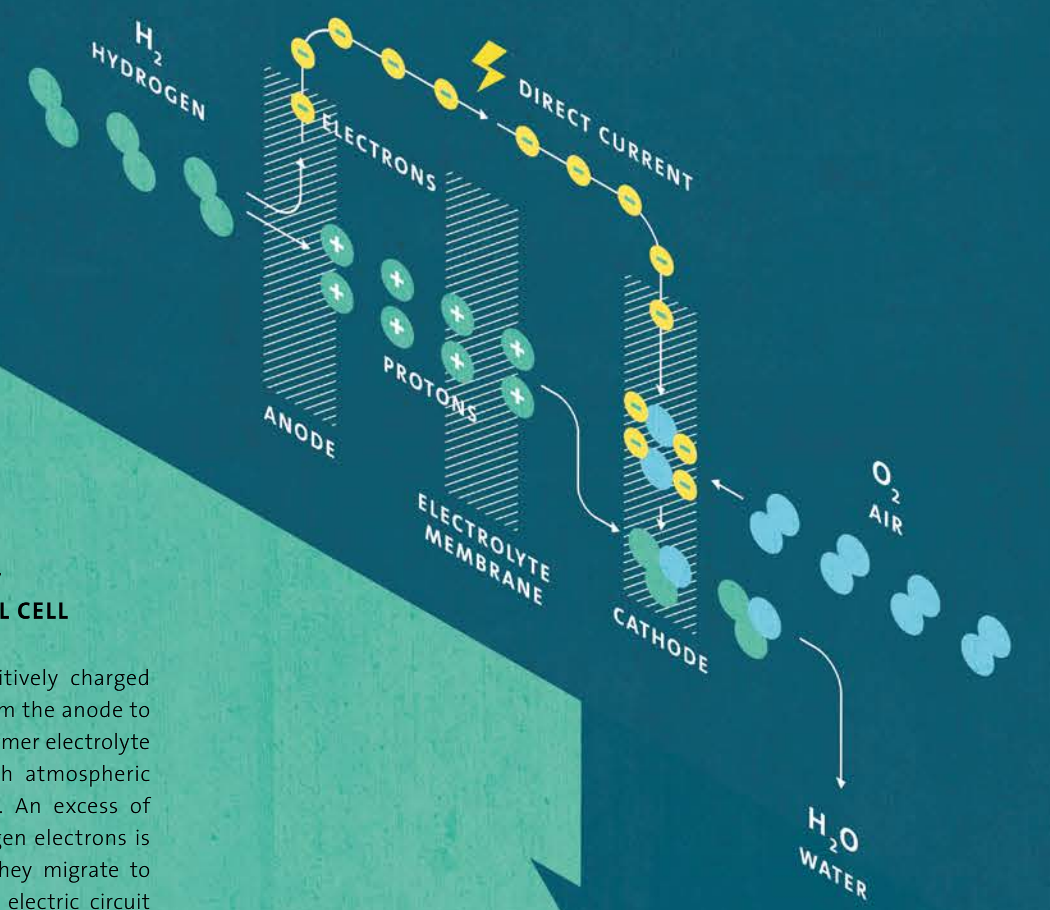
To use hydrogen as an energy source in vehicles, it has to be transported from the electrolysis facility to the consumer. Special tank trucks and railway cars are used to store and transport the hydrogen as a pressurized gas. There are also tanks that are cooled to –253 °C (–423 °F) so they can carry liquefied hydrogen. But in a largely climate-neutral world, these trains and trucks would have to run on renewable energy or on fuels derived from them. One alternative: transporting the gas over long distances and in large quantities through pipelines, with a relatively low expenditure of energy.

STATION 5
HYDROGEN FUELING STATION

Aside from the fact that the pumps are operated a bit differently, fueling vehicles with hydrogen hardly differs at all from fueling them with liquid fuels. The gas must be conveyed into the vehicle from the supply at the substantial pressure of 700 bar. As a result, the filling hose is firmly locked with a coupling at the vehicle's nozzle and is automatically tightened. The vehicle data that are important for fueling are communicated to the fuel dispenser via an infrared interface. The actual fueling process takes three to four minutes for a car and is comparable to current fueling processes, although the ranges of 400 to 500 kilometers (250 to 310 miles) are somewhat less.

STATION 6
VEHICLE WITH FUEL CELL

While the fueling processes for fuel cells resemble those for internal combustion engines, the hydrogen is actually powering a true electric vehicle. The gas is converted back to electricity in a fuel cell and then used to feed energy into an entirely normal electric motor. In relation to mass, hydrogen has a greater energy density than any other fuel. That means it can deliver acceptable ranges for buses and trucks. One disadvantage is that hydrogen is very light and its energy density in relation to volume is very low. That's why it has to be highly compressed. Even then, hydrogen tanks take up more space than conventional fuel tanks – but still considerably less than today's lithium ion batteries.



STATION 7
INSIDE THE FUEL CELL

Within the fuel cell, positively charged hydrogen ions migrate from the anode to the cathode through a polymer electrolyte membrane and react with atmospheric oxygen to become water. An excess of negatively charged hydrogen electrons is produced at the anode. They migrate to the cathode if a separate electric circuit connects them to it: That means electricity is flowing — although it is only half of the current used to produce the hydrogen. To boost efficiency, a gas diffusion layer from Freudenberg feeds the gases to the reaction process as homogeneously as possible. Water vapor is the only waste product to reach the environment. The water returns to the circuit.

STATION 8 = STATION 1
WATER
Circuit closed.