Huge amounts of green hydrogen will be needed to create a sustainable economic system. As a result, Evonik is working together with partners to develop a new membrane that will make environmentally friendly water electrolysis competitive.
We have learned that we greatly benefit by working together with small companies such as Enapter because they are flexible and can very quickly try out new things,” says Conradi. “Moreover, having direct contact to the people involved is very helpful when you want to validate and implement a technology.”

Enapter’s AEM electrolyzers aren’t big systems. Instead, they look rather like server cabinets with slide-in modules arranged one on top of another. Each of these modules is a separate unit that produces half a cubic meter of hydrogen per hour. “This makes the technology so easily scalable,” says Jan-Justus Schmidt, who studied aerospace engineering and is now setting up series production in Germany.

In water electrolysis, electricity is used to split water into oxygen and hydrogen. However, most hydrogen is currently still produced from carbon-based sources such as methane by means of steam reforming. This is mainly due to the fact that this traditional process is much less expensive than electrolysis (see the article on the hydrogen-energy economy, beginning on page 30). “One of the reasons for this is the relatively high price of electricity,” says Conradi. “Another reason is that electrolysis systems require a very high level of investment.” Evonik wants to help reduce the cost of the equipment by introducing an innovative membrane technology.

PROVEN TECHNOLOGY WITH SOME WEAKNESSES

The workhorse of the established processes is alkaline electrolysis (AEL). It is the method that is most like those illustrated in schoolbooks, consisting of two electrodes that are inserted into a highly concentrated potassium hydroxide solution (pure water is not conductive enough). At the cathode, the water molecules split into hydrogen and hydroxide ions. The hydrogen rises as a gas while the hydroxide ions move through the alkaline solution to the anode, where they react to form oxygen and water. To ensure the products of the reaction remain apart and don’t recombine with a bang, a porous membrane—a diaphragm—separates the anode side of the electrolyzer from the cathode side.

“The technology is robust and the cell material is pretty inexpensive,” says Conradi. For example, the catalysts that cause the reactions to start at the electrodes include nickel, cobalt or iron, while the housing components are made from stainless steel. The investment costs amount to about €800 per kilowatt of power and experts think that the amount will drop to as low as €600 by 2025.

One problem with AEL is that the diaphragm is porous. This means that it lets gases through so that the possibility of operating the facility under pressure is limited. As a result, the hydrogen has to be compressed so that it can be stored and transported further, consuming a lot of energy in the process. In addition, the porous membrane can only be operated at low power densities. The diaphragm can handle a maximum of 600 milliamperes per square centimeter of membrane surface. In practice, this means that a much smaller electrolyzer can be used to produce the same amount of hydrogen.

In PEM electrolysis, membranes are more than just a barrier to water. They are also made of an ionomer and are permeated with catalyst particles. “However, AEM lets us use non-precious metals such as nickel for this purpose, which is significantly less expensive,” says Conradi. “This is possible because the process operates in an alkaline environment. As is the case with the AEL process, the water is split flows across the anode. The hydrogen ions that are released move from the anode through the membrane to the cathode side, where they combine to form hydrogen molecules. A PEM electrolyzer is not only operated at higher current densities than an AEL system, it can also handle greater load fluctuations. And because it can be operated under pressure, less energy is subsequently needed for hydrogen compression. However, despite its technological advantages, the high investment costs of PEM systems pose a considerable barrier to market entry. “PEM cells operate in an acidic environment, which means that the materials need to be very robust,” says Conradi. “The catalysts have to be made of precious metals such as platinum and iridium, while the cells have to consist of titanium or even of platinized titanium. Investment costs are calculated to be €3,000 or more per kilowatt of power using today’s technology.”

HIGHER OUTPUT, LOWER COSTS

This is where the promising AEM process comes into play. Over the medium term, Evonik hopes to develop a system that costs €500 to €600 per kilowatt. An AEM cell has the same structure as a PEM cell. It can also be operated under pressure and with a high level of power output. The centerpieces of this system is also a membrane made of an ion-conducting plastic known as an ionomer. Electrodes lie on both sides of the membrane. They are also made of an ionomer and are permeated with catalyst particles. “However, AEM lets us use non-precious metals such as nickel for this purpose, which is significantly less expensive,” says Conradi. This is possible because the process operates in an alkaline environment. As is the case with the AEL process, the water is split flows across the anode. Two H₂O molecules give rise to one hydrogen molecule and two hydroxide ions (OH⁻). The hydroxide ions then move through the membrane to the cathode side, where they react to form oxygen and water (see the illustration on page 33).

To achieve such a combination is a real challenge. “An alkaline environment is aggressive as well,” says Alejandro Oyarzun Barnett from the Norwegian re-
The AEM water electrolysis

High pressure and an aggressive environment: The AEM process puts great demands on the material. To enable hydrogen production to take place under controlled conditions, electrolyzers consist of many individual cells that are connected in series to form stacks. These cells harbor the actual reaction that splits water into hydrogen and oxygen.

The cells’ components include the bipolar plates—solid metal structures that enclose the membrane electrode assembly on both sides in order to channel the inflow and outflow of liquids and gases. The porous transport layers at the electrodes, through which the gas from the electrodes is led off, are another example. “These are a key component that isn’t yet available on the market,” says Barnett’s colleague Shubhi Khosla. “Although we are building on the experience gained from the production of PEM cells, we are working with completely different materials and have to continuously compare costs and performance.”

The new modules are being tested in Evonik facilities. “We can test new materials on a small scale before quickly using them on a larger scale,” says Jan-Justus Schmidt. In this way, a private technical pastime could turn into a product that will take the world by storm.

The reaction in the electrode

The electrode layer also consists of an ion-conducting polymer within which metallic catalyst particles are suspended.

The cells’ components include the bipolar plates—solid metal structures that enclose the membrane electrode assembly on both sides in order to channel the inflow and outflow of liquids and gases. The porous transport layers at the electrodes, through which the gas from the electrodes is led off, are another example. “These are a key component that isn’t yet available on the market,” says Barnett’s colleague Shubhi Khosla. “Although we are building on the experience gained from the production of PEM cells, we are working with completely different materials and have to continuously compare costs and performance.”

The new modules are being tested in Evonik facilities. “We can test new materials on a small scale before quickly using them on a larger scale,” says Jan-Justus Schmidt. In this way, a private technical pastime could turn into a product that will take the world by storm.

The AEM water electrolysis

High pressure and an aggressive environment: The AEM process puts great demands on the material. To enable hydrogen production to take place under controlled conditions, electrolyzers consist of many individual cells that are connected in series to form stacks. These cells harbor the actual reaction that splits water into hydrogen and oxygen.

The cells’ components include the bipolar plates—solid metal structures that enclose the membrane electrode assembly on both sides in order to channel the inflow and outflow of liquids and gases. The porous transport layers at the electrodes, through which the gas from the electrodes is led off, are another example. “These are a key component that isn’t yet available on the market,” says Barnett’s colleague Shubhi Khosla. “Although we are building on the experience gained from the production of PEM cells, we are working with completely different materials and have to continuously compare costs and performance.”

The new modules are being tested in Evonik facilities. “We can test new materials on a small scale before quickly using them on a larger scale,” says Jan-Justus Schmidt. In this way, a private technical pastime could turn into a product that will take the world by storm.