A solar hydrogen system that co-generates heat and oxygen

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The LRESE parabolic dish. Credit: LRESE EPFL

EPFL researchers have built a pilot-scale solar reactor that produces usable heat and oxygen, in addition to generating hydrogen with unprecedented efficiency for its size.

A parabolic dish on the EPFL campus is easily overlooked, resembling a satellite dish or other telecommunications infrastructure. But this dish is special, because it works like an artificial tree. After concentrating solar radiation nearly 1,000 times, a reactor above the dish uses that sunlight to convert water into valuable and renewable hydrogen, oxygen, and heat.

"This is the first system-level demonstration of solar hydrogen generation. Unlike typical lab-scale demonstrations, it includes all auxiliary devices and components, so it gives us a better idea of the energy efficiency you can expect once you consider the complete system, and not just the device itself," says Sophia Haussener, head of the Laboratory of Renewable Energy Science and Engineering (LRESE) in the School of Engineering.

"With an output power of over 2 kilowatts, we've cracked the 1-kilowatt ceiling for our pilot reactor while maintaining record-high efficiency for this large scale. The hydrogen production rate achieved in this work represents a really encouraging step towards the commercial realization of this technology."

The work builds on preliminary research demonstrating the concept on the laboratory scale, using LRESE's high-flux solar simulator, which was published in *Nature Energy* in 2019. Now, the team has published the results of their scaled-up, efficient, and multi-product process under real-world conditions in the same journal.

Waste not, want not

Hydrogen production from water using solar energy is referred to as artificial photosynthesis, but the LRESE system is unique for its ability to also produce heat and oxygen at scale.

After the dish concentrates the sun's rays, water is pumped into its focus spot, where an integrated photoelectrochemical reactor is housed. Within this reactor, photoelectrochemical cells use solar energy to electrolyze, or split water molecules into hydrogen and oxygen. Heat is also generated, but instead of being released as a system loss, this heat is passed through a heat exchanger so that it can be harnessed—for ambient heating, for example.

In addition to the system's primary outputs of hydrogen and heat, the oxygen molecules released by the photo-electrolysis reaction are also recovered and used.

"Oxygen is often perceived as a waste product, but in this case, it can also be harnessed—for example for medical applications," Haussener says.

Industrial and residential energy

The system is suitable for industrial, commercial, and residential applications; in fact, LRESE-spinoff SoHHytec SA is already deploying and commercializing it. The EPFL start-up is working with a Swiss-based metal production facility to build a demonstration plant at the multi-100-kilowatt scale that will produce hydrogen for metal annealing processes, oxygen for nearby hospitals, and heat for the factory's hot-water needs.

"With the pilot demonstration at EPFL, we have achieved a major milestone by demonstrating unprecedented efficiency at high output power densities. We are now scaling up a system in an artificial garden-like setup, where each of these 'artificial trees' is deployed in a modular fashion," says SoHHytec co-founder and CEO Saurabh Tembhurne.

The system could be used to provide residential and commercial central heating and hot water, and to power hydrogen fuel cells. At an output level of about half a kilogram of solar hydrogen per day, the EPFL campus system could power around 1.5 hydrogen fuel cell vehicles driving an average annual distance; or meet up to half the electricity demand and more than half of the annual heat demand of a typical four-person Swiss household.

With their artificial photosynthesis system well on its way to scale-up, Haussener is already exploring new technological avenues. In particular, the lab is working on a large-scale solar-powered system that would split carbon dioxide instead of water, yielding useful materials like syngas for liquid fuel, or the green plastic precursor ethylene.

More information: Isaac Holmes-Gentle et al, Kilowatt-scale solar hydrogen production system using a concentrated integrated photoelectrochemical device, *Nature Energy* (2023). DOI: 10.1038/s41560-023-01247-2

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