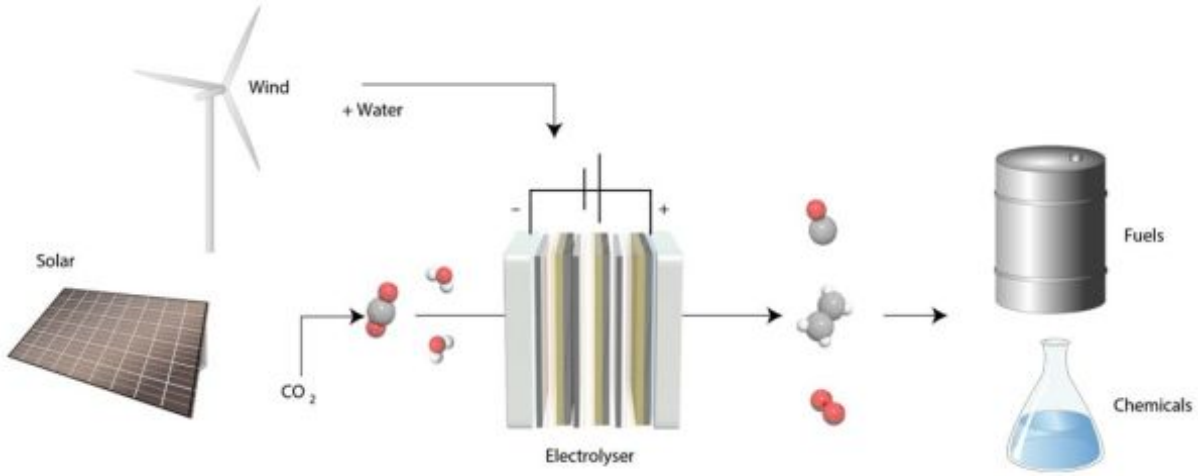


# The present and future of carbon-efficient CO2 conversion systems

A new review study published in Nature Sustainability offers an analytical overview of the four novel approaches of electroreduction of CO2 (CO2R) that could achieve carbon-efficient electrosynthesis of the waste CO2 to obtain value-added products, such as fuels and feedstocks.

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The petrochemical sector provides products that play a pivotal role in our modern society: fuels, plastics, fertilizers, and even detergents, among others. The drawback of such benefits is that there is always a price to pay: this sector is one of the of the main energy users worldwide and makes up 18% of today's industrial CO2 emissions; not even to mention that the projections in the upcoming years foresee a drastic increase in these gas emissions. Electroreduction of CO2 (CO2R) has bloomed in recent years as a promising solution to mitigate the environmental impacts of CO2 emissions by the chemical industry. CO2R is the

chemical process that allows the conversion of waste CO2 captured from the atmosphere, waste emissions, or biological processes into carbon-based molecules that underpin our society using renewable or green energy. These value-added products can be used as fuels and feedstocks (e.g. to manufacture materials) opening the door to circular economies. One of the most important carbon-based feedstocks is ethylene - the world most produced organic compound.

CO2R electrolyzers break down CO2 molecules and recombine the resulting units with hydrogen to form new molecules. There has been a large progress during the last years in terms of selectivity towards specific products (e.g. ethylene) and productivity (how much product per time one can make). Now, CO2R technology faces another challenge: the overall system energy efficiency. A large fraction of CO2 is converted into unwanted carbonates, and their processing imposes extremely high energy (and hence cost) penalties.

A new study, recently published in the journal Nature Sustainability, offers an analytical overview of four novel approaches that could achieve carbon-efficient electrosynthesis. That is, they can minimize the CO2 loss to carbonate, enabling a high Single Pass Conversion (SPC) efficiency, and lowering these crucial energy penalties.

In the study, ICFO Prof. Pelayo Garcia de Arquer, along with researchers from the University of Toronto including Adnan Ozden, Jianang Erick Huang, Joshua Wicks, and, Prof. Edward H Sargent and Prof. David Sinton among others, offer a quantitative comparison of the advantages, drawbacks, and challenges of the most promising technologies enabling a high SPC. These encompass CO2R based on novel membranes (e.g. bipolar membranes); CO2R operation in acidic media; tandem reactions; and direct conversion capture solutions.

The authors describe the characteristics of the different routes and highlight the main technical challenges for each of these CO2 conversion pathways, such as degradation, voltage losses, coke formation, or C-C coupling issues. Several solutions to address these limitations are also provided at the catalyst, membrane, and reactor level.

To conclude, the researchers offer a roadmap towards the technoeconomic viability of ethylene synthesis from CO2R in the path to its large-scale deployment.

**Original study**

Ozden, A., Garcia de Arquer, F.P., Huang, J.E. et al. Carbon-efficient carbon dioxide electrolysers. Nat Sustain (2022). https://doi.org/10.1038/s41893-022-00879-8