



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 techno-economic 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 electrolyzers. Nat Sustain (2022). <https://doi.org/10.1038/s41893-022-00879-8>