An integrated, net-negative system captures carbon and produces ethylene

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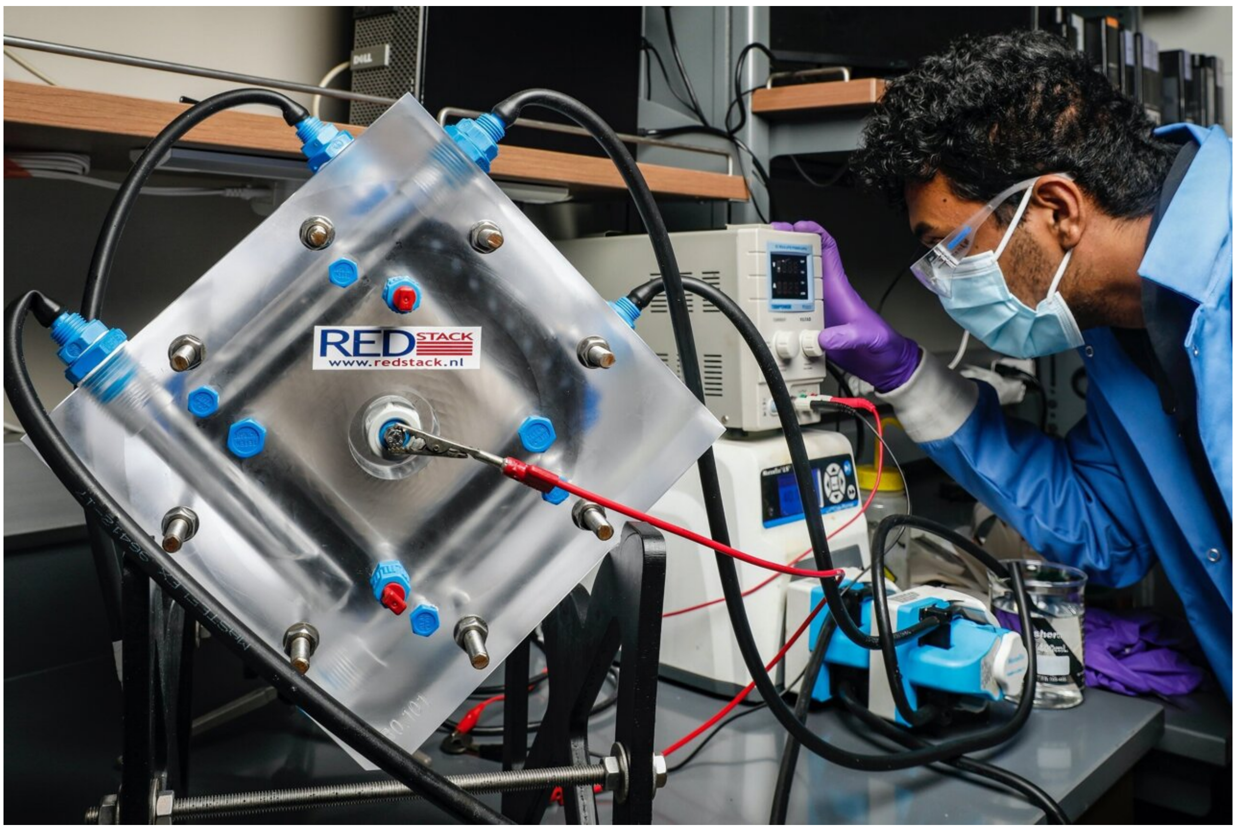


UIC graduate student Rohan Sartape in Assistant Professor Meenesh Singh's lab, with the department of chemical engineering. Credit: Jim Young/UIC Engineering

Engineers at the University of Illinois Chicago have built a machine that captures carbon from flue gas and converts it to ethylene.

The device integrates a carbon capture system with an ethylene conversation system for the first time. Moreover, the system not only runs on electricity, but it also removes more carbon from the environment than it generates—making it what scientists call net-negative on carbon emissions.

Among manufactured chemicals worldwide, ethylene ranks third for carbon emissions after ammonia and cement. Ethylene is used not only to create plastic products for the packaging, agricultural and automotive industries but also to produce chemicals used in antifreeze, medical sterilizers and vinyl siding for houses, for example.

