
A Nel Hydrogen containerized PEM Electrolyser
IMAGE: CONSTELLATION ENERGY CORPORATION

CONTAINERIZED ELECTROLYSERS: ENABLING RAPID DEPLOYMENT OF SAF PRODUCTION FACILITIES

The single largest-volume raw material in SAF production, the carbon intensity of hydrogen is a key consideration for SAF producers.

BY LYNN GORMAN

Those in the hydrogen generation business are enthused about the supply and demand situation for sustainable aviation fuel (SAF). According to David Wolff, director of industrial product sales at Nel Hydrogen, the hydrogen market is hyped up right now, fueled by new U.S. government initiatives—the Inflation Reduction Act, for one—and the establishment of hydrogen hubs. All this attention has created a sort of "gold rush" mentality surrounding all things hydrogen. While it is breathtaking, it also warrants caution by stakeholders to focus on practical hydrogen applications now and in the foreseeable future. "SAF is an outstanding example of a business that makes sense now, and the momentum is building quickly," Wolff says.

There are various routes to make SAF, but all SAF raw material options require hydrogen to modify feedstock and biomass molecules into complex hydrocarbons suitable for aviation fuel. SAF will require massive production of hydrogen, and that new supply of hydrogen must be made in a manner that meets the standard for sustainability—essentially, no net fossil carbon can be added to the environment.

The Inflation Reduction Act differentiates "green" hydrogen, which is made from renewable energy, and typically would be solar, wind or hydro from "clean" hydrogen, which includes hydrogen made from nuclear electricity. Together, both renewable and nuclear power satisfy the sustainability requirements to feed electrolytic hydrogen generation, which uses electricity to crack water, or H2O, into clean hydrogen and byproduct oxygen.

Hydrogen made via the electrolysis process is of particular interest to produce clean hydrogen for SAF production because electrolysis is highly scalable, according to Wolff. "It's a challenge to make a small steam methane reformer to make hydrogen from natural gas," he says. "But electrolyser technology scales relatively easily."

There are electrolysers already commercially available that range from the size of a coffee cup up to many tons of capacity per day of capacity. There is an experienced electrolyser supplier base, which minimizes the technology risk for SAF producers. There are also a large number of electrolysers operating today. And, perhaps most importantly for the overarching goal, there are no carbon emissions from the process, as long as the energy feedstock does not generate carbon emissions.

Further, on the cost side of the ledger, electrolysis enables monetizing excess and low-value electricity supplies, and that has encouraging potential for both stranded renewable energy and nuclear energy that is too expensive to sell at a profit. For example, there are periods of time in the middle of the afternoon when there is excess solar power. There is excess wind power on certain days, especially during the winter months when capacity factors are high and cooling loads are low. Nuclear plants contend with excess energy above grid needs almost every night. Electrolysis is uniquely compelling to the nuclear power economics by creating profitable nighttime electricity markets. Those plants can create hydrogen all night long and feed the grid all day long. And in doing so, a nuclear power plant can serve two profitable markets. Finally, the U.S. Treasury is releasing guidelines under which the deployment of electrolysis will incentivize clean energy investments for the production of low-carbon hydrogen.

According to the International Air Transport Association, the global aviation industry is set to require 120 million metric tons (mt) of clean hydrogen a year by 2050, with 100 mt to produce SAF and 20 mt for H2-powered aircraft. So, 100 million mt of clean hydrogen a year for SAF by 2050 equals 274,000 mt per day of hydrogen production. Carrying this math through, 274,000 mt per day of hydrogen would entail about 650,000 MW of electrolysis hydrogen production.

There are two types of electrolysis systems that are generally considered commercially mature right now. One is alkaline electrolysis, and the other is proton exchange membrane (PEM) electrolysis. There are other types in development that also show promise. Alkaline technology has historically been used for large-capacity hydrogen plants. Alkaline cell stacks costs less on a per-kilowatt basis because they do not use precious metals as catalysts as PEM does, and alkaline equipment has been commercially deployed for almost a century. Conversely, PEM electrolysers are compact, and can ramp quickly with variable energy sources. They can also achieve a similar range of hydrogen production from pounds per day to hundreds or thousands of tons per day. PEM electrolysers have been working in the field commercially for about 50 years.

