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Turning pollution into potential

Groundbreaking new method enables sustained production of methane from carbon dioxide, advancing sustainable fuel development.

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Carbon dioxide (CO₂) is one of the world's most abundant pollutants and a key driver of climate change. To mitigate its impact, researchers around the world are exploring ways to capture CO₂ from the atmosphere and transform it into valuable products, such as clean fuels or plastics. While the idea holds great promise, turning it into reality - at least at a large scale - remains a scientific challenge.

A new study led by Queen's University (Canada), with the collaboration of ICFO researchers **Dr. Viktoria Golovanova** and **Prof. F. Pelayo Garcia de Arquer**, paves the way to practical applications of carbon conversion technologies and may reshape how we design future carbon conversion systems. The groundbreaking research addresses one of the main roadblocks in the carbon conversion process: catalyst stability.

In chemical engineering, a catalyst is a substance that accelerates a reaction - ideally, without being consumed in the process. In the case of carbon conversion, catalysts play a critical role by enabling the transformation of CO₂ into useful products such as fuels and building blocks for sustainable materials.

Copper-based materials are the most efficient catalysts for converting CO₂ into methane, the main component of the natural gas used in water and home heaters, and for electricity generation. However, these copper catalysts undergo significant transformation in the process, and keeping the system working for a long period of time remains critically challenging.

The team has developed an innovative method to synthesize and recycle the copper catalyst during the electrochemical reaction within the carbon conversion system. These exciting results were recently published in [Nature Energy](#).

In this approach, what is added to the system is not the copper catalyst per se, but a catalyst precursor (a substance that requires activation to become an active catalyst). Researchers then use electric signals to dynamically form catalysts in situ during the CO₂ conversion process.

What's better: when electric signals are turned off, the catalyst goes back to its precursor form. Repeating this cycle ensures selective and stable performance over extended periods. This is one of the most stable systems for carbon conversion to date, say

Dr. Dinh, lead author of the study from Queen's University. In traditional carbon conversion systems, once the CO₂ reduction reaction gets started, it needs to keep running to avoid catalyst degradation. But in the new system, when the reaction stops, the catalyst turns back into its precursor form. Once the system is turned back on, in a matter of seconds, it produces new catalyst and restarts the carbon reduction reaction.

"Our role was to visualize the catalyst surface using scanning electron microscopy, which revealed how its structure evolves during operation," shares Viktoria Golovanova, talking about ICFO's contribution to the study. "Together with the team, we helped interpret these results and discuss how the recoverable strategy enables the catalyst to remain stable and efficient during long-term use." Stability during intermittent operations is crucial for integrating carbon conversion systems and intermittent renewable energy sources, like solar or wind power. Dr. Dinh and team are energized about the new possibilities these findings present, especially for the production of methane. As a next step, Dr. Dinh's lab will attempt to apply this same process to produce ethylene, ethanol, and other products. The team will also work to scale up the technology to prepare it for practical applications, paving the way for a more sustainable future.

Reference:

Gao, G., Khiarak, B.N., Liu, H. et al. Recoverable operation strategy for selective and stable electrochemical carbon dioxide reduction to methane. *Nat Energy* (2025).
<https://doi.org/10.1038/s41560-025-01883-w>

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