

Floating 'artificial leaves' ride the wave of clean fuel production

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A floating artificial leaf—which generates clean fuel from sunlight and water—on the River Cam near King's College Chapel in Cambridge, U.K.
Credit: Virgil Andrei

Researchers have developed floating "artificial leaves" that generate clean fuels from sunlight and water, and could eventually operate on a large scale at sea.

The researchers, from the University of Cambridge, designed ultra-thin, flexible devices, which take their inspiration from photosynthesis—the process by which plants convert sunlight into food. Since the low-cost, autonomous devices are light enough to float, they could be used to generate a sustainable alternative to petrol without taking up space on land.

Outdoor tests of the lightweight leaves on the River Cam—near iconic Cambridge sites including the Bridge of Sighs, the Wren Library and King's College Chapel—showed that they can convert sunlight into fuels as efficiently as plant leaves.

This is the first time that clean fuel has been generated on water, and if scaled up, the artificial leaves could be used on polluted waterways, in ports or even at sea, and could help reduce the global shipping industry's reliance on fossil fuels. The results are reported in the journal *Nature*.

While renewable energy technologies, such as wind and solar, have become significantly cheaper and more available in recent years, for industries such as shipping, [decarbonization](#) is a much taller order. Around [80% of global trade](#) is transported by cargo vessels powered by [fossil fuels](#), yet the sector has received remarkably little attention in discussions around the climate crisis.



A floating artificial leaf—which generates clean fuel from sunlight and water—on the River Cam near the Bridge of Sighs in Cambridge, U.K. Credit: Virgil Andrei

For several years, Professor Erwin Reisner's research group in Cambridge has been working to address this problem by developing sustainable solutions to petrol which are based on the principles of [photosynthesis](#). In 2019, they developed an [artificial leaf](#), which makes syngas—a key intermediate in the production of many chemicals and pharmaceuticals—from sunlight, carbon dioxide and water.

The earlier prototype generated fuel by combining two light absorbers

with suitable catalysts. However, it incorporated thick glass substrates and moisture protective coatings, which made the device bulky.

"Artificial leaves could substantially lower the cost of sustainable fuel production, but since they're both heavy and fragile, they're difficult to produce at scale and transport," said Dr. Virgil Andrei from Cambridge's Yusuf Hamied Department of Chemistry, the paper's co-lead author.

"We wanted to see how far we can trim down the materials these devices use, while not affecting their performance," said Reisner, who led the research. "If we can trim the materials down far enough that they're light enough to float, then it opens up whole new ways that these artificial leaves could be used."

