Lowering Atmospheric Carbon Dioxide in a Large-Scale Renewable Energy Electrochemical Process: The Future Is Here

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What if carbon dioxide (CO_2), a prevalent greenhouse gas, could be transformed into higher-value fuels and chemicals using low-cost, renewable electricity?

Researchers at the National Renewable Energy Laboratory (NREL) have been focusing on improving electrochemical routes to convert CO_2, which would otherwise be released into the atmosphere, into a range of value-added products. Previously, limitations in energy efficiency, scalability, product selectivity, and production rate (the rate at which electrons transfer, measured in the form of current density for electrochemical devices) have prevented widespread adoption of these devices to reduce CO_2 either from manufacturing emissions or from capture directly from the atmosphere. However, recent results from NREL show enhanced process performance that enables the scale-up of an electrochemical process to reduce CO_2 that has not been possible until now.

In research newly published in *ACS Energy Letters*, NREL scientists detailed the electrochemical reduction of CO_2, a process in which CO_2 is converted into formate, a chemical compound used as a hydrogen source for the synthesis of chemicals from biomass. In the article, the research team created a high rate of formate production and product selectivity, the latter of which is critical to reduce the need for further costly separations processes downstream. The formate could then be fed to biological organisms or coupled with enzymes, resulting in robust interactions between the formate and enzymes that yield high-density chemicals or fuels, such as ethylene or ethanol, respectively.

Although research on the conversion of CO_2 to formate has become more prevalent, the research community has often faced the challenges of production rate, product selectivity, or cell size. But NREL's process achieves all three metrics simultaneously for the first time, enabling a pathway toward square-meter-scale testing of electrochemical conversions.

"This is where we want to be. At this scale, we can study phenomena in a similar way to what has been done for fuel cells and hydrogen-producing electrolyzers," said Kenneth Neyerlin, a chemical engineer at NREL and co-author of the study.

The paper is the first published research conducted within a larger Electrons-to-Molecules research initiative led by a collaborative team at NREL.

"We're using expertise that we have across the laboratory, on the electrochemical side and also on the biochemical side, to go from CO_2 to high-value chemicals or fuels," said Randy Cortright, NREL chemistry research advisor.

The program's larger goal is to use highly efficient electrons at industry scale to convert a waste compound such as CO_2 into a multitude of more useful industry-relevant, energy-dense fuels or chemicals, such as polyethylene, which has a large global market.

"It's not necessarily critical that we make formate. Rather, in a broader realm, we're doing electrochemical conversion of waste molecules into useful chemicals," Neyerlin said. "We want to tackle CO_2 emissions overall, and now we have the larger-scale platform to do it."

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