Electrolysis begins with the electrolyser's cell stack. That's the engine of the electrolyser, akin to the chip in a computer. Every cell stack is made up of many electrolytic cells, each of which is an electrochemical reactor. Add water, an electrolyte and DC power, and it creates hydrogen and byproduct oxygen. "The cell stack gets surrounded by what we call the balance of plant (BOP)," Wolff says. "BOP can be supplied by the electrolyser maker, or it can be supplied by an engineering, procurement, construction (EPC) contractor, or perhaps another third party. As companies scale up electrolysis, the number of cell stacks also multiply. Cell stacks scale linearly, while shared BOP may be scaled by using ever larger vessels.

The BOP is where experts such as EPC contractors can best use their expertise to drive cost reduction in the plant. These include electrical and water supply, controls and safety management, water and oxygen gas management, hydrogen purification and compression, and heat management. According to Wolff, PEM is best suited to small footprint applications and offers simple, straightforward equipment that does not require downstream compression or gas purification. It is this equipment, he believes, that will be used for the initial stages of the SAF production journey.

"Currently, Nel PEM containerized systems are capable of producing up to 1 ton a day of hydrogen," Wolff says. "Soon, that will be higher than 1 ton a day as development continues. Further, taking the same PEM stack technology, and packaging it innovatively, we will provide cell stack subsystems that can produce four tons a day."

PEM stack modules, which are containerized cell stack systems, along with a shared BOP in larger hydrogen systems, can produce several tons of hydrogen each day. Alternatively, the largest plants might omit containerization and be placed in buildings using bare, uncontainerized cell stacks in groups of dozens to create even larger-scale hydrogen production. The cell stacks can be arrayed in a number of different configurations. "The point is as the plant gets bigger, more and more cell stacks can be serviced together with shared BOP," Wolff adds.

The advantages of containerized PEM electrolysis are several. They include predictable availability. The equipment is made in a factory; it is not assembled in the field. There are minimal technology and supply chain risks. There are also minimal infrastructure requirements in the field. Basically, the needs are deionized water, electricity, the ability to dispose of waste water, and the customer hydrogen header pipe to take the produced hydrogen. Highly skilled tradespeople are not necessary to do field fabrication, and systems can be installed in any weather season. Because the systems are highly standardized, companies receive an assured level of support from manufacturers that have made hundreds of such systems. It is believed that PEM electrolysers, at least initially, will play the larger role when coupling to renewable energy grids because their ability to respond instantly to electrical supply changes and downstream process needs.

"There is even innovation happening right now for hydrogen-using companies to consider employing a blend of alkaline and PEM systems," Wolff says. "For instance, if you wanted 100 MW of electrolysis capacity, lowest possible deployed cost, and the ability to ramp up and down to meet a certain amount of renewable energy, then you might deploy 70% alkaline and 30% PEM. That would give you the lowest deployed cost because alkaline systems are less expensive to buy and are slightly more electrically efficient. Meanwhile, the PEM portion of the plant can dynamically track the ups and downs of the electrical supply."

To match the ramp-up of hydrogen needs for the SAF market and others, the electrolysis industry is investing to meet these growing needs. "The priority as equipment makers is increased cell stack production," Wolff says. "We are also making significant headway to achieve a lower cost per unit of capacity."

The industry is also working to achieve wide geographic servicing because SAF will be made all over the world using local feedstocks whenever possible. As an example, Nel is building new electrolyser equipment manufacturing plants in Europe and a new factory near Detroit, Michigan. When fully developed, the Detroit plant alone will have a production capacity of up to 4 GW alkaline and PEM electrolysers.

Hydrogen is the single largest-volume raw material in SAF production; hence hydrogen carbon intensity is a key consideration for SAF producers. Hydrogen made via zero-carbon electrolysis is a viable solution.

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