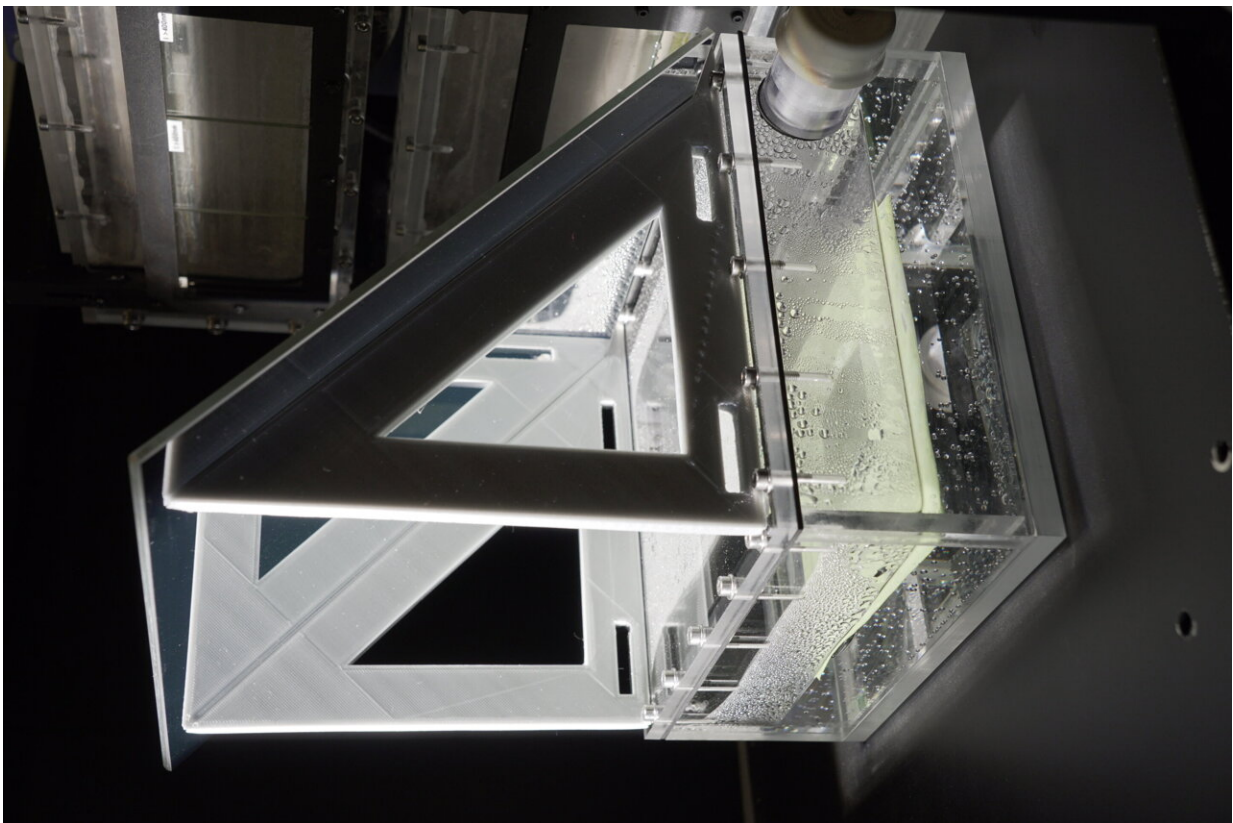
For the new version of the artificial leaf, the researchers took their inspiration from the electronics industry, where miniaturization techniques have led to the creation of smartphones and flexible displays, revolutionizing the field.

The challenge for the Cambridge researchers was how to deposit light absorbers onto lightweight substrates and protect them against water infiltration. To overcome these challenges, the team thin-film metal oxides and materials known as [perovskites](#), which can be coated onto flexible plastic and metal foils. The devices were covered with micrometer thin, water-repellent carbon-based layers that prevented moisture degradation. They ended up with a device that not only works, but also looks like a real leaf.

"This study demonstrates that artificial leaves are compatible with modern fabrication techniques, representing an early step towards the automation and up-scaling of solar fuel production," said Andrei. "These leaves combine the advantages of most solar fuel technologies, as they achieve the low weight of powder suspensions and the high performance

of wired systems."

Tests of the new artificial leaves showed that they can split water into hydrogen and oxygen, or reduce CO₂ to syngas. While additional improvements will need to be made before they are ready for commercial applications, the researchers say this development opens whole new avenues in their work.



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"Solar farms have become popular for electricity production; we envision similar farms for fuel synthesis," said Andrei. "These could supply coastal settlements, remote islands, cover industrial ponds, or avoid water evaporation from irrigation canals."

"Many renewable energy technologies, including solar fuel technologies, can take up large amounts of space on land, so moving production to open water would mean that clean energy and land use aren't competing with one another," said Reisner. "In theory, you could roll up these devices and put them almost anywhere, in almost any country, which would also help with energy security."

More information: Erwin Reisner, Floating perovskite-BiVO₄ devices for scalable solar fuel production, *Nature* (2022). [DOI: 10.1038/s41586-022-04978-6](https://doi.org/10.1038/s41586-022-04978-6).
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