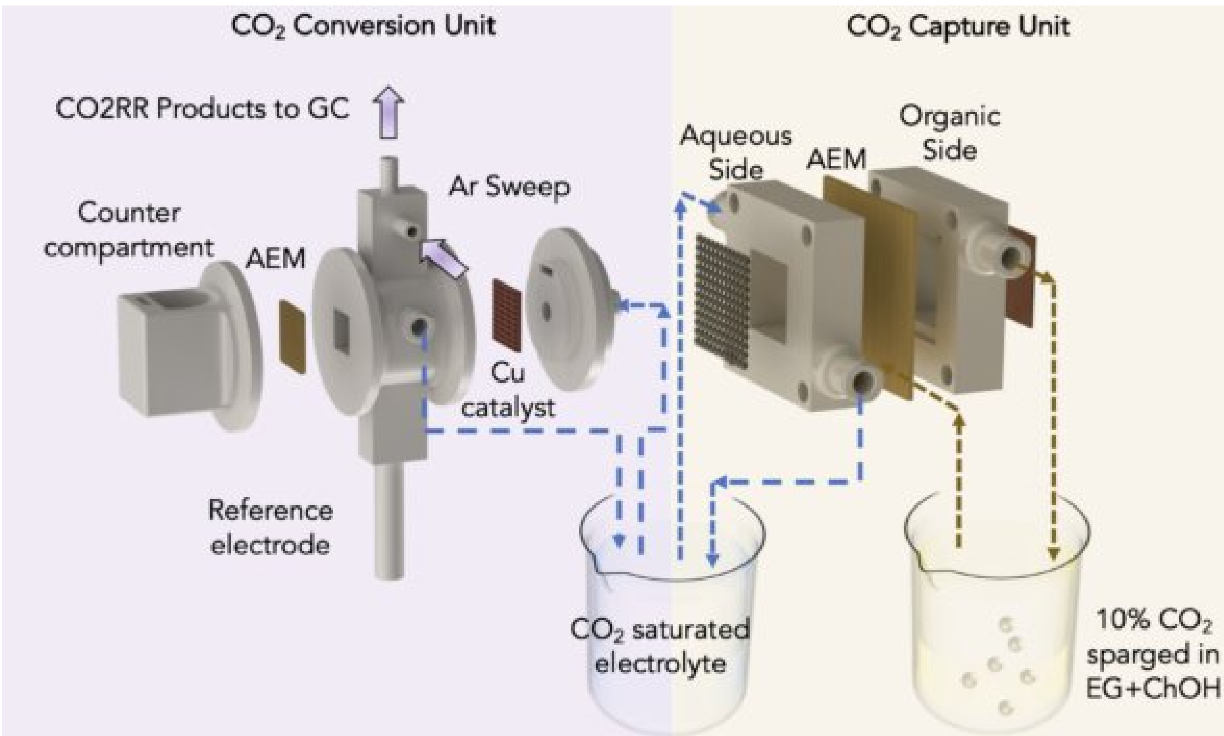
The system and the results of the UIC College of Engineering scientists' experiments are published in an *Energy & Environmental Science* paper titled "Fully-Integrated Electrochemical System that Captures CO_2 from Flue Gas to Produce Value-Added Chemicals at Ambient Conditions."

"This is the first demonstration of a net-negative, all-electric integrated system to capture carbon from pollutants and create a highly valuable resource," said Meenesh Singh, UIC assistant professor in the department of chemical engineering.

"There is an urgent need to develop efficient technologies for integrated carbon capture and conversion to sustainably produce net-negative fuels. Currently, integrated carbon capture and conversion systems are highly energy-intensive and work in a discontinuous cycle of carbon dioxide capture and reduction. Efficiently integrating carbon capture with the conversion system eliminates the need for transportation and storage, and thereby increasing its energy efficiency."

The integrated carbon capture and conversion system developed at UIC continuously captures carbon dioxide from flue gas to produce high-purity ethylene.

"This is an important milestone in ethylene decarbonization," Singh said.



Schematic of the integrated system with migration-assisted moisture-gradient CO_2 capture and electrochemical CO_2 reduction reaction. Credit: Meenesh Singh, et al.

To capture carbon from the air or flue gas, Singh's lab modified a standard artificial leaf system with inexpensive materials to include a water gradient—a dry side and a wet side—across an electrically charged membrane.

On the dry side, an organic solvent attaches to available carbon dioxide to produce a concentration of bicarbonate, or baking soda, on the membrane. As bicarbonate builds, these negatively charged ions are pulled across the membrane toward a positively charged electrode in a water-based solution on the membrane's wet side. The liquid solution dissolves the bicarbonate back into carbon dioxide, so it can be released and harnessed for CO_2 conversion.

The system uses a modular, stackable design that allows the system to be easily scaled up and down.

To convert captured carbon dioxide to ethylene, Singh and his colleagues used a second system in which an electric current is passed through a cell. Half of the cell is filled with carbon dioxide captured from a carbon capture system, the other half with a water-based solution. An electrified catalyst draws charged hydrogen atoms from the water molecules into the other half of the unit separated by a membrane, where they combine with charged carbon atoms from the carbon dioxide molecules to form ethylene.

The UIC researchers integrated the two systems by feeding the captured carbon dioxide solution to the carbon conversion system and recycling it back. The closed-loop recycling of solution ensures a constant supply of carbon dioxide from flue gas and its conversion to ethylene.

To test their integrated system, the researchers implemented a 100-square-centimeter bipolar membrane electrodialysis unit to capture carbon dioxide from the flue gas and hydraulically connected it to the 1-square-centimeter electrolysis cell to produce ethylene.

They were able to test the system continuously, 24 hours per day for seven days. The system was not only stable the entire time, it also captured carbon at a rate of 24 grams per day and produced ethylene at a rate of 188 milligrams per day.

"In the journey to make ethylene production green, this is a potential breakthrough," Singh said. "Our next step is to scale up the integrated carbon capture and conversion system to produce ethylene at higher rates—a rate of 1 kilogram per day and capture carbon at a rate higher than kilograms per day."

Co-authors of the study include Aditya Prajapati and Rohan Sartape of UIC, and Miguel Galante, Jiahan Xie, Samuel Leung, Ivan Bessa, Marcio Andrad, Robert Somich, Marcio Reboucas, Gus Hutras and Nathalia Diniz of Braskem.

More information: Aditya Prajapati et al, Fully-integrated electrochemical system that captures CO2 from flue gas to produce value-added chemicals at ambient conditions, *Energy & Environmental Science* (2022). DOI: 10.1039/D2EE03396H

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