CHEMISTRY

Seawater splitting could help green hydrogen grow

Corrosion-proof electrolyzers could tap ample supplies of saltwater

By **Robert F. Service**

Few climate solutions come without downsides. "Green" hydrogen, made by using renewable energy to split water molecules, could power heavy vehicles and decarbonize industries such as steelmaking without spewing a whiff of carbon dioxide. But because the water-splitting machines, or electrolyzers, are designed to work with pure water, scaling up green hydrogen could exacerbate global freshwater shortages. Now, several research teams are reporting advances in producing hydrogen directly from seawater, which could become an inexhaustible source of green hydrogen.

A green hydrogen plant in Spain will consume vast amounts of fresh water.

PHOTO: ANGEL GARCIA/BLOOMBERG VIA GETTY IMAGES

"This is the direction for the future," says Zhifeng Ren, a physicist at the University of Houston (UH). However, Md Kibria, a materials chemist at the University of Calgary, says for now there's a cheaper solution: feeding seawater into desalination setups that can remove the salt before the water flows to conventional electrolyzers.

Today, nearly all hydrogen is made by breaking apart methane, burning fossil fuels to generate the needed heat and pressure. Both steps release carbon dioxide. Green hydrogen could replace this dirty hydrogen, but at the moment it costs more than twice as much, roughly $5 per kilogram. That's partly due to the high cost of electrolyzers, which rely on catalysts made from precious metals. The U.S. Department of Energy recently launched a decadelong effort to improve electrolyzers and bring the cost of green hydrogen down to $1 per kilogram.

If they succeed and green hydrogen production skyrockets, pressure could build on the world's freshwater supplies. Generating 1 kilogram of hydrogen using electrolysis takes some 10 kilograms of water. Running trucks and key industries on green hydrogen could require roughly 25 billion cubic meters of fresh water a year, equivalent to the water consumption of a country with 62 million people, according to the International Renewable Energy Agency.

Seawater is nearly limitless, but splitting it comes with its own problems. Electrolyzers are built much like batteries, with a pair of electrodes surrounded by a watery electrolyte. In one design, catalysts at the cathode split water molecules into hydrogen (H+) and hydroxyl (OH-) ions. Excess electrons at the cathode stitch pairs of hydrogen ions into hydrogen gas (H_2), which bubbles out of the water. The OH- ions, meanwhile, travel through a membrane between the electrodes to reach the anode, where catalysts knit the oxygen into oxygen gas (O_2) that is released.

When seawater is used, however, the same electrical jolt that generates O_2 at the anode also converts the chloride ions in saltwater into highly corrosive chlorine gas, which eats away at the electrodes and catalysts. This typically causes electrolyzers to fail in just hours when they can normally operate for years.

Now, three groups are reporting efforts to halt this corrosion. Researchers led by Nasir Mahmood, a materials scientist at RMIT University, Melbourne, reported in the 8 February issue of *Small* that by coating their electrodes with negatively charged compounds such as sulfates and phosphates, they could repel negatively charged chloride ions and prevent the formation of chlorine gas. The RMIT team reported virtually no degradation in its electrodes for up to 2 months, although it generated only a trickle of hydrogen. Since then, in unpublished work, the researchers have bolstered their setup to produce hydrogen as fast as commercial freshwater electrolyzers, Mahmood says.

Shizhang Qiao, a nanotechnologist at the University of Adelaide, and his colleagues made changes to a second type of electrolyzer that uses a membrane permeable only to H+ ions. This setup split water molecules at the anode instead of the cathode, snatching away electrons to free H+ ions. The ions migrate through the membrane to the cathode where they combine with electrons to make H_2. Qiao and his colleagues coated their electrodes with chromium oxide, which attracted a bubble of OH- ions that repelled chloride ions. The device split seawater for 100 hours at high currents without degradation, they report in the 30 January issue of *Nature Energy*. "I'm very happy to see such a clever design," says UH materials physicist Shou Chen.

Zongping Shao, a chemical engineer at the Nanjing University of Technology, and his colleagues took a third tack to fending off chloride. They surrounded the electrodes with membranes that only allow freshwater vapor to pass through from the surrounding bath of seawater. As the electrolyzer converts fresh water to hydrogen and oxygen, it creates a pressure that draws more water molecules through the membrane, replenishing the freshwater supply. In the 30 November 2022 issue of *Nature*, Shao and his colleagues reported their setup operated for 3200 hours with no sign of degradation. "It's like an internal distillation process," says Haotian Wang, an applied physicist at Rice University.

The membranes that screen out the salt resemble those in commercial desalination plants, which are already efficient enough to produce fresh water while adding only about $0.01 per kilogram to green hydrogen's cost. That's why Kibria says fiddling with electrolyzers doesn't make as much sense as simply attaching green hydrogen projects to desalination plants. "We don't need to reinvent the wheel," he says. "This is a solved problem."

Mahmood disagrees. For starters, he says, desalination isn't a ready option for countries that can't afford large-scale capital projects. Moreover, he says, corrosion-resistant electrodes may also be useful for tapping other impure water sources, such as wastewater and brackish water. "We need to keep working on alternative technologies," he says. ■